Research on Beijing Urban Job and Housing Balance and Job Accessibility

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Content

1 Literature Review

1.1 Urban Spatial Evolution and Job-Housing Balance

The evolution of urban job-housing structure has reflected the deep changes of urban spatial pattern caused by urban economic growth and land expansion. The formation, development, expansion and growth of modern cities have all undergone the process from agglomeration to diffusion and re-agglomeration to re-diffusion. The transformation between urban agglomeration and diffusion reflects the process of agglomeration and suburbanization of job and housing, which consequently form the monocentric and polycentric job-housing spatial structure. Questions including whether there is corresponding commute mode for different job-housing structure, which job-housing structure is more efficient in terms of transit and which transport system is a better fit to the future urban spatial development have been the focused issues of many scholars. The first part of the research mainly analyzed the spatial developing features and trends of the metropolises worldwide. The influence of job accessibility on labor market has also been investigated. Based on the comprehensive review, we discussed the urban spatial evolution of Beijing in the second part.

1.1.1 Urban Spatial Evolution: Agglomeration and Diffusion

The Industrial Revolution pushed urbanization in the 19th century. A large number of people concentrated into cities, which resulted in many urban problems including large-scale expansion and generated a series of urban planning ideas. “Garden City”, an ideal urban layout concept, brought forwards the urban spatial development model featuring job-housing matching in medium-sized cities, but the idea was broken by increasingly prosperous urban economic growth and modern metropolises were being formed gradually. Later, the “Organic Diffusion” theory and “Satellite City” building theory emerged, achieved development and were practiced in many metropolises in the U.S. and western Europe. Building satellite cities effectively mitigated the population pressure facing downtown areas, but disadvantages were also exposed gradually. The major problem is that the expansion of downtown areas and satellite cities caused cities to expand around a bigger spatial scope. Therefore, in the monocentric urban structure, growth of

CBDs in scale in downtown areas and population suburbanization are two features that develop simultaneously, and are results of urban agglomeration and diffusion.

Comparative urbanization: Divergent Paths in the Twentieth Century by Brain J. L. Berry, published in 1973, makes comparative analysis on "agglomeration and then diffusion" of many cities around the world. Berry called the urban characteristic as the "post-industrial era", which means the emergence of population suburbanization and "counter-urbanization". The urbanization all over the world described by Berry is the result that urban agglomeration and diffusion economic mechanism combine to work on urban development. Some scholars made analysis from the angle of "urban development stages", such as Peter Hall and Hay (1980), L. H. Klasson (1981) and Van Den Berg (1982). They defined urban areas as functional urban areas (relatively economically independent areas).A core city refers to all adjoining areas with employment density above a certain level. The inland of each core area is got according to the commuting model. When the growth rate of inland population is higher than that in the core city, the concentration stage shifts to relative diffusion, then absolute diffusion at last. Afterwards, after conducting empirical studies in some countries in West Europe, North Europe, and South Europe, some scholars found agglomeration and diffusion of cities share similarities in different development stages, but differ from each other in terms of factors influencing industrial features, residence and employment.

Works of domestic scholars include *Agglomeration and Diffusion – New Theory of Urban Spatial Structure* (2000) and *China's Urbanization: Pattern • Process • Mechanism* (2008) by Gu Chaolin, *Urbanization* (a translation, 2009), C*omparative Study of Chinese and Foreign Urbanization* (2006) by Gao Peiyi and *China's Urbanization Process* (2009) by Fan Hengshan. They introduce and summarize western urbanization study methods and theories, conclude urbanization process and experience of western countries, and make comments on features and stages of domestic urbanization. Chen Xueming (2003) presented a panoramic picture of the urban development in the history of the U.S. and uncovered the essential characteristic that industrialization promotes urbanization; urban population growth shifts from rural population moving into cities, and then to intercity migration while population growth areas switch from central areas to suburbs; population suburbanization leads to diffusion of urban industries, and thus formation of the polycentric urban structure and mega cities. Sun Qunlang (2003, 2004) analyzed major reasons for suburbanization in the U.S. in details: road construction, private cars, communications technologies among other technologies and industrial revolution; suburbanization is closely related to urban economic development stages and industrial structures and the rise of the tertiary industry accelerate further development of urban suburbanization; suburb residence policies of governments and racial segregation combined to catalyze development of suburbanization; humanistic factors including social cultures and values are also important factors influencing suburbanization. Chai Yanwei (1995), XuHeping (2000), Wu Qiyan (2000), Wang Yali (2004) among other scholars reviewed and summarized development experience and lessons of metropolitan areas in the U.S. and West Europe as well as their theory studies. Meanwhile, some domestic scholars undertook comparative studies on China's urbanization development stages. Zhou Yixing (1999, 2000), Zhao Xinping (2002) and Liu Binglian (2004) summed up features and the overall trend of China's urbanization and discussed issues including the low urbanization level, why suburbs are major population growth areas, fast growth of urban population, and features of two-way development of population migrating into suburbs.

The law of development amid urban development – "agglomeration and then diffusion" – is not only embodied in urban population development, but also well embodied in development of the job spatial structure. With migration of population in central cities into suburbs, jobs in cities start diffusing to outskirts from CBD. Employment subcenters sprang up in some international metropolises at the end of the 19th century, when the monocentric structure of cities evolved to the polycentric structure and the urban job-housing spatial structure continued development with diverse features.

The Coming of Post-Industrial Society by American urban economist Daniel Bell, published in 1973, introduces the theory of three stages in human social development: the pre-industrial society, the industrial society and the post-industrial society. According to *The Third Wave*, a book published in 1980 by American futurist Alvin Toffler that shocked the world, the first wave of the human being was the agricultural society (from 8000 B.C. to 1650); the second wave was the industrial society (from 1650 to 1955); and the third wave was the post-industrial society (from 1955 to now). After the World War II, urban development in different countries gained new life and urbanization stepped into a higher-level development stage. The third wave which scholars name as the "post-industrial era" is overwhelmingly characterized as below in terms of the urban spatial structure: employment suburbanization becomes more obvious and central cities gradually shift from industrial production centers to agglomeration centers of the tertiary industry including business, trade, financial, real estate, IT, etc; employment density of central cities including CBDs fall and employment diffuses further to suburbs of metropolises; and there are more employment subcenters and some subcenters emerge in the urban fringe.

American economist Edwin Mills (1972) calculated gradient changes of population and industrial density in American cities from 1910 to 1960. Analysis shows that with furthering of urban population suburbanization, the density gradients of jobs in sectors including manufacturing, wholesale and retail and services decreased. The spatial layout of density achieved balanced development from the urban center to suburbs. Macauley (1985) revised the model about the density changes between employment and population with the calculating method of exponential function to measure the declining percentage of population and employment density each mile from CBDs to suburbs. Smaller density gradient means higher suburbanization. Study shows that population in the average gradient of 18 metropolitan areas in the US fell over 50% in different industries between 1948 and 1980.

Employment suburbanization amid industrial shifts in different stages exhibits certain rules. Domestic scholars interpreted the feature of urbanization in west countries. Sun Qunlang (2005) and Zhou Chunshan(2007) divided employment suburbanization into three stages. Different industries presented different location features of spatial agglomeration. Robert (1998) and Rosenthal (2001) said different sectors benefited from different kinds of agglomeration economy and they chose locations from different angles. Headquarters of large multinationals and companies engaged in finance and high-end business services are inclined to CBDs as these sectors need face-to-face communications and convenient, professional services. Some flexible special sectors, including computer, information and other high-tech sectors, also need space agglomeration to incubate innovation capabilities. Instead of CBDs, they can form agglomeration to some extent in long and narrow areas, like the Silicon Valley. In addition, high-speed network informationization makes some companies remove offices of some rear-end departments to office parks in suburbs. Wholesale and retail, construction and service sectors more opted to stay in suburbs, where they are close to the consumer market and costs are relatively lower. Employment diffusion in metropolises has two trends. First, the proportion of total jobs available in CBDs – the employment center – falls, but no new agglomeration had been formed in the vast urban area. The second is the diffusion of employment. Diffused jobs form new agglomeration in some urban areas, and many employment subcenters are formed and the monocentric urban structure shifts to the polycentric pattern.

Scholars in various fields elaborated on and analyzed the agglomeration and diffusion phenomena in the spatial structure of urban development from different dimensions. In the1970s, with the rapid development of new technologies and new industries, there sprang up a large number of concentrated “new industrial zone” in big cities in Europe and the United States and etc., triggering extensive discussion among regional economics and economic geography circles on the microeconomic mechanisms of the concentrated economic phenomenon, which mainly centers round the two aspects of endogenous and exogenous decision locations. Masahisa Fujita and Ogawa (1982) found that there is a trade-off relationship between the commuting and transportation costs and the variable concentrated economy. If the level of economic concentration is relatively high, and the further distance from CBDs, the lower the level of concentration, then a single CBD will form while residential buildings will be located on either side; if the concentrated economy is balanced in location with higher commuting costs than transportation costs, then the employers tend to live close to work places and the land is used in the decentralized mode. Henderson and Slade (1993) extended the model discussion on that basis and elaborated on the effectiveness of the monocenter - polycenter structure by the game between two developers: when the city is relatively small, the monocenter urban structure is effective; when the city gradually expands, the cost of commuting for workers and transportation of goods grows more rapidly than the level of concentrated economy does, then, the polycenter structure is efficient.

The discussion on endogenous economic concentration is mainly based on the Von Thunen Model, the research of which takes the hypothetical that the city or business district itself pre-exists, so later many scholars introduce the “external economy” concept of Marshall into the discussion of the concentrated economy. Liu Changquan (2009) made a comprehensive review on research of foreign concentrated economic externalities in different periods and made an analysis of how the share of labor and share of infrastructure play their roles.

Among the discussion on urban concentration and diffusion, economist Krugman’s elaboration (2000) in the *Development, Geography and Economic Theory* is more systematic and influential. He believes there are mainly three kinds of motivating effects in geospatial economy concentration, which are the market access effect, the effect of living costs and the market's congestion effect.The first two effects together form concentrated force, which is conducive to geographically concentration and mutual promotion of manufacturers and consumers; the latter effect forms centrifugal force, encouraging manufacturers to diffuse geographically. *Spatial Economics*, a relatively systematic research outcome of Masahisa Fujita, Krugman and Venables in the field, focuses on the two issues of where and why economic activity takes place and analyzes the balanced situations between centripetal and centrifugal forces in the concentrated economic phenomenon. In the book, these three models are elaborated: the regional model of "center-periphery" mode, the urban model of evolution of urban hierarchies and systems, and the international model of industrial concentration and international trade. And authors disclosed how the relationship among the three elements from the manufactures' angle of increasing returns, transportation costs and element flow results in the forming and changing of spatial economic structure by building microeconomic models. The "center-periphery" model simulates the dynamic evolution process of the urban spatial structure under different assumptions, followed by a discussion on monocenter and polycenter urban structure in the urban development. As to the formation mechanism of the polycenter structure, the book simulated the spatial status resembling three corners of an equilateral triangle, and, based on different circumstances of transportation costs, illustrated the economic power structure formed by different urban structures. In the urban hierarchical evolutionary model, the role of catalysis of location advantage is emphasized, while the new center will expand its scale by self-reinforcing and continuous development after established, showing the self-organization role of the spatial economy.

When analyzing the economic power mechanism of enterprises' transferring to the suburbs, Michelle·J·White (1998) summarized five specific incentives from abstract economic principles: first, enterprises' relocation may shorten commuting distance for workers, and saved commuting cost enables enterprises to pay lower wages; secondly, land prices fall as the distance from the CBD decreases and emigration from the CBD may bring benefits from a reduced land rent; thirdly, without traffic jams as in the CBD center, transportation costs can be cut down; fourthly, the weakened CBD concentrated economy may reduce the productivity of labor in some enterprises, and concentrated economies have different roles on different types of enterprises, for instance, some of the industries make earnings without the spatial concentration; fifthly, the development of computers and communication technologies has a profound impact on CBD's location advantages, and the Internet communication mode in the information age will weaken the concentration effect brought by enterprises being close to each other.

1.1.2 Monocenter Urban Spatial Structure and Job-Housing Balancing Policies

Job-housing separation surely intensifies during the population suburbanization process, and thus forms the "center-periphery" "monocenter" city space structure. The increasingly worsening issues of urban traffic congestion and environmental pollution due to growing traffic demand are the reflection of conflict in supply and demand between urban growth and environmental carrying capacity. It is under such an urban development background, the job-housing balancing policies are emphasized and favored by urban planners and researchers. The job-housing balance is an urban planning-related public policy, which is often under wide discussion as an important policy in the urban traffic field. The goal of these policies is to reduce traffic volume and demand on a long distance travel by adjusting the spatial relationship between employment and housing, thereby reducing traffic congestion, environmental pollution and other urban problems.

The job-housing balance refers to the balance or self-contained situation in a regional unit in which residents live or are located. The proposing of the policies reflects problems caused by urban spatial growth and the ever-worsening job-housing separation. On the fast roads in California and Los Angeles Bay of the US, especially on transport corridors connecting the city center with the suburbs, the degree of traffic congestion is getting worse and the central area of the city is suffering from enormous traffic pressure due to urban expansion. Therefore, many governments released the corresponding job-housing balance policies to make the job and housing closer, thereby to reduce the rapidly growing commuting demand and traffic congestion. For instance, some North American cities apply planning intervention policies to achieve the regional job-housing balance, requiring that in the city center, small-area apartment shall be available, or surrounding the employment center are built with medium-density residential projects, rather than the low-density rural-style residential projects. (Cevero, 1996).

Researches on the job-housing balance mainly center round the three core issues. Firstly, the basic balance between residential population and employment positions, which is a planning issue regarding mixed land use; by regulating the nature of land development, basic conditions for easy job-housing balance is provided to increase the proportion of locally residential population and locally employed population. This reduces the cross-region traffic demand between regions, thus easing traffic congestion (Giuliano, 1989; Handi, 2005).

The second is the connotation of job-housing adjacency, i.e. the geographical adjacency between occupation place and residential place. For instance, to build residential community surrounding the concentrated center of employment positions, or provide opportunities for residents of large residential communities to work near, thereby reducing commuting distances and easing the increase in long-distance commuting demand (Cevero, 1996; Mark, 2003; van der Mithen, 2003).

The third is how to measure the balance level of occupation and living. A measurement indicator is needed to determine the level of balance between occupation and living. The job-housing ratio of a geographical unit, regional independence and etc. can all be used as the evaluation indexes for job-housing balance level. The evaluation faces some difficulties, such as how to determine the regional unit for job-housing matching, that is, within how big the scope to examine the job-housing balance level. If a too large unit in the economic society is taken, there is little significance in the discussion on job-housing balance; if a scope within which certain commuting time can be accessed, then the threshold for the commuting time is also not easy to determine. (Giuliano, 1991)

The performance result of job-housing balancing policies is under widespread controversy, and many researchers questioned whether the policies function in easing traffic congestion. Giuliano (1991,1995) and Downs (1992) found in the study that the implementation of the job-housing balancing policy failed to achieve the expected goal of less commuting time. Firstly, in double income families, work places can vary significantly, and the frequent change of jobs of residents make it difficult for them to have fixed work places; secondly, migration and mobility of residents are restricted by regional exclusion policies and housing discrimination barriers. In order to protect local resources, interests and wishes of existing inhabitants, many local governments limit the development of new housing, or the development of low-profit housing projects so as to hinder the entry of low-income people into the community. Thirdly, in addition to job accessibility, there are other factors, such as education, health care, business facilities, community, culture and other factors influencing the final choice of residents to pick their residence locations. Giuliano (1991) made an analysis on job-housing changes in several administrative districts in Los Angeles from 1940 to 1985, and found that the job-housing proportion of each administrative district tended to be balanced, but there was no necessary link between a reasonable job-housing ratio and easing traffic congestion. She believes that job-housing matching is a part of the urban development process, and the result of various co-functioning factors that affect job-housing relationship.

JK Brueckner and DA Fansler (1983) adopted the empirical approach in first to support the model of monocentric urban structure. They made cross-section analysis with 40 independent and small cities from the metropolitan areas in America. The research findings show that on one hand, variables including urban population, income and agricultural land rents are major determinant variables to measure the urban land scale. On the other hand, the transport cost is not statistically significant by indirectly measuring the percentage of commuting by public transport and percentage of households owning more than one car. They believed the research results can support the opinion of urbanization being a rational market process. The necessity of rational expansion of the city was proposed. McGrath D T (2005) used more complete data of 33 urban areas in America from 1950 to 1990 to empirically estimate the urban space size of cities of the monocentric urban spatial structure. He adopted semilog function equation to make cross-section analysis of urban population, income, transport cost and agricultural land rents and found that these variables are all statistically significant, which is different from conclusions of JK Brueckner and DA Fansler. His estimation model explained nearly 80% of the scale difference of urban land uses which made him to come to the conclusion of urban space expansion being a result of an orderly economic process. Most researchers adopted data of developed countries such as America. Deng (2008) considered the possibility of using previous research findings to explain urbanization and urban land use issues in developing countries like China. They made the analysis with GIS technique and data of over 2000 counties in China from 1995 to 2000. Except for the conventional economic factors, they also added the yields of industrial sector and service sector in the GDP, geographical and climatic factors such as rainfall, temperature and altitude. When only the economic factor was considered, variables such as urban population, income, transport cost and agricultural land rents are all statistically significant. Although most of the geographical and climatic factors were also statistically significant, the share is very small. Y Song and Y Zenou (2006) built a monocentric urban spatial model to test the relationship between property tax and urban space expansion. They adopted GIS technique and two-stage least squares and logarithmic linear utility functions to make empirical analysis on 448 cities from the population census in America in 2000. The results showed that variables including urban population, income, transport cost and property tax are all statistically significant. While the agricultural land rent is not. Their model explained 85% of the scale difference of urban land uses in America and indicated the greatest effect of property tax on urban size. Moreover, they also concluded that the urban space size is the decrease function of property tax.

When analyzing the impact of job-housing relationship on commuting time, Wachs(1993) proposed that there are various causes behind urban traffic congestion while the job-housing relationship is just one of them. These factors like urban population growth, more private cars, increased proportion of women workers, slowdown in construction of urban expressway networks, increased non-commuting volume during rush hours will make traffic congestion worsen. Moreover, while mapping out job-housing balancing policies, the government does not actively guide residents to choose to live in the vicinity of work places or to work in the residential neighborhood. Therefore, the mixed land use in residential and commercial development does not directly lead to certain job-housing relationship between local residence and local employment in a real sense.

Cevero (1996) put forward empirical research on and responded to these questions regarding job-housing balancing policies. He believes that the implementation of these policies reflects not only the control of the regional job-housing ratio index, but more importantly, increasing the proportions of intra-regional local employment and local residential population. He believes that the increase in job-housing distance is because of the relatively low proportions of intra-regional local employment and local population to a larger extent, thus leading to growing demand for cross-regional commuting; while enhancing the regional independence and self-containment capability has an obvious effect on reducing car use, increasing the proportion of walking and shortening commuting time etc. In addition, he also proposed that the key to good job-housing spatial balance is to build affordable housing for employees, in particular to provide housing security in employment concentration centers. To solve traffic congestion problems, adverse effects of job-housing imbalance need to be eliminated, and economic instruments can also be taken to implement policies to encourage public transport development and adjust parking prices, to realize direct and effective management by traffic demand management.

1.1.3 Job-Housing Spatial Structure Evolution under Polycenter Development Trend

With economic growth of cities, the trend of employment diffusion promotes the formation of the polycenter employment city layout. In the 19^{th} century, during the development of European and American metropolises, there appeared a common polycenter spatial structure. With qualitative changes in the monocenter urban structure due to population suburbanization, so the new job-housing spatial relationship gradually came into being.

Many urban planners and researchers believe that, compared with the monocenter "center periphery" job-housing pattern, the polycenter urban structure is able to make job and housing spaces closer to each other, decrease dependence on downtown CBDs and reduce long-distance commuting trips. Employment suburbanization develops along with that of population, especially the emergence of employment sub-centers in the periphery of cities, which are closer to inhabitants in suburbs, and attracts suburbanites to work at job sub-center nearby, thus reducing "center-periphery" traffic demand and alleviating traffic pressure in downtown areas. Some scholars also raised the hypothesis to explain this phenomenon. The "time budget" hypothesis (Grubler, 1990) believes that the selection of transportation modes and the adjustment of job-housing locations will maintain a tolerable range of travel time, say, within 1 to 1.5 hours per day. The "Co-location hypothesis" of job-housing reckons that there is a constant of average commuting time and distance between the job and housing points in spatial relationship, and under control of this constant, the two places tend to be chosen to be close to each other. Gordon (1985; 1991) found from his comparative study on characteristics of the urban spatial structure and commuting distance of metropolitan areas in the northeastern and western United States that with expansion of the city, the average commuting distance of residents in the northeastern cities has been extended, but that in the western cities does not show significant changes. When analyzing the reasons, he believes that the western cities have the polycenter urban development pattern, which has an impact on commuting distances and avoid an increase in them.

Zhong Guo Ping(2016) took Zhongshan city as an example which is a polycentric city with low density to study the job-housing spatial pattern. The result shows that the job-housing ratio, commuting time and commuting distance varies in space with regions and the layer structure is not obvious. The job-housing distribution of the city is even as a whole. It is nearly balanced in the downtown area. While the surrounding towns especially the Northwest cluster and East cluster have a higher job-housing ratio than the downtown area. Both the average commuting time and commuting distance of the whole city is significantly lower than metropolises in China and developed countries. Since the proportion of commuting trips from surrounding towns to central area is small, it did not generate large traffic from peripheral area to the city center. More generally, the commuting flow is within the city center and peripheral area.

However, some other scholars found in empirical researches that the “co-location” theory plays a limited role in the polycenter urban structure. During the evolution of that structure, characteristics on changes of commuting distance vary from different cities. In some cities, it decreases, but in another some, it increases. Bannister (1997) found in his study on European and North American metropolises that the general increase of commuting distances during employment diffusion is mainly the result of two aspects in urban development: on the one hand, the population who lives in metropolitan areas yet takes jobs in other places is increasing; on the other hand, the distance between job and housing in the metropolitan area also increases. Data of French metropolitan areas from1990 to 1999 shows that: the internal commuting distance within metropolitan areas increased by 16% in the decade. Newman (1997) made a study on commuting traffic on 11 European metropolitan cities and found that the average commuting distance rose from 8.1 km in 1980 to 9.6 km in 1990, up by 18.5%; the total amount of long-distance commuting trips also increased significantly. Gordon (1986) found in his study on Los Angeles that the average commuting distance of residents in the sub-center is longer than that in downtown city (especially those inhabiting and living in the center of the city).This is because there is a small sum of residents living in the sub-center but taking jobs in the urban center, with a long commuting distance; and most of residents living and working in sub-center have a relatively short commuting distance; therefore, taken as a whole, the average commuting distance of the sub-center is relatively long, but for most commuters, the polycenter structure is conducive to improving commuting distance. Cervero (1998) found that against the backdrop of multi-structure evolution in the San Francisco metropolitan areas, the average commuting distance of 22 employment centers increased from 10.6 km to 11.8 km, up by 12%; from 1980 to 1990, the commuting distance of sub-center residents grew by 26.66%, with a growth rate much higher than those central cities. Sun Bin Dong and Tu Ting(2013) provided the decision basis of polycentric strategy for megacities in China through testing the effectiveness of polycentric concept with empirical study of Shanghai. They adopted the statistical approach and questionnaire data to analyze the job-housing balance issue in Shanghai. The research indicates that the farther the distance between job center and central center is, the lower the average commuting time is. Therefore, the polycentric structure is conductive to reduce the total commuting time. The main reason is the lower congestion of the surrounding regions and the higher proportion of commuting by car. The job-housing balance theoretically should be one of the reasons as well. However, the Shanghai case didn't show better job-housing balance under the polycentric structure.

Cervero (1998) further analyzed the disputed empirical findings and explained why jobs are diffusing to suburbs but not shortening commuting distances with data indicating job-housing changes in the Los Angeles Bay: This is mainly because of exclusion policies in high-concentration areas and the tax-based financial competition system. The serious shortage of affordable housing for workers results in job-housing imbalance; in addition, the fall in proportions of local housing and local employment is a key reason behind the increase of commuting volume. Van Der Laan (1998) also found in a study that in the cross-commuting polycenter urban structure, the average commuting distance of main centers or sub-centers with relatively strong independence will be shortened.

Evidently, development of the polycenter pattern changed the "center-periphery" job-housing spatial structure, and the employment sub-centers show strong influence in the new job-housing spatial structure, but the employment diffusion trend has not formed adjacent job-housing spatial relationship in a full sense. The emergence of employment sub-centers shortens the job-housing distance for some residents, but lengthens that of some others, making the job-housing spatial structure more complex.

1.2 The Relationship between Job-Housing Spatial Structure Evolution and Transport Development Mode and Commuting Efficiency

1.2.1 Job-Housing Spatial Structure and Commuting Efficiency

The fundamental patter of the job-housing spatial structure is decided by the urban spatial structure which is one of the important factors affecting commuting efficiency; under the similar job-housing condition, the shorter the commuting distance is, the higher the commuting efficiency will be, and this ideal urban structure is described in "garden city". But from the "industrial society" to the "post-industrial society”, the urban space has gone through different development periods of the monocenter and polycenter urban structure, and the urban issues of job-housing separation have been the focus of the research scholars and planning practitioners are discussing.

First of all, the urban spatial structure determines the extent of the separation of job and housing. The monocenter urban structure will easily bring about the job-housing separation between the center and periphery. In the 1950s, the urban industrialization process promoted the rise of ‘satellite cities’ in the United States and Europe with a large number of people moving outside cities and the development of the monocenter city structure becoming mature. Spence (Spence, 1995) once depicted the monocenter structure of London, Manchester, Birmingham and other cities from 1971 to 1983. He found that the commuter volume showed an increasing trend within 20 kilometers range from downtown London; 7 km from downtown Birmingham and 5 km from downtown Manchester. Although the spatial range of the city indicates slight difference, the ‘center-periphery’ job-housing separation brought by monocenter space structure, is making the commuting time rise along with growing commuting distances; meanwhile, traffic congestion and other problems have become increasingly severe. This issue is also prominent in the development of Asian cities. In the 1970s, the dramatic decrease of the population in Tokyo formed a sharp contrast with the increase in CBD jobs (Chengri Ding, 2010). In the 1990s, Beijing and Shanghai experienced the intensifying job-housing separation during population suburbanization. Both the commuting distance and time had been increased obviously. Therefrom, the urban spreading pattern and the monocenter urban structure efficiency raised concerns and doubts.

With the arise of polycentric urban structure in some American and Western European cities in the 1990s, many researchers believe that diffusing development of jobs in the polycenter structure will be in favor of the residents who had moved to the outside of cities for job-housing proximity to reduce commuting distances and improve commuting efficiency. However, the structure of empirical analysis indicates great differences. Gordon’s (Gordon, 1991) research on 20 U.S. metropolitan cities showed that, during the formation of polycentric spatial structure, the commuting time of 18 cities had presented the downward trend. But Bookout(1992) found that the metropolitan vehicle per kilometer in the U.S. had increased by 38% in the 1990s with the cross-regional commuting ratio rising from 21% in the 1980s to 24% in the 1990s and the job-housing separation situation continuing to deteriorate. Cevero (Cevero, 1996) had provided explanation on this issue. In his view, the job-housing ratio in a certain area is just a static matching relationship for job-housing space, and the real factors that impact commuting efficiency are the region's of self-containment capability, that is, the proportion of the local residence and local working population. Thomas (Thomas, 1969) used the indicator Independence to measure this factor, expressed by the ratio of the traffic in the total traffic around the area to evaluate the actual balancing relationship of the job-housing space. The higher traffic capacity within one area indicates a higher self-containment of the area, and therefore, the commuting time will be reduced and the commuting efficiency will be increased and vice versa. The polycentric urban structure may reduce commuting time for some residents. However, the sub-centers of the employment stimulate the increase of the cross-regional traffic which will increase the commuting time for other residents. The ratio of residents in the sub-centers working in this center will be less than the proportion of residents in other sub-centers, and the average commuting distance shows an increasing trend.(Annie, 2005). Thus the real job-housing balance rests on the balance between local housing and local job in one certain region and the ability of self-containment.

Chinese researchers have different viewpoints upon the job-housing balance and transport issues based on the domestic city features of high population density and the reality of the agglomeration economies of modern service industry. Some researchers taking Guangzhou and Nanjing for examples presented that cities in China should also actively practice mixed land uses to deal with urban traffic problems by avoiding the separation of job and housing(Lin Hong, Lijun, 2008; Qian Lin Bo, 2000). While Ding Cheng Ri(2010) believed that the highly mixed land use is one of the outstanding characteristics of Chinese cities which is also one of the important reasons of severe traffic congestions. On one hand, this is due to the decreasing employment density with the increasingly mixed land use. The transport accessibility of commuting trips is thus reduced. On the other hand, this is due to the chaotic and random traffic flow caused by the disperse distribution of mixed land use which could bring the disturbance to the traffic. Furthermore, since the demand of commuting trips in China is inelastic, the benefits of mixed land use for Chinese cities are not significant. Zheng Si Qi (2012) also pointed out that the mixed land use reduced the agglomeration economic benefits and labor productivity and is not conductive to the specialization of land use. The split land module produced segmented labor markets which reduced the transport accessibility of commuting trips at the macro level. Moreover, Zheng Si Qi also studied the wage compensation and wage premium in Beijing showing that enterprises have already started balancing the agglomeration economies and the commuting cost. The government should avoid blindly promoting job-housing balance at the expense of agglomeration economic benefit.

1.2.2 Job-Housing Spatial Structure and Commuting Traffic Spatial Distribution

The spatial distribution of residential commutes can effectively reflect the spatial layout of different function divisions in urban structure and the job-housing separation. The increase of urban population will inevitably bring the profound changes to the urban structure. Diffusion of urban population makes large numbers of people live in the suburbs and work in the central cities, which forms a monocenter urban structure; while the diffusion of employment promotes growth of jobs along the edge of the city, and the sub-centers of employment gradually generates significant attraction on the surrounding commute flow, and the spatial distribution of the commute flow presents new features.

Changes in the urban structure influences the distribution features of the commute traffic flow direction and flowrate, and this impact has been the important content of the study fields in the growth of urban space. Characteristics of the spatial organization of urban commuting flows can clearly reflect the interaction between the bidirectional mechanisms of the concentration and decentration in urban economic and social activities, and the development of employment centers showed strong space ‘centripetal force’. While the growth of the employment sub-center is the new space ‘centripetal force’ generated by the economy under the ‘Centrifugal force’. And the urban space presents the spatial patterns of ‘Multi-cores’ development.

Alain Bertaud(Alain Bertaud, 2001) described the organizational mode of the commuting space under the monocenter-polycentric space structure. He summed up four common urban spatial structures (see Figure1-1): Mode A is the typical commuting mode under the structure of the monocenter city with high density of employment position gathering centrally in the urban center areas as well as convenient infrastructure and the residents gather through the outskirts of the city to this center with the commuting flower presenting radially spatial distribution. Mode B is called the "urban village" (Urban Village) model with the urban space made up by a plurality of monocenter grouping and the residents living in the vicinity of the jobs' location. The regional independence of each group is strong, meanwhile, there is almost no long-distance spanned commute flow, and the residents can go to work by bicycles or on foot. This city spatial structure is the idealized mode of urban space in many urban planners' expectations, while it fails to become reality in the real urban development. Mode C is the polycenter urban structure with no obvious main city center, formed by multiple sub-centers; and jobs infrastructure presents a balanced distribution of built-up areas and urban commute flow indicates a randomly distributed form. Mode D is the mode of a combination of monocenter - polycenter with a main center and a plurality of sub-centers, and the commute flow presents a coexisted and radial spatial form and random distribution with more significant cross-traffic. Alain Bertaud believed that in the actual urban structure, Mode D is a combination pattern of monocenter and polycentric structure under which pattern there is one center and many sub-centers. The commuting flow appears both radial and randomly distributed with obvious cross-region trends. Mode D is presented by most of the polycentric urban structure. This is mainly because, the employment sub-centers are attractive to residents across the city as well just like traditional employment centers. But the difference in spatial patterns is that each job center will generate spatial attraction to the residents in built-up areas; and the commute OD presents the spatial relationship of the random distribution. In the cases of the other conditions remaining unchanged, the commuting distance of the polycentric structure is longer than that of a single central structure. For a specific region of the city, the higher the accessibilities is, and the higher the land price is, the faster the growth of the polycenter urban structure is and the greater the attractions to the surrounding commute flow are.

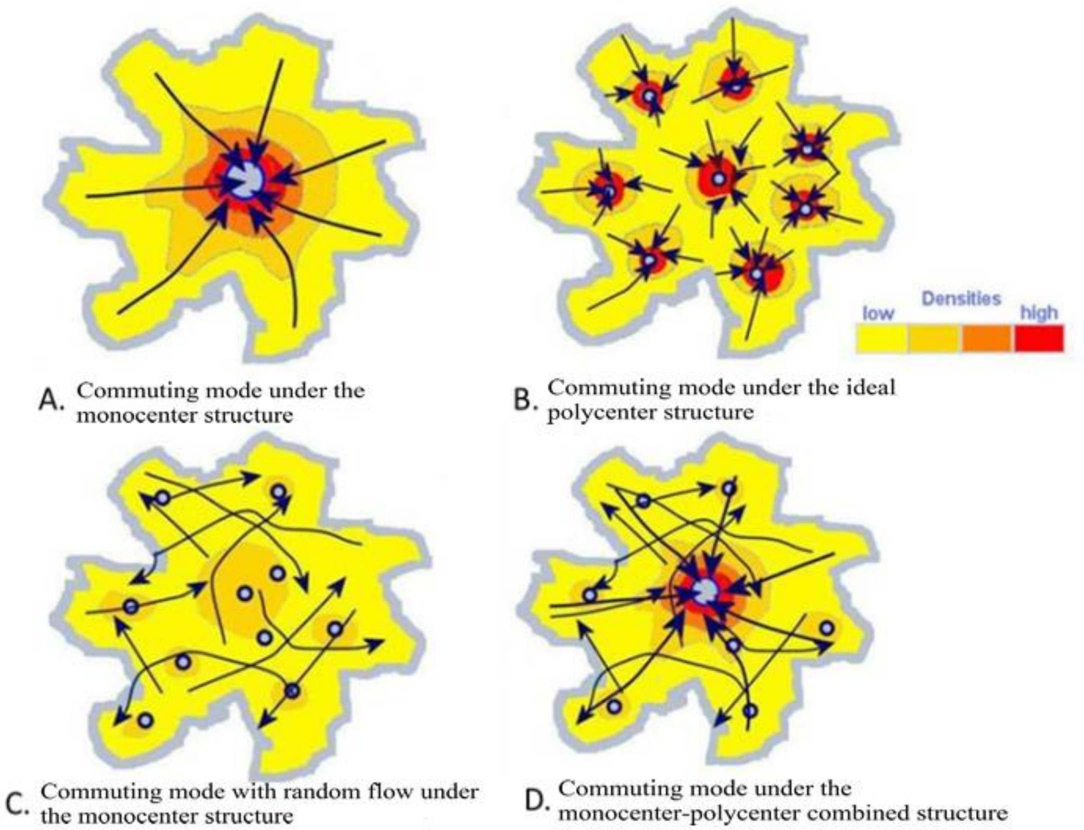


Figure 1-1 Metropolitan Spatial Structure and its diagram of

Zhao Pengjun (2010) also used a similar diagram to present the spatial form of urban structure and commuting organization patterns, but he believed fully polycentric urban structure (B-mode) was possible to be achieved by mixing land development and construction of compact city. Under the complete polycenter structure, the outside of the city is also in the status of high-density development, and have a higher job-housing balanced level within the region. Residents outside the city choose to work in employment sub-centers nearby, which can reduce the number of people working in downtown under the circumstance of a single central structure, therefore, for the suburbanites, their commuting distance can be reduced. The development of the high-density of the outside city under the polycenter structure can improve the independence of the region, and effectively reduce traffic jams caused by the spreading development of the low-density of the outside city under the condition of the monocenter structure. He believed that Mode D was an urban structure formed in the transition process from monocenter to polycentric centers. The character of this structure is that the residency of the city periphery and the comprehensive development of the industry is quite lower, which is between the mono and polycenters. Spatial distribution of commute flow exhibited the features of random distribution while the spatial features of ‘center-periphery’ still is presented in general; meanwhile, the spatial attraction of the main center of the traditional city is stronger.

In the study on the flow distribution problem of commuting space, the empirical analysis in many cities shows that the growth rate of employment sub-centers is obvious, and in the formation of polycentric urban structure, the increasing commuting traffic of the employment sub-centers often exceeds the traditional employment center. Cervero(1994) and Anne(2005) found similar condition when they studied the forming process of cities in America and France. The proportion of residents working in the sub-centers is higher than that in the traditional centers. Cervero believed that the polycenter urban structure did not bring the expectation of the ‘job-housing proximity’. Reasons including the job-housing imbalance, poor regional self-independence and failing to satisfy the job-housing demand of residents finally result in a substantial increase in the cross-district traffic.

Meng Bin (2009) studied the commuting flow distribution of Beijing central area and the surrounding satellite city coming to the conclusion that the central area is still the main direction of the commuting flow. This indicates the inexorable status of Beijing central area as the job center.

Thus, in the process of international metropolises’ development, the urban structure has a profound impact on the direction of commuting flow and spatial distribution of the commuting flow. The "center-periphery" pattern formed under the monocentral structure brings about the spatial distribution of radiated commuting flow, and the job-housing separation has increased the long-distance commuting traffic. While the combined commuting space distribution formed under the polycenter structure has not fully realized the vision for improving the overall efficiency of the urban commuting due to the surge in the sub-centers commuting, the job-housing imbalance in the districts and other reasons.

1.2.3 Job-Housing Spatial Structure and Transport Development Mode

The job-housing spatial structure is analyzed from two dimensions of job-housing space distribution and job-housing density. The job-housing space distribution will influence the spatial organization mode of commuting, while the adapted commuting organization mode can improve the operating efficiency of city space; and job-housing density can affect how transport modes are selected, then the adapted transport development pattern can promote sustainable development of city space.

In the debate on which urban structure, the monocenter or the polycenter can enhance the efficiency in urban operations, we can't get the situation suitable for all city features. This is because the city's operating efficiency is not only related with spatial distribution features of the job-housing space but also related with the developing mode chosen by the job-housing space density and transport means. The research of Hillman (Hillman, 1983) and Stead (Stead, 1999) discovered that increasing urban population density could decrease the commuting distance of all transport means. Focusing on low-density cities in terms of the urban spatial form, Dominic (Dominic, 2001) further elaborated on the positive significance that increased population density have on optimizing the traffic patterns as well as increasing the commuting efficiency. He thinks that increasing population density can increase the contact of residents in social activities and reduce motorized holiday travels; secondly, expand the coverage of service facilities and reduce the need to travel over long distances; thirdly, reduce the trip distance of housing and jobs, as well as service facilities; fourthly take advantage of public transportation facilities effectively, and reduce the motorized travels choice.

Alain Bertaud (Alain Bertaud, 2001) described the effects of the public transport guiding high-density land development to the developing modes of the urban space. In his view, different cities' structure enjoyed a certain urban transport mode which was suitable for it. As shown in Figure 1-2, the cities of high density –monocenter spatial structure suits for the development of public transport modes, while the low density — polycentric spatial structure suitable for the development of the private motorized transport mode. On the other hand, land use patterns guided by different transport modes have an impact on the development trend of urban spatial morphology. For example, contrasting with these two low-density cities of Atlanta and Barcelona, the different city form brought by public transport guiding the land development will be found. The population density along the track in Barcelona is much higher than the city of Atlanta leading to two different development paths: Urban space of Atlanta shows low-density spreading development, while Barcelona's urban space has been developed to a compact, high-density urban pattern.

Thus, the job-housing space form and the development mode of urban transport enjoy mutual interaction. The urban structure with high-density characteristics is more suitable for the public transportation-oriented transport development strategy; meanwhile, the expansion mode of urban space guided by the public transportation can avoid the disorder spread of the urban periphery. Only with the adapted development between the urban space and transport modes, the sustainable growth of urban space can be promoted.

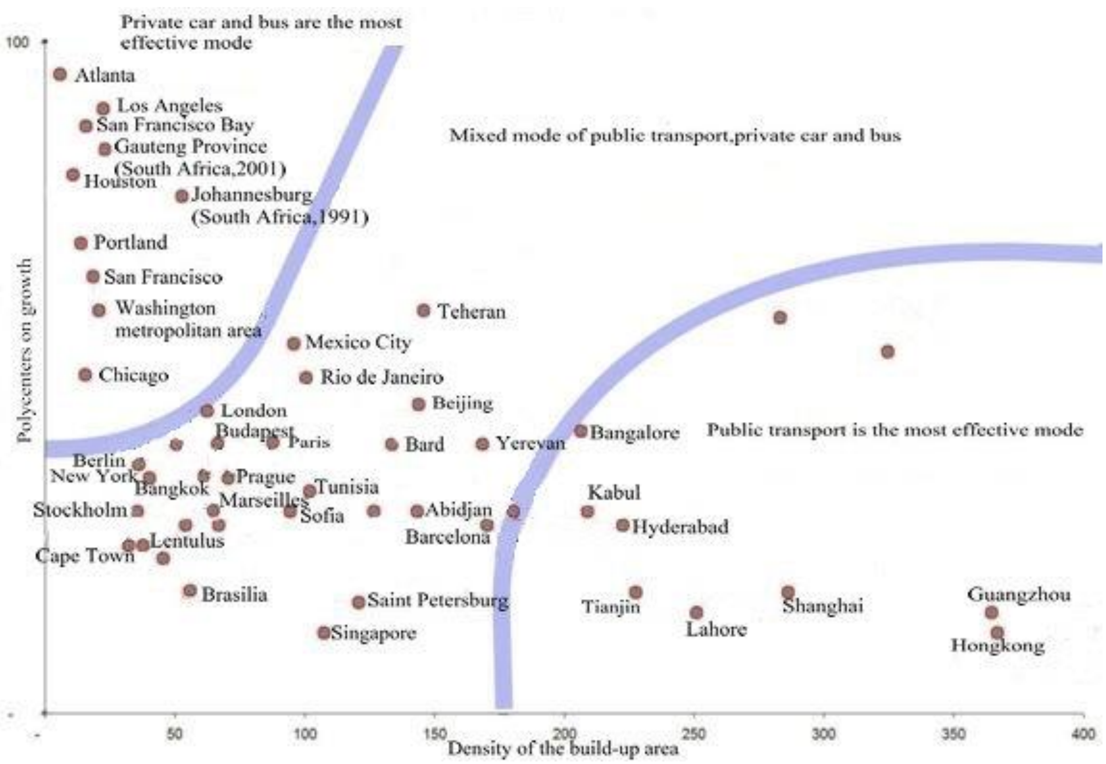


Figure 1-2 International Metropolitan Spatial Structure and the main mode of transportation (Alain Bertaud, 2001)

1.3 Impact of Employment Accessibility on Labor Market Performance

1.3.1 The Measure of Employment Accessibility

Accessibility is a measure to assess job-housing space structure and traffic infrastructure development, which reflects the land use and infrastructure policy level (Giles, 2004) of a region. Discussion of spatial structure evolution shows an insight into the change in the job-housing spatial relationship by accessibility analysis, and into problems about the traffic level and commuting efficiency at the job-housing ends.

Accessibility measure indicators and methods have different emphases given different research purposes and objects. Generally there are four types listed as below:

(1) Based on the measurement of transport facilities

Accessibility measure from this perspective is mainly about evaluation of the service level of the transport infrastructure, such as the degree of traffic congestion, the average road network speed, etc. This method is primarily used for transportation planning study with main indicators like the traffic speed, time spent in traffic jams, rush hour duration and so on.

(2) Based on spatial position measurement

Accessibility measure from this perspective is mainly to evaluate the accessibility of certain locations in the macro-spatial structure. This measure describes the accessibility level of the spatial distribution behavior, such as the number of the jobs available within 30 minutes' reach starting from one certain point. This method is mainly used to study urban planning and economic geography with the main index of travel time and costs between OD, supply and demand spatial distribution of opportunity, population levels divided by incomes and education level and so on.

(3) Measurement based on individual characteristics

Accessibility measure from this perspective is mainly to evaluate the accessible level of individuals, for example, within a certain time, a certain degree of freedom of individuals participating in activities. This method is mainly to measure the limitation degree under certain environmental conditions on the freedom of individuals to engage in activities, such as time budget of selectable activities, and travel speed in the particular transport system with the primary evaluation indicators such as travel time between locations of activities and the number as well as spatial distribution of opportunities provided.

(4) Measurement based on effectiveness

Accessibility measure from this perspective is mainly to evaluate the utility value gained from the activities of spatial distribution. This method is commonly used in economic research with the main evaluation indicator of transport costs between different venues of activities, distribution of opportunities offered, transportation time or costs within a certain period, individuals or people of a certain kind and so on.

The above measurement methods of accessibility show pros and cons in the angle of evaluation, and the selection of the evaluation indexes involved is directly related to the evaluation target. Wherein, the accessibility measurement of spatial position is of great significance to study on job-housing spatial evolution. Real cases from the perspective of the theory in current urban space research commonly use the research method of the gravity model; and the most famous one is the potential model proposed by Hansen (Hansen, 1959) and used to measure the accessible opportunity from a region to all the other areas, including the impact brought by the opportunities provided by the minimum and maximum distances. Model formula is listed as below:

$$A_i = \sum_{j=1}^{n} D_j e^{-\beta c_{ij}}$$

A_i is the accessible value from i zone to all j areas;

C_{ij} is the commuting costs from i zone to j zone;

β is the sensitivity parameters for commuters costs;

The potential model overcomes some shortcomings of the theory method, comprehensively considers the impact of land use and transport factors, and absorbs some means of other models to take the distance attenuation factors into account. The value and advantage of this methodology is to use the more easily obtained land and traffic data to evaluate accessibility issues of traffic and other urban public facilities.

In a later study, Ingram (1971) proposed two concepts: relative accessibility and integral accessibility, and constructed an accessibility model based on spatial obstruction. The model formula is:

$$sA_i = \frac{1}{J} \sum_{j \epsilon J-i} d_{ij}$$

In the formula, i and j refer to the starting point and the endpoint, respectively, J refers to the endpoint set, d_{ij}refers to the spatial barrier between i and j, and $A_i$refers to the accessibility of the point i. The space barrier model is the simplest and most intuitive accessibility model. The model will overcome the difficulty of space barrier as the core. Usually, the space barrier (spatial distance and time distance) between two cities will be taken as the measure of accessibility. The smaller the space barrier is, the better the accessibility will be. However, the model lacks other considerations for traffic demand and land use. Subsequently, Allen WB, Liu D and Singer S (1993) optimized it based on this model, deduced the spatial obstruction between all the points according to the model, and in order to be able to compare the inter-city road networks and topology calculation, and it has also been standardized. In addition, Mackiewicz and Ratajczak (1996) proposed a topological calculation method based on the layout of the road network and the number of links to calculate the spatial accessibility. Such ways and methods of calculation not only need to consider the shortest distance between two points, but also take into account the reachable factors such as the number of roads and the spatial layout between two points, which is compared with other ways and methods. The difference is that it ignores the type and size of activities distributed in space and the calculation is carried out only from the perspective of space resistance of the network. Its advantage is that it can analyze the characteristics of the network connection well, and then objectively compare the morphology and distribution of the physical space in many cities horizontally and is scientific to a certain degree. However, the disadvantage is that there is no activity of people thinking, so it has poor adaptability and the scope of application will therefore be subject to certain constraints.

Wachs M and Kumagai T (1973) put forward the concept of accumulative accessibility calculation based on opportunity accumulation. It focuses on the ease of access to development opportunities in cities. It refers to the number of work places and job opportunities for residents starting from their places of residence by taking certain modes of transportation. The idea of this measurement method is that people have different numbers of opportunities for development that they can access during different travel periods. As long as they are long enough, they can access all opportunities for development. The accessibility index calculated by this method is the opposite of the calculation based on space barrier. The accessibility value does not decrease with the increase of distance but increases with the increase of distance. Later, Black J and Conroy M (1977) proposed a concrete method of calculating accessibility based on chance accumulation, which is:

$$A_i = \sum_j O_{ij}$$

In the formula, t is the preset threshold value, O_{ij} refers to the opportunity of j sub-region, j refers to the sub-region whose distance (time and costs, etc.) to the sub-region i is less than t, i.e., the sub-region within the threshold value range. The main consideration of this model is the accumulation of the number of opportunities that travelers can access from a certain mode of transport from the point of origin to a certain area of travel. When using this model for evaluation, we first need to set a threshold (cost or time threshold), then the accessibility of a particular node is within the above set threshold (cost or time threshold) and the node can get the sum of all the opportunities. The larger the A_i value is, the larger the accessibility. However, the deficiency of this model is that the threshold t cannot be easily determined. When the threshold t is large enough, the departure site can reach all the opportunities within the scope of the study, so that A_i loses its significance.There are many similarities between ways to measure reachability based on spatial obstruction and based on chance accumulation. For example, if you want to increase the accessibility of a point, you need to try to increase the mobility of that point. In other words, the higher the mobility of a point, the higher the accessibility of this point. With the continuous improvement of traffic technology in the modern era, the speed of traffic also increases, prompting a "time-space convergence", and this can get better accessibility.

In the research of urban traffic planning, the accessibility calculation method based on spatial interaction is the most widely used. This method considers accessibility as the ease of reaching an activity destination, which is not only negatively impacted by two spatial barriers but also positively affected by the size of the activity. This approach effectively combines land use (representing urban activities such as development opportunities or service facilities) and transportation systems (representing travel costs, travel time and other costs). Later, on the basis of Hansen's potential model, Shen (1998, 2001) optimized it by taking into account the "demand side" and concluded that the accessibility of a test not only involves calculating the potential energy of the development opportunity at that point, but also the need for development opportunities must be considered at this point. Because development opportunities exist in areas with different potential needs, the ability to approach development opportunities is partly determined by the region's potential demand for development opportunities. In accessibility calculation, only the supply and demand factors are considered in order to more fully examine the accessibility of employment opportunities in all districts. And you can judge the accessibility by comparing the supply and demand of employment opportunities. If the supply of job opportunities is greater than the demand, it can be qualitatively considered as more accessible to employment in the region, otherwise the employment accessibility of the region is considered to be poor. Of course, the relationship between the supply and demand of employment in a certain area is also affected by the overall employment supply and demand.

Based on the analysis of the functional index of urban centers, Chen Shaopei and QiuJienni (2014) applied and improved the potential models to make comprehensive calculations and spatial differences analysis on the accessibility of prefecture-level cities in Guangdong Province. The results show that the urban accessibility of Guangdong and the spatial pattern of the economic link reflected by this show a concentric circle structure and radiate outward from Chancheng and Shunde districts in Foshan. The urban agglomerations of Pearl River Delta in Guangdong Province show the best accessibility and strength of economic connection. However, the northern and eastern and western cities lack the horizontal connection in the transport network structure, and are far away from the economic center's geographical position and overly dependent on the driving forces of the Pearl River Delta urban agglomeration. Under the combined influence of other factors, the degree of accessibility and economic linkages are the worst. Ma Shuhong et al. (2017) studied the impact of land use and transportation system characteristics in Xi'an on regional traffic accessibility by using spatial utility model. Considering the factors of time, cost, transfer, service quality and other factors as well as the passengers' individual attributes, it is found in the results that the average accessibility of the region within the walls reaches the highest at 0.9064; the average accessibility outside the tricyclic is the lowest with a value of 0.4418; the size of accessibility diminishes layer by layer as the distance from the city center increases.

When Shen Qing (1998) was in the study of low-income employment accessibility, he founded employment feasibility of the model space based on the gravity model; and the advantage of this approach is that: (1) the "job-housing ratio" evaluation indicator can only measure the matching relationship of the static structure in the job-housing space, and this method will introduce the commuting OD relationship into the model which can reflect real dynamic job-housing relationship; (2) It is suitable for measuring job-housing space of polycenter which can clearly show the accessibility features of each space unit; (3) factors of the urban space and traffic characteristics are brought into the model simultaneously, which not only objectively reflects the static matching issues about the job-housing space, but also truly reflects the job-housing O-D dynamic spatial relationship; (4) Unlike Hansen transportation accessibility model, this one is the job-housing relationship based on the spatial structure, essentially reflecting the job-housing (E / W), and therefore in principle, we hope this accessibility value is less than 1.

1.3.2 Impact of Employment Accessibility on Commuting Behavior

Commuting is a traffic behavior created by separation of job and housing space. Commuter traffic reflects the correlation between residential and employment locations in the city (labor market and real estate market); commuting is an important research direction and research content in many disciplines such as economics, urban planning and geography.

In their research, Lucas and Rossi (2002) established a balanced model of urban spatial structure. The model proposed that the internal location of urban enterprises and urban residential location selection hypothesis as the endogenous conditions. By solving this model, it is found that the balance of urban spatial structure is a single-center model when the urban agglomeration is strong and the cost of commuting economy and commuting time are high. At the other extreme, when the urban agglomeration is low and the cost of commuting economy is high and the time cost is high, the urban spatial structure is characterized by a balanced integration of the working space and the living space, which leads to a variety of different urban spatial structures between the two extremes. This shows that the economic agglomeration of cities and commuter economy, time cost are important determinants for city commuters to choose to live and get employed. Wachs (1993) proposed that job matching is one of the factors that affect commuting time. The increase of urban population, the increase of private cars, the increase of the proportion of women working, the slowdown of urban expressway network construction, the peak time non-commuter traffic growth and other factors will extend commuting time. Liu Zhilin and Wang Maojun (2011) measured the accessibility of employment in 124 streets in Beijing and used it as a measure of dislocation of working space, discussed the relationship between dislocation of working space and resident commuting time, but found that under the conditions of controlling social economic attributes and housing conditions, the influence of street employment accessibility on commuting time is not significant.

Meng Bin, Zheng Limin, and Yu Huili (2011) analyzed the changes of commuting time in five years and found that commuting time changes are related to not only socio-economic attributes such as age and academic qualifications, but also transportation development factors such as subway construction and changes in commuting styles. At the same time, through comparing the typical employment concentrated areas with the residential districts, it is found that the functional orientation of different districts in urban planning also has a significant impact on the commuting time of residents. Meng Bin (2009) studied the separation of job and housing of urban residents in Beijing. The study found that urban residents in Beijing had a one-way commuting time of 38 minutes, of which 43.7% of residents had commuted for more than 40 minutes and were commuting with major US cities during the same period. By comparison, it is concluded that Beijing residents commute for a long time. Based on a study of commuter travel data in the United States, Badoe (2000)analyzed non-motorized commute travel patterns and found that commuters with higher education tend to opt for non-motorized travel patterns; high-income commuters, for their part, choose to work from home with less use of walking or bicycle for commuting; car ownership rate, gender differences, racial differences, job distribution will affect commuters to choose different non-motorized modes of travel in urban areas, as well as the possible application of non-motorized commuting mode in different regions of the city. There is also a big difference in the possibility of using non-motorized commute travel modes in different regions of the city. Hanson (1982) considered that the socio-economic variables (social factors) have a significant impact on commute travel behavior. The social factors referred to are mainly age, gender and the use of private cars. Its influence is higher than the impact of urban form and balance of work and accommodation on commuting behavior. Bao Dan-wen and Guo Tang-yi (2014) quantified the uneven distribution of employment opportunities in urban areas by introducing the weight coefficient of employment opportunities, and analyzed the influence of dislocation of job-and-space space in Nanjing on commuting behavior. The research shows that there are obvious differences in employment accessibility in the main urban area of Nanjing City, showing a trend of decreasing gradually from the center to the periphery, and the decreasing degree becomes more and more obvious. At the same time, employment accessibility has a significant impact on the commuting time of low-income people, and the improvement of accessibility helps to reduce commuting time. ZhengSiqi and Cao Yang (2009) studied the deciding mechanism of the space between residence and employment by taking Beijing as an example and found the unique historical path dependence and institutional transformation in Chinese cities, which increased the complex spatial relationship of "housing-job". First, the turnover rate of housing stock is still low. Real estate housing occupies a dominant position close to the urban labor market but may not be accessible to those most in need of these locations, which will reduce the urban space efficiency. Second, as the planned economy, most of the city's high-quality public service facilities are still concentrated in central urban areas, lagging behind suburbanization of housing and industries, which may result in additional commuting. Thirdly, urban spatial planning has not taken into full consideration market forces and will affect the efficiency of urban space.

In the face of many influencing factors, Chen Tuansheng (2007) proposed the concept of travel chain based on the data of Beijing resident OD survey and analyzed the travel behavior of the research object. Combining with the logistic model, commuters' traffic mode choice behavior was studied and constructed. In addition, it also analyzes the influence of commuters' social-economic attributes and commuting characteristics on departure time of commuters, and focuses on the validity of the model. In studying the job-housing relationship in the Atianta metropolitan area, Sultana (2002) used a stepwise multiple regression model to explore the impact of commuting. The dependent variable he chooses is the one-way commute time per employee for each 7-mile buffer. The independent variables are the unbalanced job-housing ratio, the imbalance between the housing affordability of employers and local housing prices, the imbalance between the skills of local residents and the types of local employment, black places of work and place of residence. Excluding the percentage of employees with the annual income above 50,000 US dollars, , all variables are continuous variables, and the regression equation comes out. Through this regression model, Sultana argues that the imbalance in job-housing relationships is the most influential determinant of workers commuting over long distances. In addition, Lobyaem (2006) also used a regression analysis method to study the traffic congestion and job-housing imbalance in the metropolitan area of Bangkok. Using the commuting time index as a dependent variable, he conducted a regression study with job-housing relationship balance (JHB), population density (D), school density (Sch) and job accessibility index (Ai) as independent variables. At the TAZ level, the job-housing relationship is a significant variable explaining traffic congestion. However, at the sub-regional level, there is no significant relationship between job-housing relationship and traffic congestion, both in terms of simplified models and complete models. Taking Beijing as an example, Wang and Chai (2009) used structural equation modeling to study the relationship between residential property (unit housing or individual housing), job-housing relationship, traffic mode and commuting time. The study concludes that residents living in units of housing have shorter commutes. Baker et al. (2005) studied the travel patterns of different income groups in Mumbai. Overall, 44% of commuter trips were carried out on foot and the proportion of low-income groups walking was as high as 63%. In addition, high-income groups often have longer commuting distances and commuting time. Houston (2005) pointed out that in studying the problem of spatial mismatch, the method of comparing commuting time is often used.

1.3.3 Impact of Employment Accessibility on Labor Market Performance

The impact of employment accessibility on labor market performance can be illustrated by factors such as job satisfaction, employment rates and household income, etc.

First of all, many scholars think that the improvement of employment accessibility can effectively increase the urban employment rate and family income (Kain 1992; Raphael 1998; Sanchez & Brennan 2008). Kawabata (2003) took Boston, San Francisco and Los Angeles as the research object to study the effect of employment-based accessibility on the employment behavior of non-car residents. The study found that the better the employment accessibility, the higher the employment rate of car residents without the car and the longer the working hours per week may be. Taking Los Angeles as an example, Ong and Miller (2005) also studied the effect of mismatch between job and occupational space and traffic mismatch, especially car accessibility on unemployment rates and reached similar conclusions. It is also pointed out that traffic mismatch has a greater impact on labor market performance than spatial mismatch. Blumenberg (2003) and Patacchini and Zenou (2005) respectively studied the employment performance of low-income women groups and different ethnic groups with different employment accessibility. The study found that groups with good car employment accessibility often have higher employment rates and monthly salaries are mainly due to the fact that good car employment accessibility increases the intensity of public job search. Taking urban transport infrastructure projects as an example, Boarnet (2007) studied the effect of employment-based accessibility on labor market performance using a double-difference model and pointed out that the improvement of traffic conditions helps to connect people to work, reduce unemployment and alleviate poverty. In a recent study, Jin and Paulsen (2017) used data from the Chicago metropolitan area to analyze the impact of employment accessibility on unemployment and household income for different income and ethnic groups. The study found that improvement in job accessibility effectively improved employment rate and household income for African-Americans and low-income groups.

In addition, many scholars also studied the factors influencing job satisfaction and their relationship. Commuting time and commuting distance have become important factors affecting employment satisfaction. By comparing the employment satisfaction of residents in the United States and European countries, Oswald (2002) found that there is a clear correlation between high employment satisfaction and gender, income, commuting time, employment environment, employment units and academic qualifications. Spies (2006) studied the effect of commuting distance on employment satisfaction of oil workers in Northwestern Russia. The study found that employment satisfaction does not necessarily decrease with the increase of commuting distance. In addition, this also depends on the business' understanding and satisfaction of this part of employees who need remote commuting. Isacsson et al. (2008) empirically examined the impact of the value of commuting time and the value of working hours on the employment satisfaction of the general public. The study found that commuting time had a significant impact on employment satisfaction. Using multivariate linear regression analysis, Johnson (2016) studied the factors influencing e-commuter employment satisfaction. The study found that the employment satisfaction of these sub-groups was usually high and correlated with age significantly. Crawley (2014), in a study of factors that affect employees' job satisfaction, pointed out that previous studies mostly ignored the impact of commuting time and mode of travel on job satisfaction and found that commuting time was negatively correlated with job satisfaction. This negative externality of commuting time can be offset by income, especially when employment satisfaction among high-income groups is less correlated with commuting time, while low-income groups are less satisfied with employment when commuting time is longer.

1.4 Conclusion

The evolvement of urban spatial structure from single-center structure to multi-center structure is the common feature of the development of modern metropolitan space. Different urban spatial structures correspond to different occupational and residential issues. In the Asian cities represented by Beijing, the process of urbanization has been changing rapidly in the past two decades. The permanent population and jobs in cities have rapidly increased in the overall scale, and the spatial layout of cities, the structure of work and residence has also shown new features. Compared with the development of metropolitan areas in Europe and the United States, Beijing has distinct characteristics in terms of factors such as geographical natural endowments, historical evolution, stages of industrial development, and urban population density. In the process of population sub-urbanization and employment center growth and differentiation, the evolution of the spatial structure of employment and residence in cities show both common characteristics and particularities. After reviewing the general rules of the development of modern metropolitan space, this part also gives the experience of developing typical international cities in the evolution of working space and commuting patterns. It provides the second part of the project to study the evolution of urban space and working space in Beijing as an important reference.

When studying the problem of balance of work and residence in cities, the existing literature usually adopts such indicators as commuting time and commuting distance to analyze the degree of segregation of work and residence of urban residents. The factors influencing commuting time include multiple factors such as travel mode, housing condition, gender, age and education, which provide a perspective for the third part of the study on residents' travel behavior in Beijing. In view of the impact of employment accessibility on labor market performance, most of the literature concludes that the improvement of employment accessibility will increase the employment rate of the population and the consistency of household income. Conclusions are drawn from the influence of employment accessibility on employment satisfaction. However, the influence of employment accessibility on employment satisfaction is also affected by factors such as income and enterprise welfare, which provides some inspiration for the study on employment satisfaction of residents in Beijing in the fourth part of the project.

In terms of research methods, this project mainly adopts the metrological regression model method to make a comprehensive analysis based on the urban population, employment data and the traffic survey data, especially the commuter travel OD data. Using ArcGIS spatial analysis method to reproduce the evolvement characteristics of urban job-housing space, especially the dynamic analysis of real-life housing-job. Based on the research results, this paper analyzes the correlation between the construction of transportation infrastructure and the characteristics of socio-economic attributes and the changing characteristics of employment accessibility under the evolvement of employment space. The results of this research can provide a reference for the study of the spatial development characteristics of Asian cities. It also provides a useful attempt to explore methods for analyzing urban job-living space as well as to evaluate the impact of investment in transport facilities on the socio-economic development.

2 Urban Space Analysis and Job Accessibility of Beijing

2.1 Urban Economy Development Background

2.1.1 Social and Economic Growth

Beijing's GDP has maintained a sustainable, stable and quick growth. In 2010, Beijing's GRP was up to RMB1, 411.36 billion, increased by 10.3% as compared with that in previous year in terms of comparable price. Beijing's GDP was doubled as compared with that in 2005. In 2015, Beijing's GRP was up to RMB2296.86 billion, increased by 6.9% and 150% as compared with that in previous year and 2010 respectively (see Figure 2-1). Beijing's GDP per capita was increased from USD10, 910 in 2010 to USD17, 064 in 2015.

Beijing's GDP per capita topped over USD3, 000 (2001), USD5, 000 (2005) and USD10, 000 (2010), the several symbolic stages in the past ten years in terms of permanent resident population. Its quick development is rare in urban development history worldwide (see Figure 2-1).

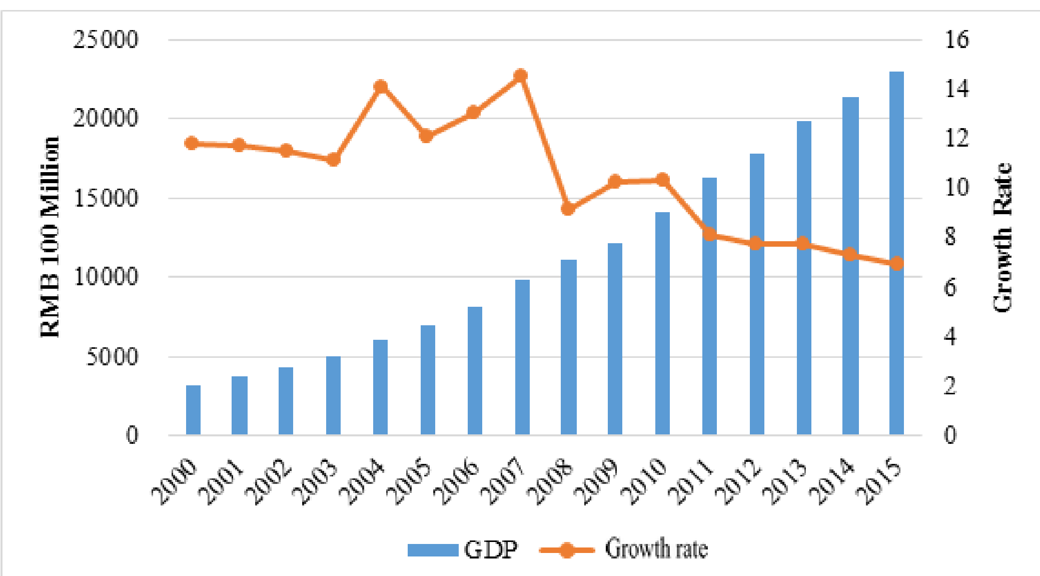


Figure 2-1 Variation to Beijing's GRP during 2000-2015

Data source: Beijing Municipal Bureau of Statistics

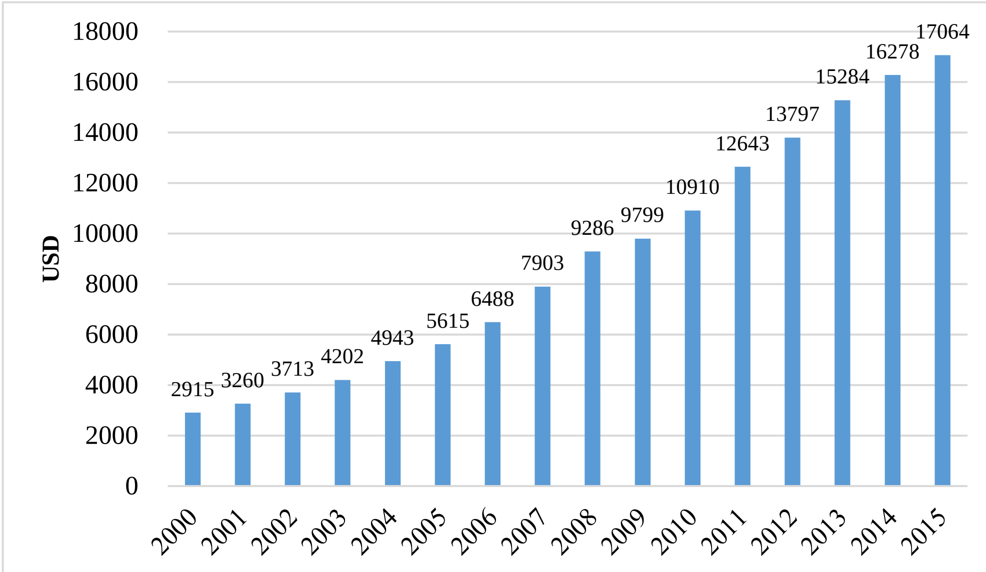


Figure 2-2 Variation to Beijing's GDP Per Capita during 2000-2015

Data source: Beijing Municipal Bureau of Statistics

In view of economic development course in U.S.A, West Europe, Japan and Singapore, such fields as industrial structure, population scale, urban space structure and social public services will be provided with similar development features when GDP per capita is developed to different economic stages: When GDP per capita exceeds USD3000, urban economy witnesses a relatively long period of high-speed growth; the service industry will rise and develop into leading industry, and economic development mode will be in a transition from investment driven mode to innovation driven mode. When GDP per capita exceeds USD5, 000, economic structure will subject to further transformation, and labor intensive industries will be upgraded in a transition to capital and technology intensive heavy industries. Meanwhile, service industry will become the pillar industry accompanied by quick rise of middle class in the society and sustainable expansion of urban space. Construction of new cities will further require integration of such functions as residence, employment and services. When GDP per capita exceeds USD10, 000, modern service industry will become a leading industry in industrial structure, and functions of cosmopolitan cities will be in a transition from production to service; whereas service types will be expanded from finance, insurance, real estate and public management to such emerging service sectors as IT, cultural creativity and operating management consultation sector. With regard to industrial spatial distribution, the trend of suburbanization in manufacturing sector will become more obvious. Most of companies will establish hi-tech industrial bases at suburbs and exurbs while maintaining their headquarters, R&D, design and distribution centers in urban area. Urban space structure will be in a transition from single center to multi ones.

Thus it can be seen that significant change to urban space structure in Beijing is due to impact from such factors as accelerated development of urban economy, industrial structure upgrading and adjustment as well as variations to residents' living demands.

2.1.2 Development Trend of Industrial Types

Viewing from specific conditions of industrial development, the tertiary industry as represented by service sector in Beijing has witnessed an accelerated development. Service industry is becoming a new orientation leading social and economic transformation in Beijing. In 2015, added value as realized in service industry was up to RMB1830.2 billion, accounting for 79.8% of GRP. It was increased by 4.8% and 10.2% respectively as compared with that in 2010 and 2005. As indicated by data obtained from Beijing Municipal Bureau of Statistics, information service, business service and science and technology service sectors are three service sectors with the highest development speed. Wherein, finance, commerce, post and telecommunication, culture and real estate have also witnessed a significant increase. Increase rate in such sectors as information technology, finance, leasing business and science consultation is over 50%. Meanwhile, proportion of manufacturing, construction and electric gas sectors is in a trend of decrease.

Table 2-1 Growth in Various Industries as Indicated by Beijing Municipal Bureau of Statistics in 2004 and 2008 (Unit: 10 thousand people)

	Total	Mining	Manufacturing	Electric Gas, Water Production and Supply	Construction	Transportation, Warehousing and Postal Service	Information Transmission/ Computer Service and Software	Whole-sale and Retail	Accommodation and Catering	Finance
2008	816.9	5.1	134.7	6.7	54.7	69.5	46.6	94.3	45.0	25.1
2004	704.2	4.1	148.7	7.8	69.6	43.0	28.5	83.2	38.4	15.0
Growth difference	112.7	1.0	-14.0	-1.1	-14.9	26.5	18.1	11.1	6.6	10.1
Growth rate	16.00%	24.14%	-9.44%	-13.61%	-21.37%	61.75%	63.57%	13.37%	17.14%	67.53%

	Real Estate	Lease and Business Service	Scientific Research, Technical Service and Geologic Survey	Water Conservancy, Environment and Public Facility Management	Neighborhood Service and Other Services	Education	Health, Social Security and Welfare	Culture, Education and Entertainment	Public Management and Social Organizations
2008	41.0	95.9	56.4	9.3	14.1	43.1	20.0	18.6	36.6
2004	31.9	63.8	38.9	7.5	19.6	38.7	16.0	16.2	33.4
Growth difference	9.1	32.0	17.6	1.8	-5.5	4.4	4.0	2.4	3.3
Growth rate	28.66%	50.28%	45.19%	24.45%	-27.97%	11.28%	24.46%	14.89%	9.88%

Data source: Beijing Municipal Bureau of Statistics

2.2 Evolution of Job-Housing Space Structure

2.2.1 Population Suburbanization

Beijing has witnessed a quick increase in urban population in recent 30 years. Total population in Beijing at the end of 2015 was 23.145 million, including 21.516 million permanent residents. This figure increased by 1.906 million as compared with that in 2010 with annual growth rate up to 2.35% (see table2-2). However, accompanied by increase in residents' income and activation of res estate market, more and more residents would shift to suburbs. Urban population is in a trend of decentralized development in the space at the same time of concentration.

Table 2-2 Growth in Urban Permanent Population in Beijing

Year	Whole City (10, 000 persons)	Annual Growth Rate	Central City (10, 000 persons)
1987	1047	-	-
2000	1357	2.02%	-
2005	1538	2.54%	952.2
2010	1961	4.98%	1173.5
2015	2151.6	2.35%	1284.7

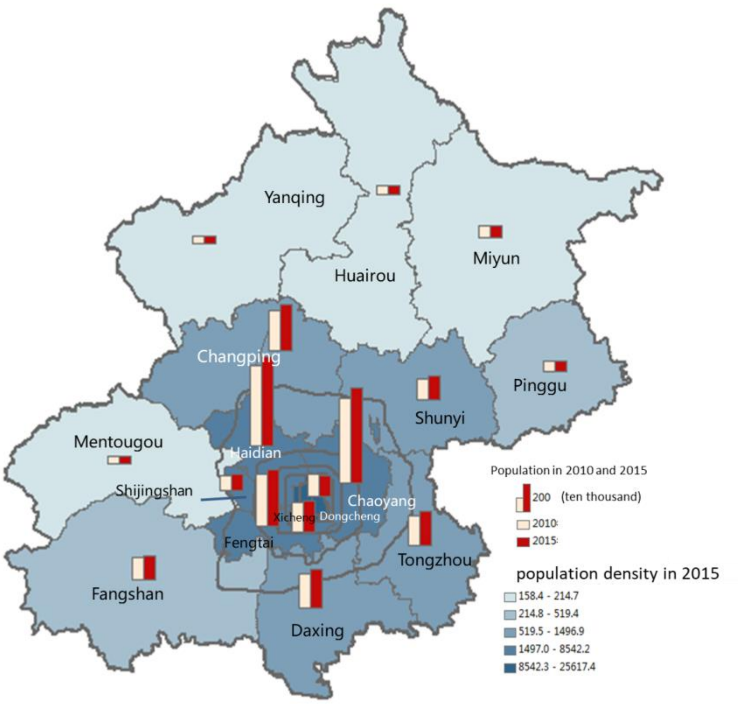


Figure 2-3: Distribution of Total Permanent Population and Density in 16 Districts of Beijing

Data source: Beijing Municipal Bureau of Statistics

The trend of suburbanization for urban space development in Beijing can be traced back to 1980s. Accompanied by increase in urban population, more and more residents begin to seek settlement at suburbs. This has resulted in quick increase in permanent population in 4 districts as represented by Chaoyang, Fengtai, Haidian and Shijingshan, and has broken down the spatial pattern of concentration of population in central city. In 1990s, outward shift of population in central city was accelerated, and quickly increased population in nearby 4 districts further expanded outward.

Suburbanization of urban population in Beijing has been further enhanced in recent ten years, which can be summed up as follows: Nearly 50% permanent population is distributed at the functional development area (Chaoyang, Haidian, Fengtai and Shijingshan), the population in Chaoyang district (3.9 million people) accounts for the highest proportion. Permanent population in Capital Core Functional Area (Dongcheng District and Xicheng District) has witnessed a gradual decrease since 2005.Nevertheless, Xicheng District has the highest population density (31, 000 people /km2).

Urban population dispersion trend in Beijing is similar to the development course in other cosmopolitan cities. As discovered by Zhang Shanyu (2003) during study of development course of Tokyo Metropolis, population growth rate is quite different in different areas of Tokyo Metropolis, which is changing accompanied by development stage of suburbanization. Growth was so quick in the circle of 10-40km during the period from 1955 to 1965, which was especially significant in the circle of 20-30km. After that, population in the circle of 10km witnessed a gradual decrease; whereas growth in the circle of 10km to 20km was significantly slowed down. The highest growth rate appeared in the circle of 30km to 40km in 1970s, which further shifted to the circle of 40-50km during 1980-1990. Population suburbanization course is typically characterized by the sequence from the near to the distant.

Population suburbanization in Beijing is also characterized by gradual outward expansion. Taking Tian'anmen Square as the city center, average radius of the 4^{th}, $5^{th}$and 6^{th} Ring Roads is up to 10km, 15km and 27km approximately. In recent 20 years, total population inside the 6^{th} Ring Road has been increased from 11.12 million to 16.34 million, and the average density has been increased from 5000 persons/km2 to 7000 persons/km2. Population scale and percentage inside the 2^{nd} Ring Road have witnessed a decrease to some extent. The percentage has been reduced by 3.2%.Percentage of permanent population inside the 4^{th}-6^{th} Ring Roads has witnessed a sustainable growth; wherein, population between the 5th and 6th Ring Roads has the highest growth rate with permanent population increased by 2.27 million (See Table 2-3).

Table 2-3: Population Distribution and Variation at Ring Roads in Beijing

Area	Land Area (m2)	Percentage	2005			2010			2015		
			Population (10000 persons	Percentage	Density (10000 persons, m2	Population (10000 persons	Percentage	Density (10000 persons, m2	Population (10000 persons	Percentage	Density (10000 persons, m2
Inside 2nd Ring Road	62	3%	138	12%	2.2	135	9%	2.2	148	9%	2.4
2nd-3rd Ring Roads	96	4%	194	18%	2.0	235	16%	2.4	257	16%	2.7
3rd-4th Ring Roads	178	8%	203	18%	1.1	262	18%	1.5	288	18%	1.6
4th-5th Ring Roads	332	15%	224	20%	0.7	329	22%	1.0	361	22%	1.1
5th-6th Ring Roads	1614	71%	353	32%	0.2	529	35%	0.3	580	35%	0.4
Total	2282	100%	1112	100%	0.5	1490	100%	0.7	1634	100%	0.7

Data source: The Traffic Survey in Beijing

It can be seen clearly on the aspect of street unit that the area subjecting to increase of permanent population was outside of North 5th Ring Road, South 4th Ring Road and East 5th Ring Road during 2005-2015. Population growth outside of North 5th Ring Road mainly concentrated at Huilongguan Street, Shahe Street, Dongxiaokou Street and Beiqijiazhen Street where Huilongguan Community and Tiantongyuan Community situated. In 2015, permanent population in such areas increased by 1.068 million to 1.969 million.

Population growth outside of South 4th Ring Road mainly concentrates at Lugouqiao, Huaxiang and Nanyuan in Fengtai District, Jiugong, Xihongmen and Yizhuang in Daxing District. In 2015, permanent population in this area increased by 1.238 million to 1.955 million.

Population growth outside of East 5th Ring Road mainly concentrates at such streets as Pingfang, Sanjianfang, Yongshun, Beiyuan and Songzhuang in Tongzhou District. In 2015, permanent population in this area increased by 0.539 million to 0.948 million.

Meanwhile, total permanent population in Dongcheng District and Xicheng District has witnessed a gradual decrease. Permanent population decreased by 0.15 million people to 1.673 million people during 2005-2015.

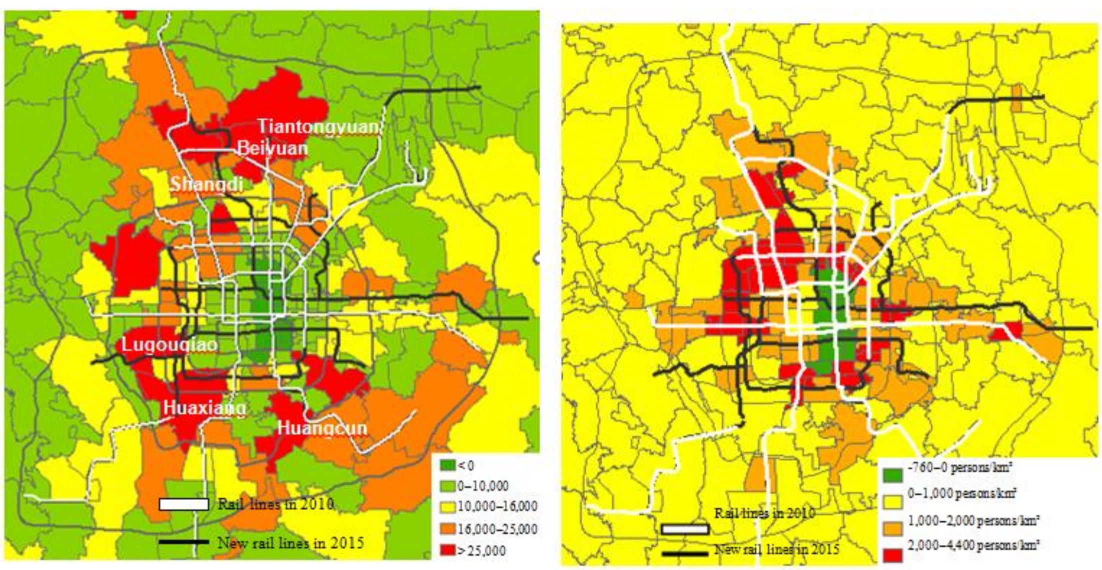


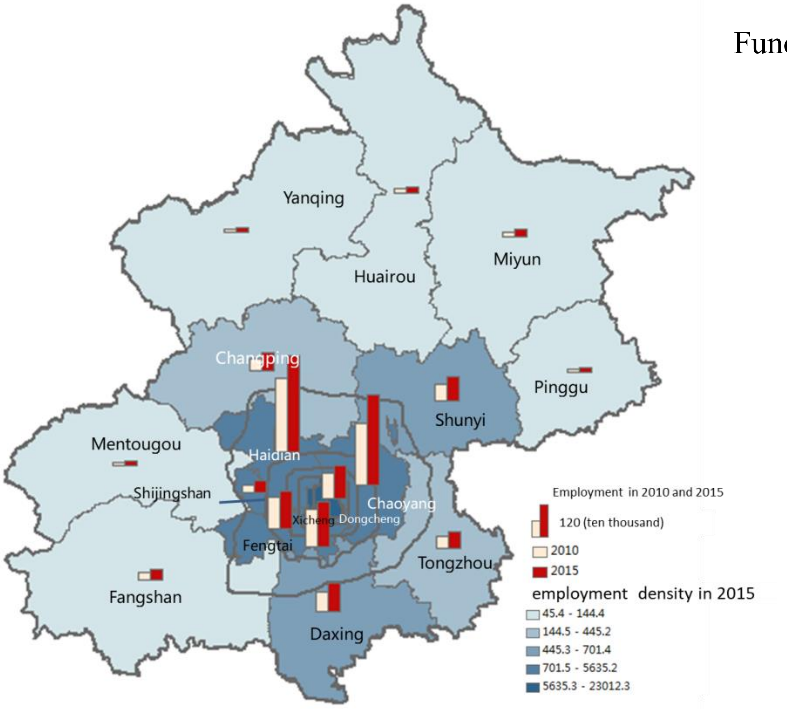
Figure 2-4 Difference value of total population and population density in 2015 and 2010 (within the 6th Ring Road)

Data source: Beijing Municipal Bureau of Statistics

2.2.2 Employment Concentration and Dispersion

The number of employees in Beijing has reached 11.567 million by the end of 2015, which increased by 1.251 million at rate of 12.13% in 2010; the number of employee in primary, secondary and tertiary industries is up to 0.524 million, 2.099 million and 8.944 million respectively. As a whole, the number of employees in tertiary industry has witnessed a sustainable growth by 16.5% as compared with that in 2010.

Viewing from growth in the number of employees in all districts and counties, Urban Functional Expansion Area



(Chaoyang/Haidian/Fengtai/Shijingshan District) is the job concentration area. Total jobs in Urban Functional Expansion Area and new development area (Fangshan/Tongzhou/Shunyi/Changping/Daxing District) have witnessed a significant growth during ten-year development; total jobs in 2015 increased by 29.3% and 43.3% respectively as compared with that in 2005. Job scale in Capital Core Functional Area (Dongcheng/Xicheng District) is basically stable, which has only increased by 23.9%. Viewing job distribution in Beijing, 71.76% jobs concentrate at 6 districts; whereas job attraction demand mainly concentrates at the central city.

Figure 2-5: Total employment and Density distribution in All Administrative Districts

Data source: Beijing Municipal Bureau of Statistics

Viewing from development of the area around ring roads, the number of jobs outside the 4th Ring Road is higher than that inside the 4th Ring Road; 71% jobs are concentrated at the central city; however, the pattern of endocentric concentration of jobs remains unchanged basically (See Table 2-4). Distribution of employment scale inside the 6th Ring Road is uneven. Employment scale and density in north city are higher than that in the south city.

Table 2-4 Job Distribution in Beijing in Previous Years

Area	Land Area (m2)	Percentage	2005			2010			2015		
			Jobs (10,000)	Percentage	Density (10, 0000 jobs/m2	Jobs (10, 000)	Percentage	Density (10, 0000 jobs/m2	Jobs (10, 000)	Percentage	Density (10, 0000 jobs/m2
Inside 2nd Ring Road	62	3%	135	19%	2.2	139	16%	2.2	137	14%	2.2

2nd-3rd Ring Roads	96	4%	165	23%	1.7	203	23%	2.1	216	22%	2.3
3rd-4th Ring Roads	178	8%	133	18%	0.7	188	22%	1.1	205	21%	1.2
4th-5th Ring Roads	332	15%	130	18%	0.4	147	17%	0.4	186	19%	0.6
5th-6th Ring Roads	1614	71%	165	23%	0.1	195	22%	0.1	252	25%	0.2
Total	2282	100%	729	100%	0.3	872	100%	0.4	996	100%	0.4

Data source: The Traffic Survey in Beijing

Spatial concentration effect has been further enhanced accompanied by increase in jobs as resulted from industrial adjustment and rise of modern service sector in Beijing. Numerous employment centers of high density and unique features have appeared in terms of spatial distribution of jobs. This has gradually formed an urban spatial layout of main employment center---CBD and numerous employment sub-centers. As discovered through analysis of data from Beijing Municipal Bureau of Statistics (2003 and 2008), spatial concentration of jobs has become more obvious. Most of jobs are concentrated in the area between East 2nd Ring Road and the 3rd Ring Road, West 2nd Ring Road and the 3rd Ring Road as well as North 3rd Ring Road and the 4th Ring Road (See Figure 2-6).

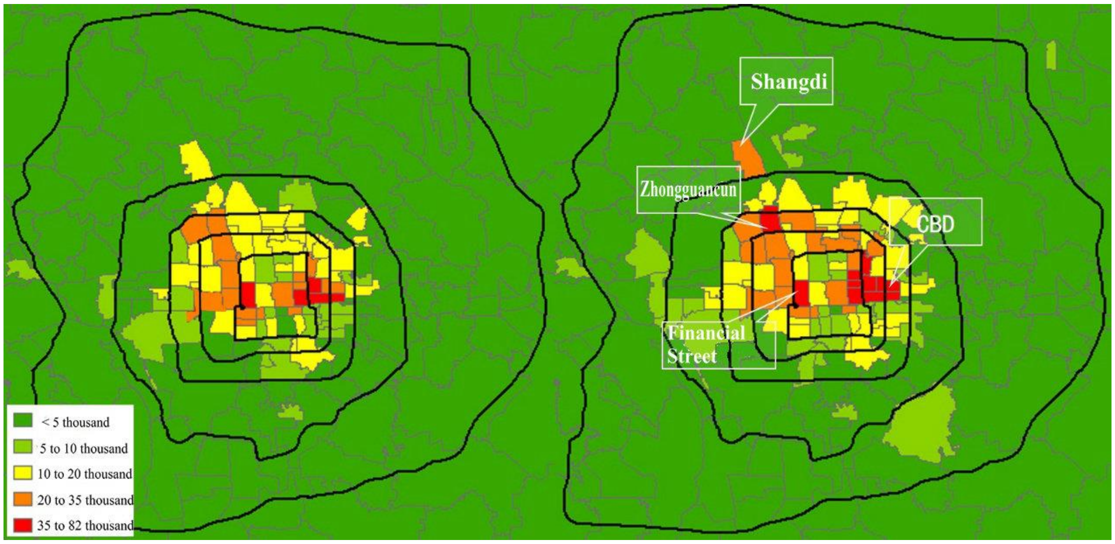


Figure 2-6: Diagram for Job Distribution Inside the 6th Ring road in 2008 and 2013

Data source: Beijing Municipal Bureau of Statistics

So far, Pan-CBD has attracted 0.872 million employees with employment density up to 37, 000-81, 000 jobs/m2; Financial Street has attracted 0.292 million employees with employment density up to 74, 000 jobs/m2; Zhongguancun has attracted 0.605 million employees with employment density up to 22, 000-48, 000 job/m2; as IT sub-center of Zhongguancun, Shangdi Software Park has witnessed a significant increase in total employment in the past 5 years with employees and employment density increased to 25, 900 employees and 27, 000 job/m2 respectively in 2013.

Employment increase in Beijing is not only represented by concentration of center city and formation of employment center, but also characterized by significant increase of jobs at suburbs. Viewing from data of Beijing Municipal Bureau of Statistics, streets having the highest increase in total employment are located at several employment centers in Yizhuang Economic and Technological Development Zone CBD, Zhongguancun Science and Technology Park, Financial Street and Beijing Airport Economic Zone (Capital International Airport). Meanwhile, total employment of such streets as Shangdi, Pingguoyuan and Xincun at the suburb of the city is also in a trend of quick increase. This is mainly determined by the development rule for dispersion of employment rate in Beijing. For instance, Shangdi has developed into a sub-center of former

Zhongguancun Science and Technology Park, which has become a new venture park. Furthermore, construction of headquarter base at the northwest of the city has brought into being concentration of more jobs at Xincun Street. On the contrary, such streets as Yangfangdian, Dahongmen, West Chang'an Street in the central city has witnessed a decrease in jobs. Some streets with higher residential population have also witnessed a decrease in jobs, including Gucheng, Niujie, Tianqiao and Guanganmen. As shown in Figure 2-7, total employment in 2013 and 2008 was in a trend of "low inside ring roads and high outside ring roads"; the number of jobs inside the 2nd Ring Road witnessed a significant decrease (except for Financial Street); whereas that at the periphery of the 3rd Ring Road witnessed a slight increase; employment center in the north and south of the city witnessed a further expansion in scale, featuring in a "funnel" spatial variation. To sum up, total employment in Beijing is dually driven by enhanced spatial concentration and dispersion of employment centers while maintaining a high growth rate.

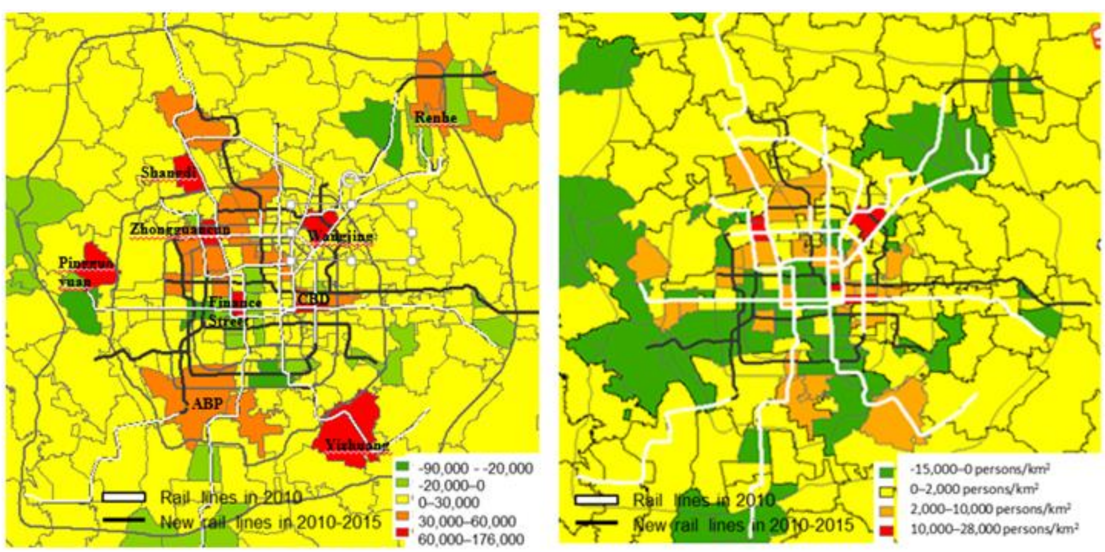


Figure 2-7: Difference value of total employment quantity and employment density along rail lines in 2015 and 2010 (within the 6th Ring Road)

Data source: Beijing Municipal Bureau of Statistics

2.2.3 Job-Housing Spatial Formation

Spatial formation of a city is to be examined based on population and employment. To see this from the demographic dimension, as compared with size of Western cosmopolitan cities, population density of megalopolis in Asia is relatively higher. As discovered by Alain Bertaud (2003) through comparison of average urban population density in 48 major cities worldwide, population density in such Asian cities as Hong Kong, Shanghai, Bombay, Jakarta and Seoul is over 30, 000 people/km2 (data in 1990); whereas population density in European cities is much lower, which is around 10000 people/m2; population density in cities in North America is even much lower, which is below 5000 persons/km2. Furthermore, there also exits slight discrepancy between population increase and expansion of land area in each city; the speed of outward expansion of urban land far exceeds the growth rate of urban population; speed of land expansion in cities in U.S.A is even faster than that in European and Asian cities; viewing from increase in population density, population density in American cities is relatively lower than that in other cities. Therefore, all megalopolises worldwide are proceeding with "urban sprawl" in the course of development; however, there exists significant discrepancy to the urban formation; Asian cities of high population density are characterized by "thick" and extensive intermediate part of "urban sprawl"; there exists high discrepancy to the population density between the central part and periphery; In some cities in North America, the center and periphery of the "urban sprawl" is characterized by limited discrepancy to the "thickness".

Viewing from development trend of spatial distribution of employment, cosmopolitan cities in U.S.A and Western Europe were in a trend of dispersion of jobs from the central city to suburbs in 1990s; percentage of jobs in conventional CBDs witnessed a decrease; whereas new employment sub-centers appeared at suburbs; percentage of jobs in such sub-centers witnessed a significant increase (Giuliano, 1991; Gordon, 1996; Daniel, 2001; McMillen, 2003). Polycentric spatial pattern of employment has become an inevitable development stage in the social and economic development course of cosmopolitan cities.

As compared with spatial development rule in big cities in Europe and U.S.A, Beijing is provided with similarity and its own development features. Beijing is in a development trend of dispersion of population and employment to suburbs accompanied by quick increase in permanent population, total employment and density of central city; in other words, internal structure of urban center is subjecting to adjustment and variation at the same time of expansion in scale. For instance, as indicated by spatial data of Washington in 1990 (See Figure 2-9), CBD has the highest employment density; whereas maximum employment density in urban center is 10 times of residential population density. As indicated by spatial data of Tokyo, an Asian city in 1998, maximum employment density in urban center is 5 times of population density (See Figure 2-10). According to analysis of job-housing space in Beijing, maximum employment density at urban center is 1.5 times of population density. Thus it can be seen that as compared with urban morphology of other cosmopolitan cities worldwide in the course of suburbanization, job-housing spatial morphology in Beijing can be summed as follows: Urban population and employment density are in a high concentration inside the 6th Ring Road; concentration intensity and growth trend of employment space is slightly higher than the population density; urban space is in a “cone” morphology, and job-housing structure is generally balanced (See Figure 2-8).

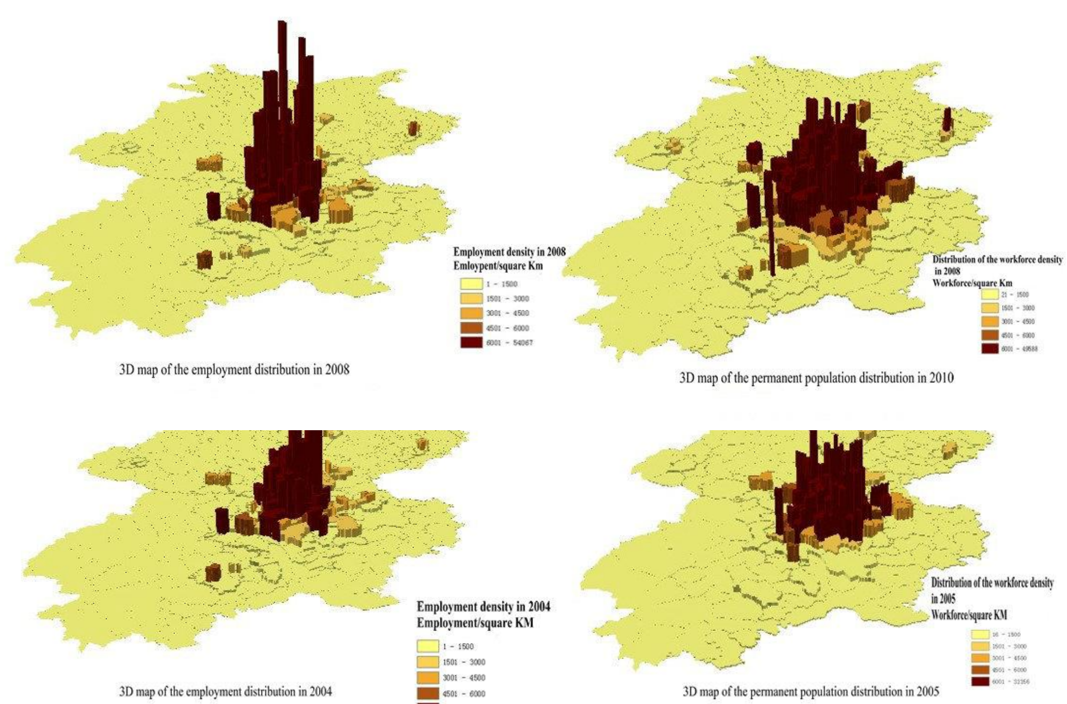


Figure 2-8: Spatial Evolution of Employment and Residential Population in Beijing

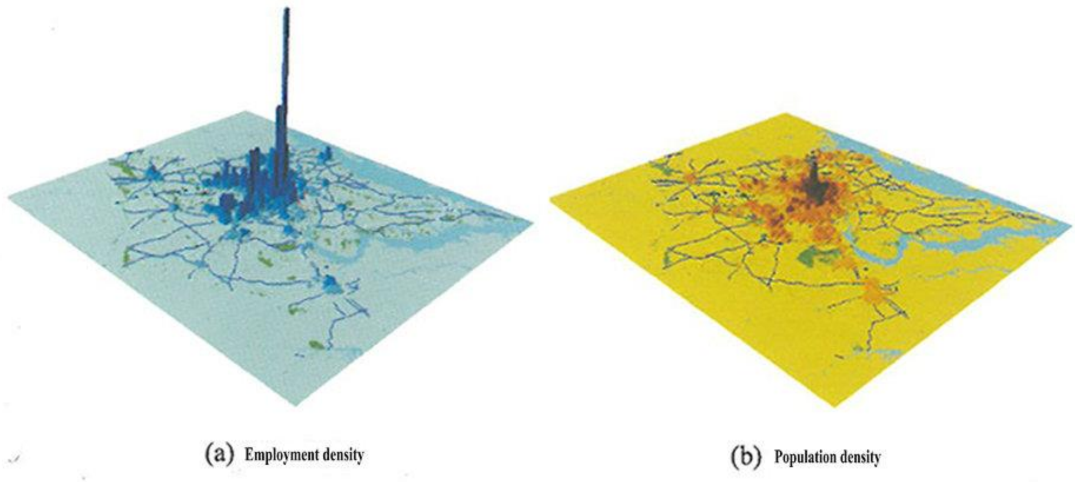


Figure 2-9: 3D Diagram for Spatial Distribution of Population and Employment in Washington (1990) (Ding Chengri, 2007)

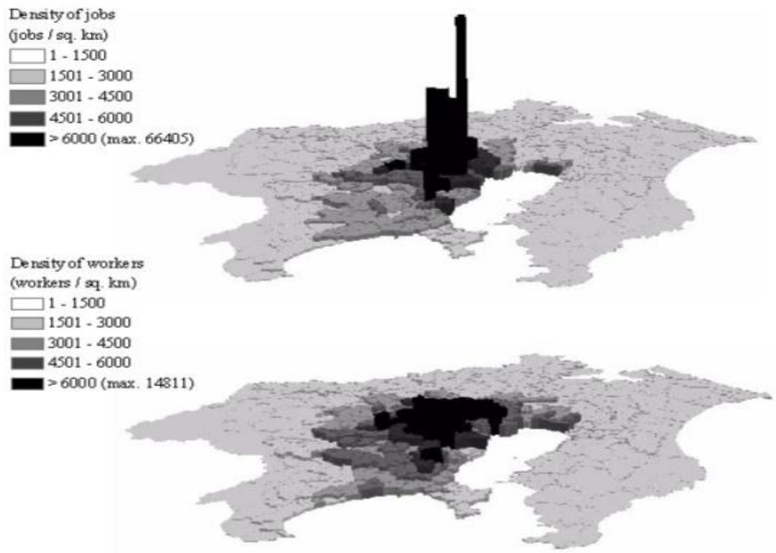


Figure 2-10: 3D Diagram for Distribution of Employment and Working Population Density (1998) (Okajima Mizuki, 2003)

2.2.4 Variation to Job-Housing Ratio

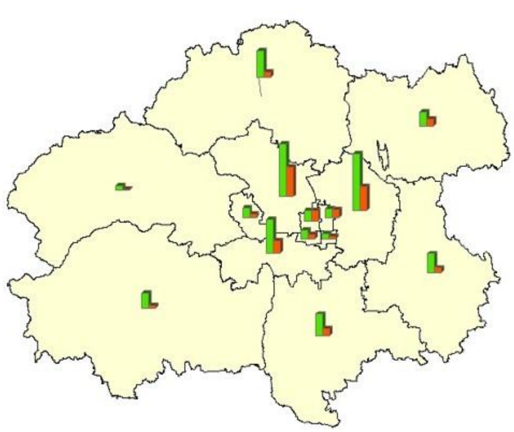
Job-housing matching is an important issue as discussed in the field of urban planning and public policies; in particular, regional job-housing matching is deemed as an indicator for evaluation of land utilization efficiency when mentioning such issues as settlement of traffic jam, improvement of regional traffic pressure and environmental pollution. An efficient and reasonable urban space structure will inevitably provide a relatively large labor and employment market for local residents; alternatively, it can provide affordable residence for employees in the employment concentration area. Therefore, job-housing ratio is gradually becoming an indicator for evaluation of urban space structure by planners and researchers; it is applicable to evaluate reasonability of composite land development and urban planning in this area through comparison of proportion of jobs and residential population inside different geographic unit area. In the opinion of some researchers, reasonable job-housing matching inside an area and improved composite land utilization can minimize “excess commuting”, which is favorable for minimization of energy consumption and long-distance travel. The hypothesis as proposed by researchers for “cooperative orientation” of job-housing is also based on the opinion on balanced job-housing development. The study is also expected to analyze evolution of job-housing matching in Beijing. As the data available for study is mainly on permanent population as indicated by Beijing Municipal Bureau of Statistics, which is in lack of direct statistics of working population, the job-housing ratio used in the thesis is mainly obtained from the ratio between jobs and permanent population.

Viewing from job-housing spatial morphology, static job-housing matching in Beijing is satisfactory; permanent populations and jobs are concentrated inside the 4th Ring Road of the city; Beijing is provided with features of a typical Asian city of high urban density.

Firstly, viewing from various administrative districts, overall job-housing matching at the urban center is satisfactory. Wherein, due to historical reasons, former Dongcheng District and Xicheng District are characterized by high concentration of enterprises and institutions, which has abundant employment resources owing to such employment concentration areas as Financial Street and Wangfujing; for this reason, this area has a relatively higher job-housing ratio[1] of

1.0-1.4, where employment demand is also higher than actual working population in this area; this area belong to traffic flow attraction area. Chaoyang District, Haidian District, Fengtai District and Shijingshan District outside the urban center have the highest concentration of urban population and jobs, accounting for 1/2 of the total in Beijing; such districts include streets of highest population density with average job-housing ratio up to 0.3-0.6. 8 districts at suburbs have a relatively low job-housing ratio; job-housing ratio in other districts is below 0.4 except for Shunyi District and Daxing District where job-housing is slightly above 0.4. Shunyi District is adjacent to Capital International Airport, which has witnessed an accelerated development in warehousing, logistics and manufacturing sectors and significant increase in jobs with job-housing ratio up to 0.5; whereas Changping District and Fangshan District have witnessed an accelerated housing development in recent years, and has attracted a mass of employees from urban center; as a result of it, job-housing ratio in such districts is below 0.3; Large residential clusters, such as Huilongguan and Tiantongyuan are located in Changping District; this is the direct reason for the lowest job-housing ratio of 0.18.

Viewing from development trend, overall spatial job-housing distribution in the city tends to be balanced; job-housing ratio at urban center and suburbs fluctuates at 0.4-1.0 and 0.2-0.4 respectively. Job-housing ratio in 6 districts at urban center basically remains unchanged except for slight decrease of job-housing ratio in former Xuanwu District. Generally speaking, urban population and jobs in Beijing are at the stage of accelerated development; whereas total population at suburbs has witnessed a quick growth; as a whole, job-housing has witnessed a slight decrease; this development trend is in consistent with the development rule for dispersion of population and employment in macro space.



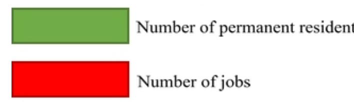


Figure 2-11: Distribution of Residential Population and Jobs in Urban Area

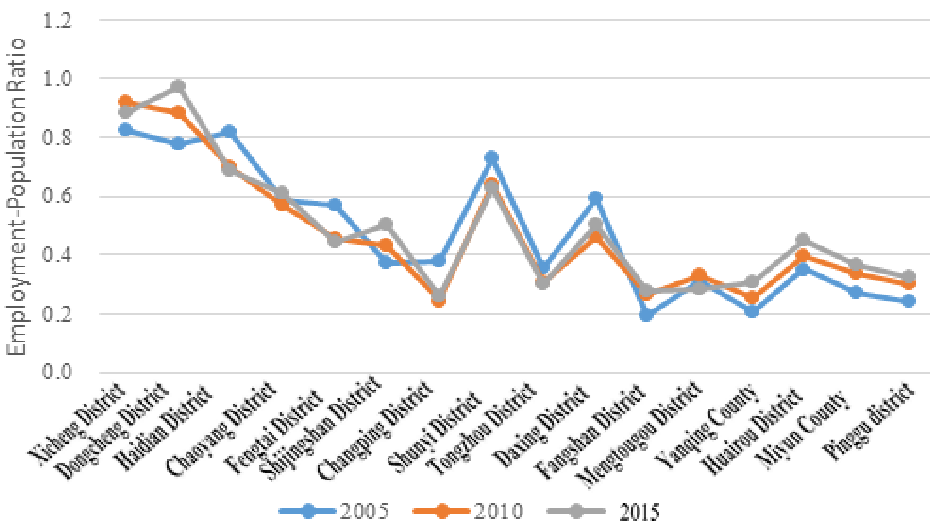


Figure 2-12: Job-Housing Ratio and Variations in All Administrative Districts

Data source: Beijing Municipal Bureau of Statistics

To make a profound investigation of spatial job-housing variations in Beijing, the study manages to make a hierarchical division of job-housing ratio in reference to conclusions as arrived at by Cervero (1996) during study of urban job-housing space in San Francisco. As pointed out by him, different ratios between employment and working population may result in discrepancy to regional job-housing features. As discovered by relevant studies, the ratio between employment and working population (J/ER) in residence oriented areas is below 0.8; whereas job-housing matching within the area is relatively balanced; the ratio between employment and working population in the self-containment area is between 0.8 and 1.25; the ratio between employment and working population in residence oriented area is over 1.25. According to data obtained from Beijing Municipal Bureau of Statistics, percentage of 18-60 years old working population is 80% approximately. Reference intervals for the ratio between employment and working population are stated as follows: job-housing ratio in residence oriented area is below 0.5; whereas that in the area with satisfactory job-housing matching and employment oriented area is between 0.5 and 0.8 and over 0.8 respectively.

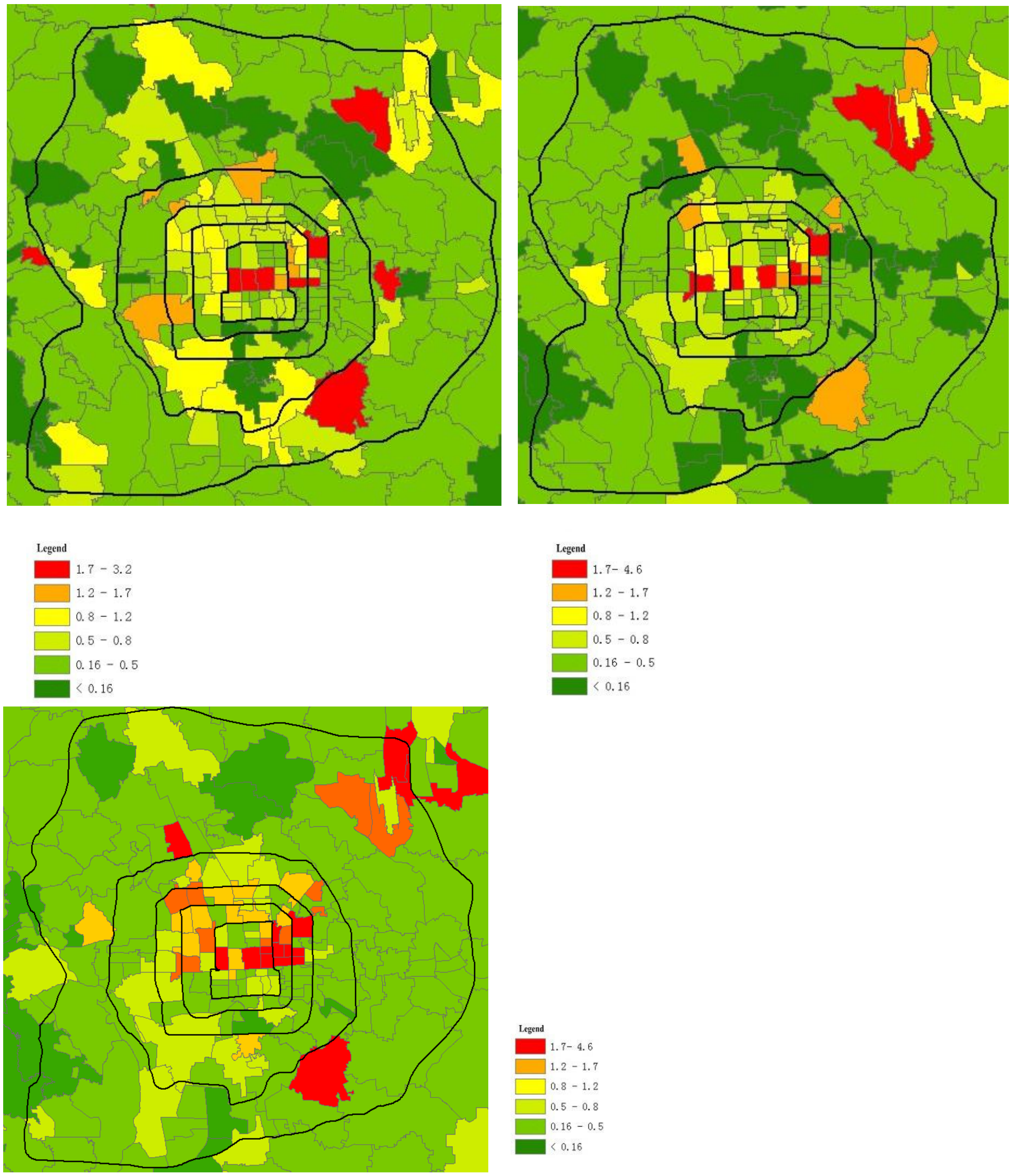


Figure 2-13: A Diagram for Distribution of Street Unit Based Job-Housing Ratio in 2005, 2010 and 2015
Data source: Beijing Municipal Bureau of Statistics

On the aspect of streets, employment center witnessing an increase in total employment has the highest job-housing ratio in Beijing.

In 2010, job-housing ratio at Financial Street, Jianguomen Street, Donghuamen Street, Yangfangdian Street, Shangdi Street, Outer Chaoyangmen Street, Outer Jianguomen Street, Maizidian Street, Hujialou Street, Tianzhu Area, Nafaxin Area, Renhe Area and Airport Street was over 1.7.

In 2015, job-housing ratio at Financial Street, Jianguomen Street, Donghuamen Street, Yangfangdian Street, Shangdi Street, Outer Chaoyangmen Street, Outer Jianguomen Street, Maizidian Street, Hujialou Street, Tianzhu Area, Nafaxin Area, Renhe Area and Airport Street was over 1.7. Such typical employment concentration areas have less residential population.

In aforesaid areas, job-housing ratio of Financial Street, Outer Jianguomen Street and Outer Chaoyangmen Street is obviously higher than that in other areas, which has been increasing in recent 10 years; job-housing matching at such streets is in the following development trend: residential population starts to move out of the area accompanied by quick growth in total employment; such streets have quickly developed into a concentration area of “excess employment”, featuring in high attraction to commuting traffic flow at surrounding streets.

On the other hand, residential center witnessing a population growth belongs to the area with lower job-housing ratio (area marked in dark green) with job-housing ratio below 0.16. For instance, employment density at such streets as Dongxiaokou, Beiqijia and Shangzhuang Town in the north of Beijing is below 10000 jobs/km2 with average residential population density up to 10, 000 persons/km2 approximately; average employment density at Fatou in the east of Beijing is 1, 000 jobs/km2 with average residential population density up to 14, 000 persons/km2 approximately; average employment density at such streets as Dahongmen, Guanyin Temple and Tiantongyuan in the south of Beijing is below 1, 500 job/km2 with average residential population density up to 10000 persons/km2 approximately. Such areas are characterized by unbalanced job-housing matching, where “excess population” is represented by higher dependence on employment concentration area.

Furthermore, job-housing ratio at street around North 4th Ring Road in the north of Beijing is relatively reasonable; this area has higher residential population density and employment density; for instance, job-housing ratio at Xueyuan Road Street, Datun and Olympic Village is between 0.5 and 0.8; this area has a reasonable job-housing matching with employment density and residential population density up to 17, 000-22, 000 job/km2 and 21, 000-33, 000 persons/km2 respectively. Job-housing ratio at such streets as Lugouqiao, Xincun (Huaxiang), Wanshou Road Street, Nanyuan Street, Dongtiejiangying and Haidian Balizhuang in the west and south of Beijing is also reasonable with average employment density and average residential population density up to 1.2 job/km2 and 8, 000 persons/km2 respectively.

2.3. Job-Housing Space and Job Accessibility Analysis

2.3.1 Commuting Space Pattern of Employment Center

Evolution of employment space in Beijing has a distinct background, namely adjustment to spatial structure accompanied by quick increase in overall scale; in particular, formation of polycentric employment centers has impact on distribution of residence of employees and variation to commuting direction and flow. The following figure shows the residence distribution of the commuting transit indicated by the Beijing Traffic Survey in 2015.

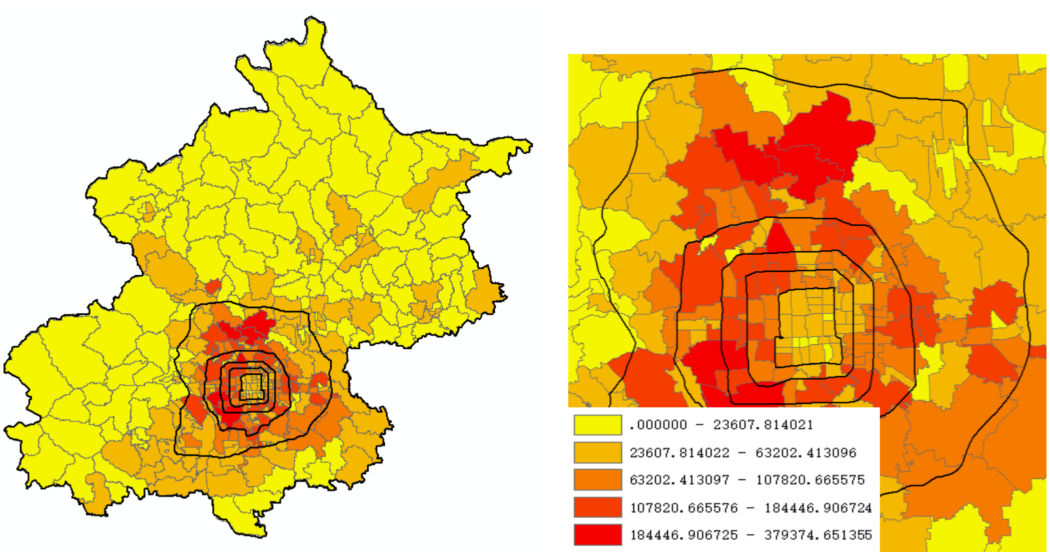
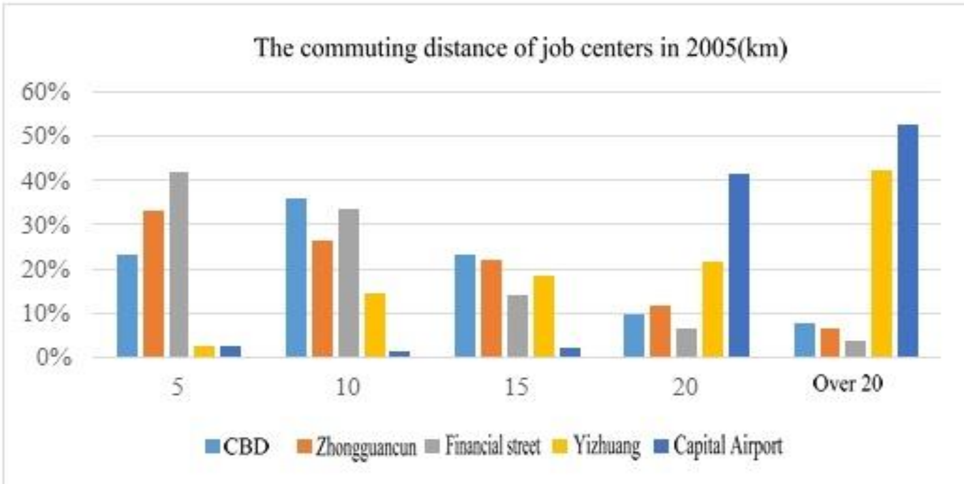
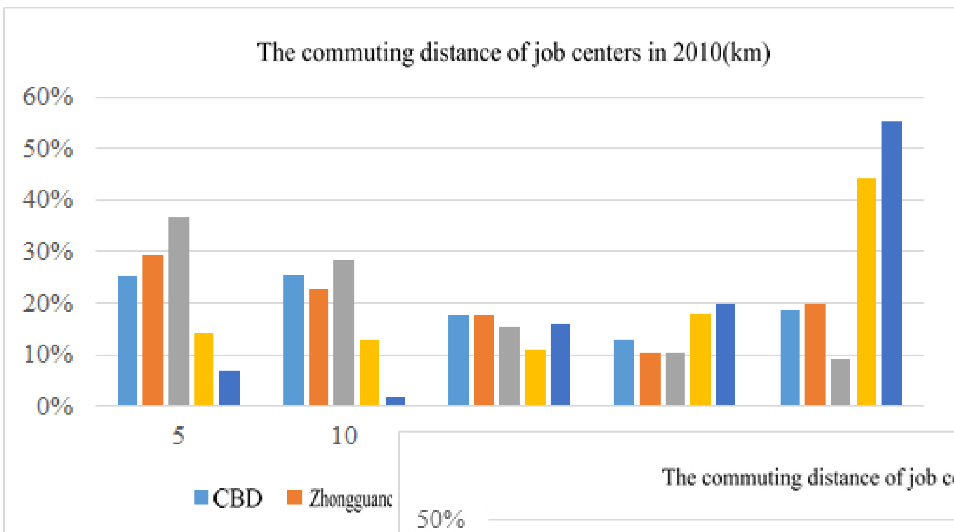


Figure 2-14: The Residence

Distribution of the Commuting Transit Indicated by the Traffic Survey in 2015

Data source: The Traffic Survey in Beijing





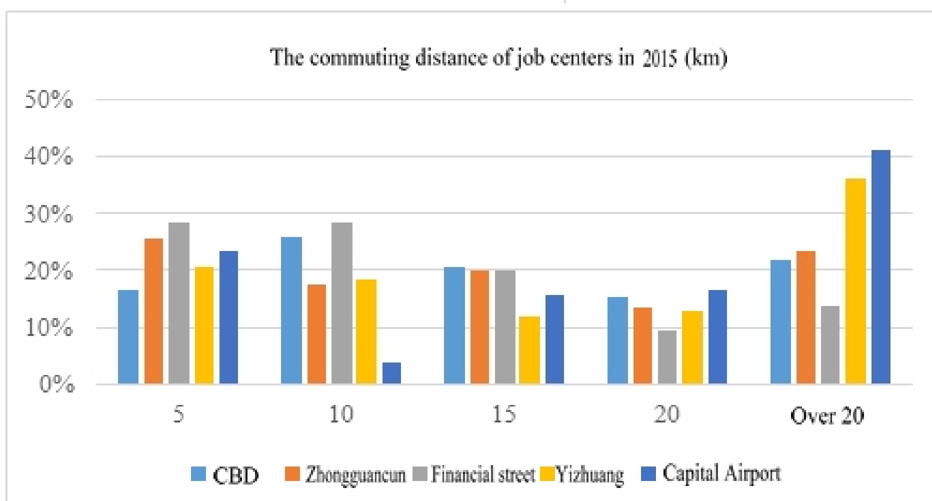


Figure 2-15: Commuting Distance of Employment Centers

Data source: Previous Traffic Survey Data in Beijing

Firstly, viewing from residence distribution of employees, the residence distribution scope of working population at each employment center is being expanded; as indicated by data obtained through comprehensive traffic survey in 2005, 2010 and 2015, proportion of long-distance travel in commuting travel has witnessed a gradual increase; major residences of working population in the area are in a trend of outward expansion no matter employment centers are located at urban center or suburbs; on one hand, this indicates that growth and expansion of employment centers have high attraction to more people; on the other hand, it also indicates the development trend for dispersion of residences of employees from employment centers.

Secondly, there exists difference to impact of different employment centers on residences; this mainly due to differential characteristics to the spatial distribution of residences of employees as brought forth by different scale of employment centers, different industrial features, different social attributes of employees and different infrastructures, such as residence supporting and traffic facilities.

(1) Larger scale of urban employment centers can attract more employees, and may result in further expansion of residences of employees. For instance, CBD and Zhongguancun Employment Center covers numerous streets, and has higher total employment, which has extensive impact on residences. Pan-CBD residences of employees are almost in full distribution inside the 4th Ring Road, which is extending outside of the 5th Ring Road.

(2) Accompanied by shift of manufacturing sector from the urban center, percentage of employees of employment centers living in the urban center will witness a reduction; for instance, working population from Yizhuang Economic and Technological Development Zone mainly concentrate nearby the Southeast 4th Ring Road.

(3) For employment centers mainly composed of middle class and high-income working population, job-housing space of its employees is relatively compact with residence distributed nearby the employment centers; taking financial Street Employment Center for instance, residence of its working population concentrates in the area around Financial Street.

(4) Convenience of traffic facilities also has impact on distribution of residences of population from employment centers; in particular, as a high-volume quick passenger transportation system, subway traffic has higher attraction to selection of employments and

residences; taking Capital International Airport Employment Center for instance, once the metro to airport is opened, working population at the airport will be in centralized distribution along the metro line, and residence percentage at Dongzhimen and Xizhimen will witness a significant increase.

Finally, employment centers also have higher attraction to residential centers in the same direction, which endows the spatial distribution of residences of working population with regional features. The “cooperative orientation” job-housing interrelation is just defined based on certain commuting cost and residential cost weighing mechanism; however, intensity of such separation is impossible for indefinite expansion; this is mainly limited by commuting cost. When urban traffic cost is generally at a low level, commuting time will become an important restriction on residences of working population. Therefore, spatial distribution of commuting flow at employment centers is provided with regional characteristics; employment centers have higher attraction to surrounding streets and residential clusters in the same direction; commuting flow concentrates at the traffic corridor linking employment centers and residential clusters in the same direction.

(1) CBD Employment Center

CBD Employment Center is mainly concentrated with such sectors as lease, commerce, science consultation, IT and real estate, which is the most important employment cluster with the largest scale and highest influence in Beijing. Working population from the center has higher income, living in the area between the 2nd and 5th ring roads to the east of city axis, Tongzhou to the east of Chang’an Street, Dongxiaoying at Laiguangying in the north as well as Jiugong and Dahongmen in the south. As shown in Figure 2-16, working population living in the area marked with brown color accounts for 65% of total at Pan-CBD. Wherein, working population living between East 4th Ring Road and Tongzhou that is in close association with residence cluster in the direction of Tongzhou accounts for 25% of total, including working population living at such streets as Sanjianfang, Gaobeidian, Nanmofang, Beiyuan, Liyuan and Yongshun; working population living inside the 3rd Ring Road accounts for 40% of the total; working population living at Wangjing, Dongxiaokou (Tiantongyuan), Huilongguan, Datun, Olympic Village and Zhongguancun in the north accounts for 15% of the total; remaining working population is distributed at Songjiazhuang Residential Center (Dahongmen and Dongtiejiangying Street) and Wanshou Road, Tiancun and Yangfangdian in the west. Viewing from overall spatial morphology, residential population is in a obvious trend of expansion outside of the 5th Ring Road, and overall intensity job-housing separation has been enhanced.

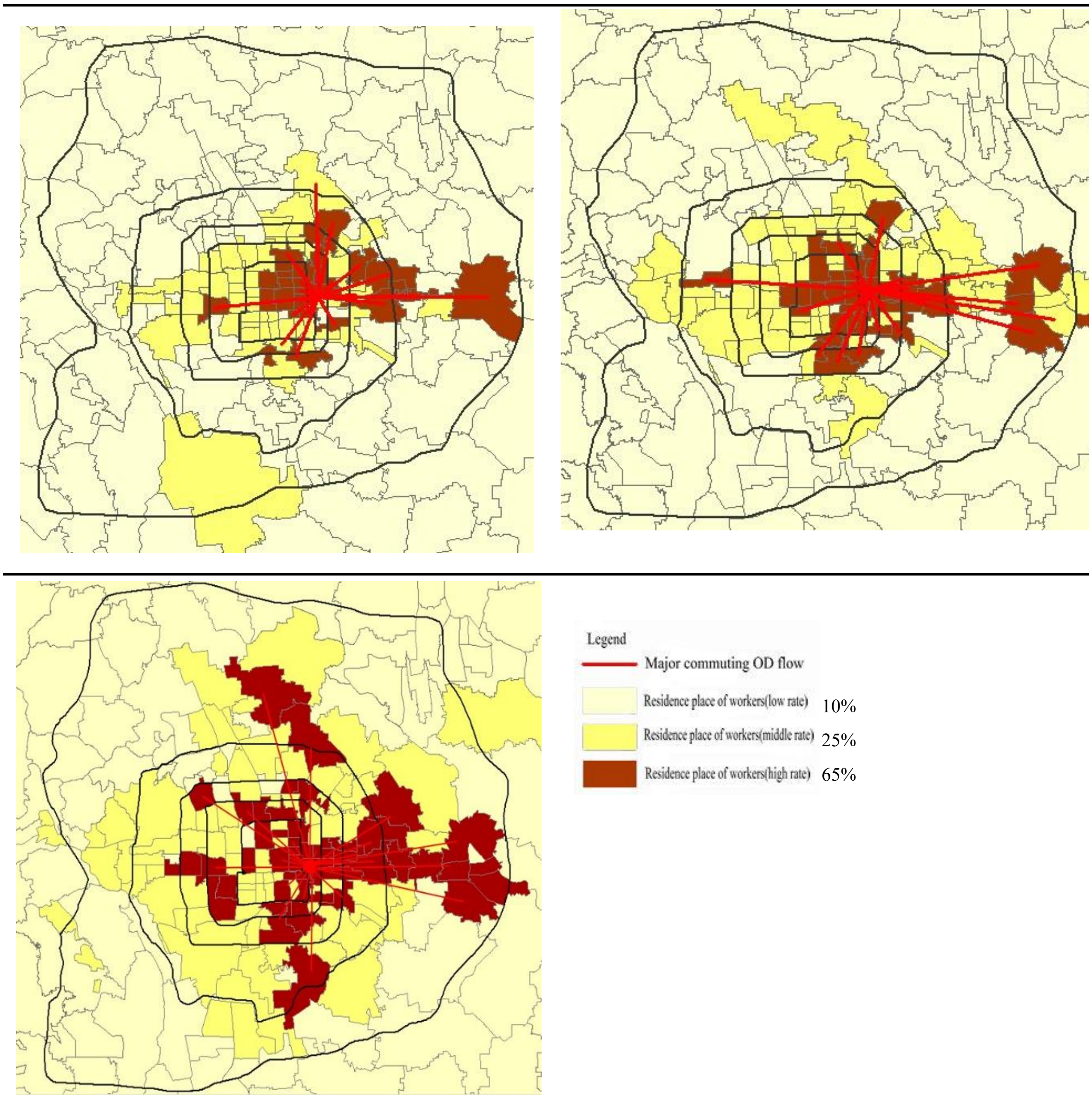


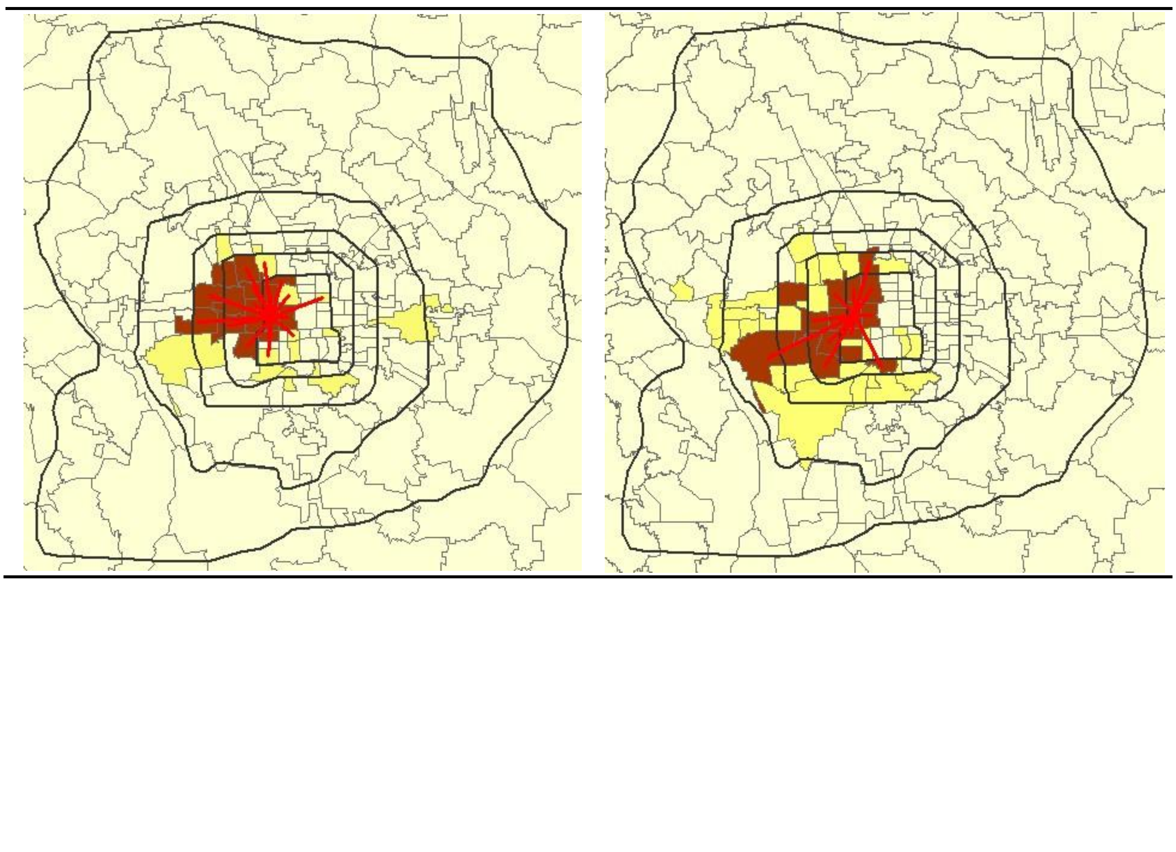
Figure 2-16: Diagram for Distribution of Residences of Employees from CBD Employment Center and

Commuting Flow in 2005, 2010 and 2015

Data source: Previous Traffic Survey Data in Beijing

(2) Financial Street Employment Center

Financial Street Employment Center is mainly concentrated with such sectors as finance, computer software and commerce, where working population has higher income with residences distributed at streets nearby Financial Street; its job-housing spatial distribution is relatively compact, and working population is distributed in expansion to the southwest. Most of employees are from the area between the west of city axis and West 4th Ring Road, Huaxiang in Fengtai, Lugouqiao, Huilongguan in the north and Dongtiejiangying Street in the south. The working population who lives in the brown area as shown in Figure 2-17 accounts for 50% of the total. As compared with 2005 and 2010, working population living at Lugouqiao, Xincun (Huaxiang), Outer Yongdingmen, Majiapu and Dahongmen (Songjiazhuang Residential Center) has been significantly increased by 10% to 15%.



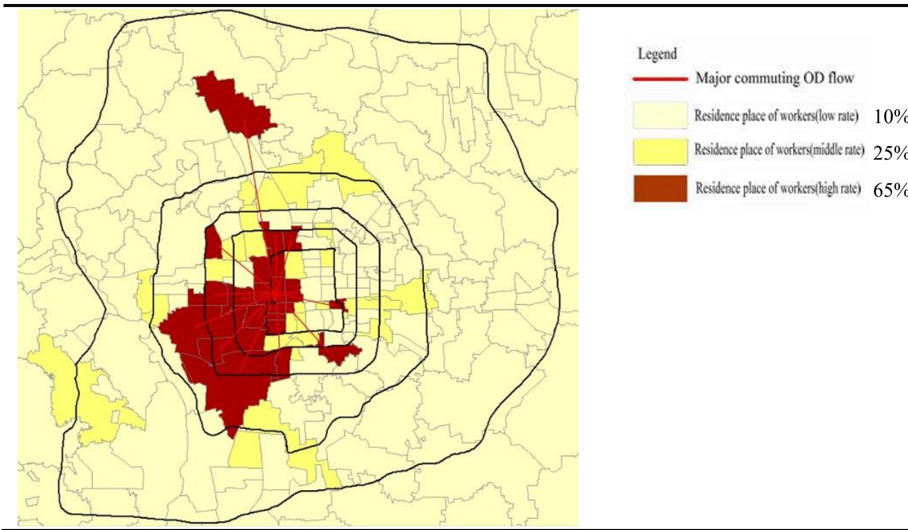


Figure 2-17: Diagram for Distribution of Residences of Employees from Financial Center and Commuting Flow in 2005-2010

Data source: Previous Traffic Survey Data in Beijing

(3) Zhongguancun Employment Center

Zhongguancun Employment Center is located at urban fringe adjacent to Northwest 4th Ring Road, which is mainly concentrated with such sectors as IT, scientific research, wholesale and retail; residences of its working population mainly concentrate at north part of the city and nearby streets; it is provided with obvious regional characteristics. Zhongguancun has always been a concentration area of residential population, of which job-housing matching is reasonable; furthermore, Huilongguan and Tiantongyuan residential clusters outside of North 5th Ring Road are 10-15km away from Zhongguancun and 5-10 km away from Shangdi Employment Concentration Area. Therefore, Zhongguancun Employment Center has formed a well-established labor force supply and demand relationship with residential centers in the north of the city. Working population living in the brown area as shown in Figure 2-18 accounts for 50% of the total, which mainly concentrates at Haidian, Zhongguancun, Beitaipingzhuang, Huayuan Road and Xueyuan Road nearby the North 4th Ring Road and such streets as Qinglongqiao, Malianwa, Qinghe, Xisanqi, Huilongguan and Dongxiaokou in the north of the city. As compared with 2005, percentage of Zhongguancun’s working population living in the north of the city has increased by 20%. Furthermore, most of working population from Zhongguancun is in a trend of expansion in southwest direction at the same time of northward expansion; in addition to such streets as Sijiqing Town, Tiancun and Wanshou Road, employees are also in an expansion to such streets as Lugouqiao, Xincun (Huaxiang) and Dongtiejiangying. This trend is associated with massive residence development in the south of city in recent years. Meanwhile, opening of Metro Line 4 has also improved efficiency of north-south commuting in the direction of Zhongguancun, and enhanced job-housing link between Zhongguancun Employment Center in the north and south residential areas.

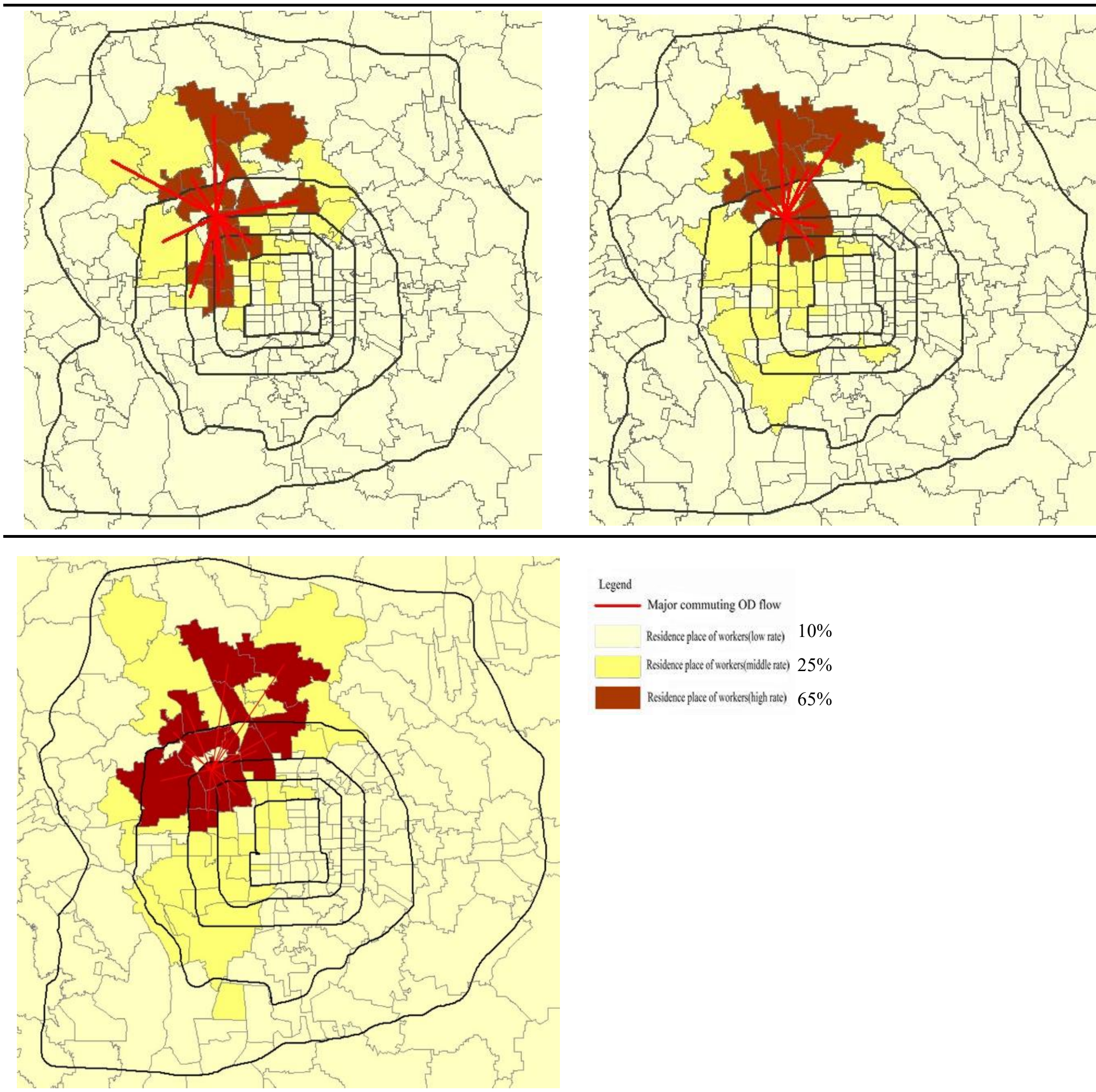


Figure 2-18: Diagram for Distribution of Residences of Employees from Zhongguancun Employment

Center and Commuting Flow in 2005, 2010 and 2015

Data source: Previous Traffic Survey Data in Beijing

2.3.2 Commuting OD Distribution under the Impact of Polycentric Employment

Spatial distribution of commuting flow is often taken as one of criterion for judgment of urban mono-centric-polycentric spatial structures (Lambert, 2003); in mono-centric urban structure, commuting traffic is often in a center-periphery concentric “tide” commuting spatial mode under the background of job-housing separation. In polycentric urban structure, commuting flow at sub-centers may become the main urban commuting flow, of which proportion may outpace impact from commuting traffic flow at main centers (Heduanruigui, 2002; Shen Qing, 2001); urban commuting spatial mode might be in various forms; when scale and cohesion of numerous employment centers are equivalent, each center may have higher attraction to surrounding area to the extent of forming a pattern for integration of numerous mono-centers within the same urban space; there might exit some commuting links and intersection among sub-centers; in the structure containing one main center and numerous sub-centers, the main center has dominant attraction to commuting traffic flow in the whole city; meanwhile, sub-centers also have certain attraction to adjacent traffic flow; there might exit frequent traffic demands and interactions between each sub-center and between each sub-center and the main center; inter-area traffic flow will be in an obvious cross distribution (Alan Bert, 2003; Zhao Pengjun, 2010).

Polycentric structure in Beijing belongs to “main center-sub-center” spatial pattern, of which spatial morphology of commuting traffic flux and flow in a trend of concentration at each employment center; there also exists cross link of commuting flow between each employment center. The study aims to make use of ArcGIS software for spatial analysis of commuting OD data on residents as obtained through comprehensive traffic survey in Beijing (2005, 2010 and 2015), and extract OD volume with commuting flow over 30 and 15 based on the proportion of samples by taking street as unit (See Figure 2-19, Figure 2-20 and Figure 2-21). As indicated by the data, commuting organization distribution and evolution in Beijing is consistent with spatial morphology of spatial pattern of multi employment centers.

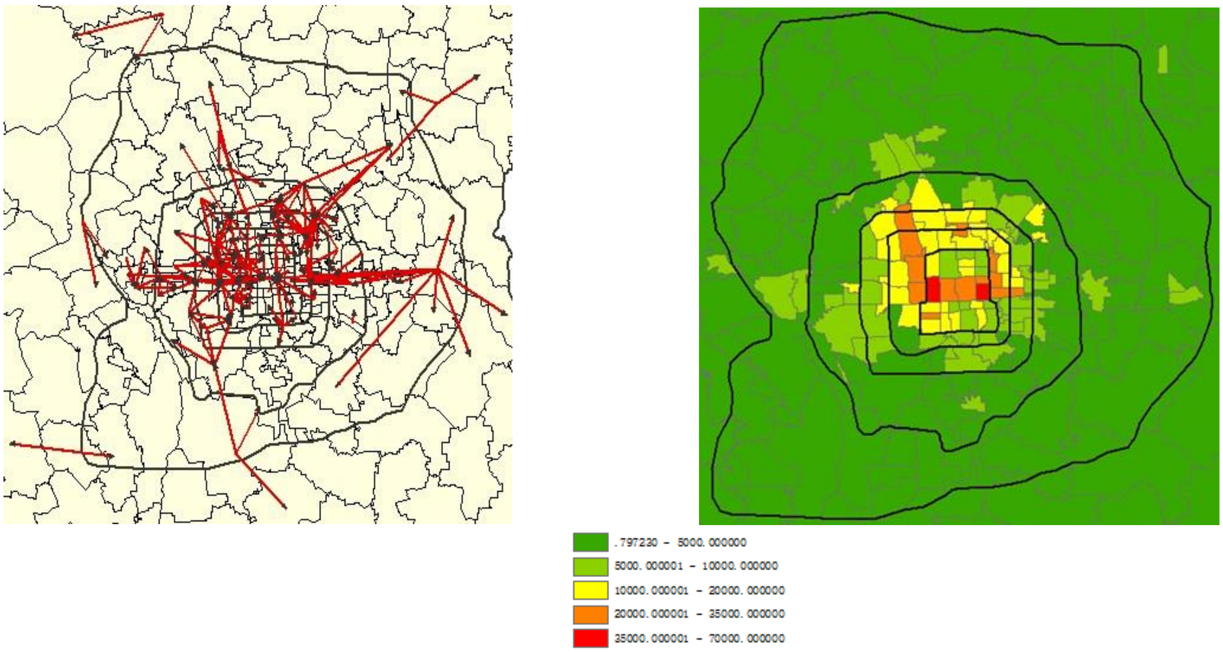


Figure 2-19: Commuting and Employment Density Distribution with OD Volume over 30 Based on Comprehensive Traffic Survey Samples in 2005

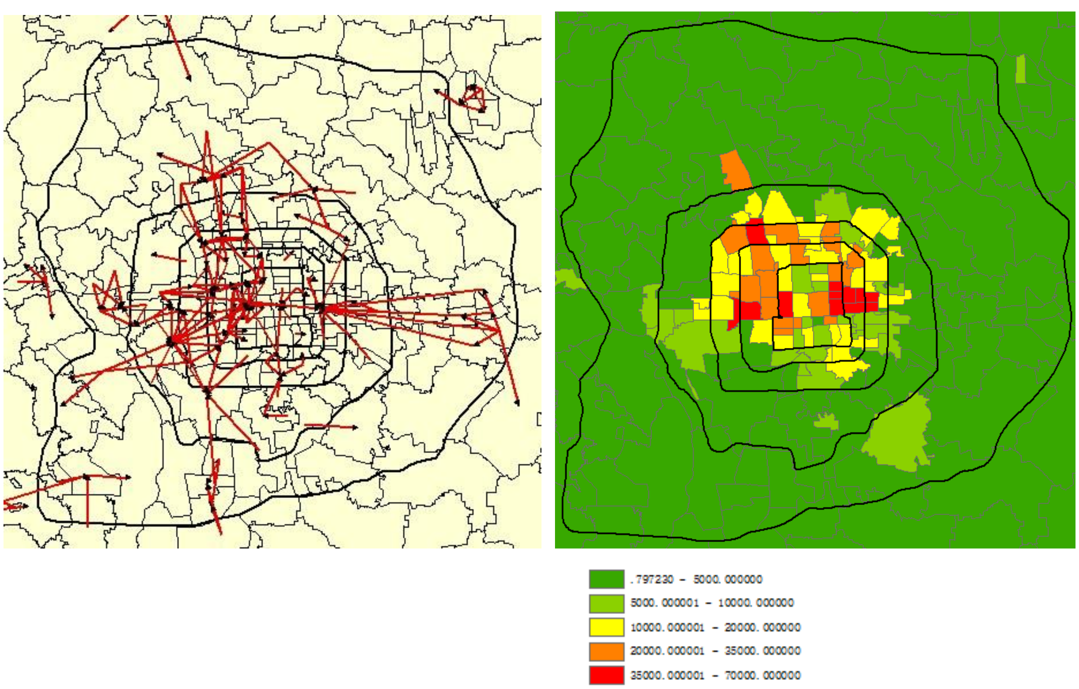


Figure 2-20: Commuting and Employment Density Distribution with OD Volume over 15 Based on

Comprehensive Traffic Survey Samples in 2010

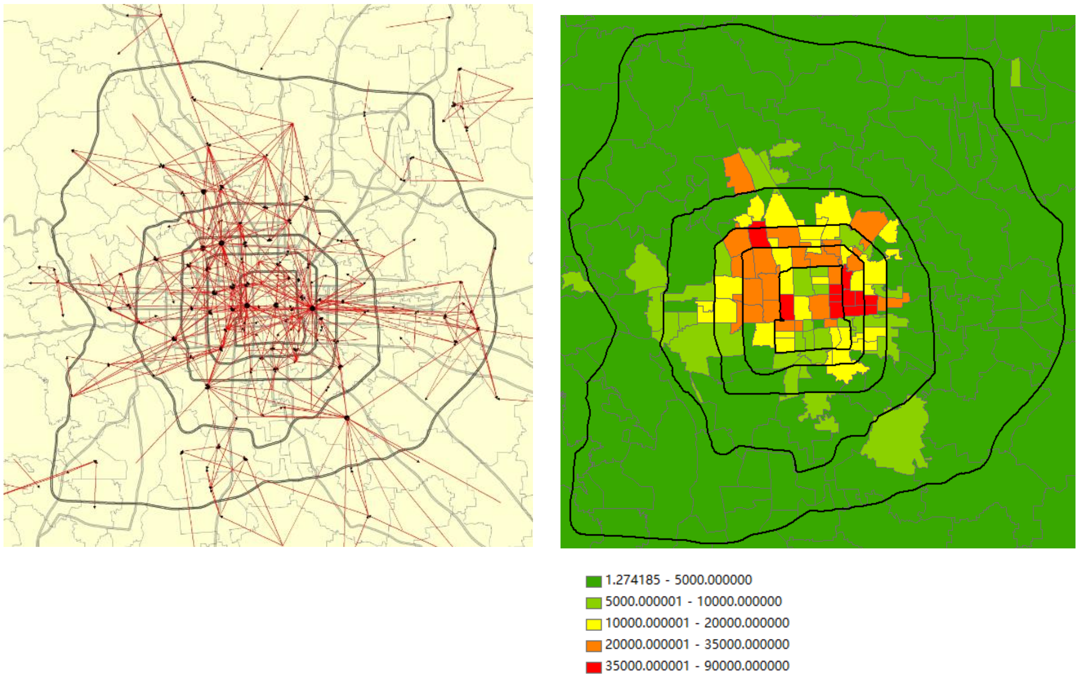


Figure 2-21: Commuting and Employment Density Distribution with OD Volume over 15 Based on Comprehensive Traffic Survey Samples in 2015

Data source: Previous Traffic Survey Data in Beijing

Firstly, polycentric employment pattern has endowed commuting OD distribution area with unbalanced spatial distribution characteristics. Area with high concentration of employment space, especially employment center has obvious attraction to peripheral commuting flow; higher employment concentration may result in extensive and intensified attraction of commuting flow.

In 2005, commuting flow shifted from suburbs to urban center (inside the 3rd Ring Road) to form a traffic flow group within the city; as concentration of jobs at CBD and Financial Street was relatively obvious in 2005, OD commuting flux and flow mainly concentrated in east and west areas, especially in the area between Northwest 2nd Ring Road and North 4th Ring Road and Guomaoqiao at East 3rd Ring Road along Chang'an Street.

In 2010, commuting flow was in a more obvious concentration at numerous employment centers. Distribution of commuting flow at urban center was provided with obvious and local regional characteristics; commuting flow shifted to various employment centers other than concentration.

In 2015, accompanied by employment dispersion, commuting flow continued concentrate at numerous employment centers; for instance, a mass of residents in the east shifted to such streets as Jianguomen, Outer Jianguomen and Outer Chaoyangmen in CBD; residents in the north shifted to such streets as Zhongguancun, Haidian, Shangdi and Beixiaguan in Zhongguancun Area; residents in the west shifted to such streets as Financial Street and Yangfangdian; residents in south shifted to Yizhuang and Fengtai Science and Technology Park.

Secondly, traffic generation intensity of residential clusters at urban fringe has been enhanced, and employment centers have high attraction to residential clusters in the same direction. Commuting generation flow at Huilongguan and Tiantongyuan in the north of the city has witnessed a significant increase; expansion of Zhongguancun Employment Center located at Northwest 4th Ring Road of the city has tremendous impact on the two residential clusters. For instance, commuting flow at Huilongguan is mainly oriented towards Haidian, Zhongguancun and Shangdi; a high commuting flow at Tiantongyuan is also oriented towards Shangdi Street. CBD Employment Center has significant attraction to commuting flow from Tongzhou in the east; commuting flow at such streets as Beiyuan, Liyuan and Yuqiao in Tongzhou is also oriented towards Outer Jianguomen Street. Commuting flow flowing from Huangcun, Jiugong and Changxingdian in Daxing that has quick population increase in the south of city to Xincun (Huaxiang) has also begun to take shape.

Finally, commuting OD distribution is also provided with the spatial characteristic of cross distribution of cross-area commuting flow. Employment increase in Beijing in recent years is manifested by accelerated development of traditional CBD, employment increase in other orientations and formation of employment sub-centers. Dispersion of population and employment in different spatial circles has resulted in attraction of each employment concentration area to commuting flow in all directions; this has endowed commuting OD with structure of cross distribution of cross-area commuting glow.

The followings are the commuting efficiency of three employment centers:

(1) CBD Employment Center

Average travel time of CBD Employment Center is 58.9 minutes; travel time distribution is as shown in the following figure; travel time of 50-60 min has the highest percentage of 17.6%, which is followed by 12.5% and 12.1% for 40-50 min and 20 to 30 min respectively. Viewing from commuting traffic means, the metro has the highest percentage of 36.3%, which is followed by 2.31% and 21.3% for car and bus respectively; percentage of public traffic is up to 57.6%; this is closely associated with convenient subway and public traffic network in surrounding areas.

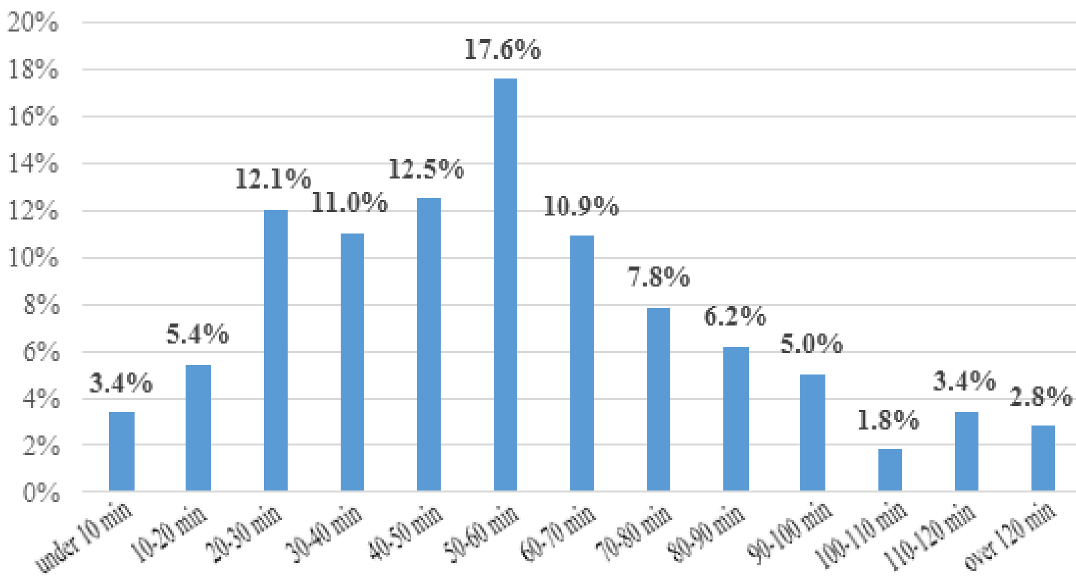


Figure 2-22 Travel Time Distribution of CBD Employment Center

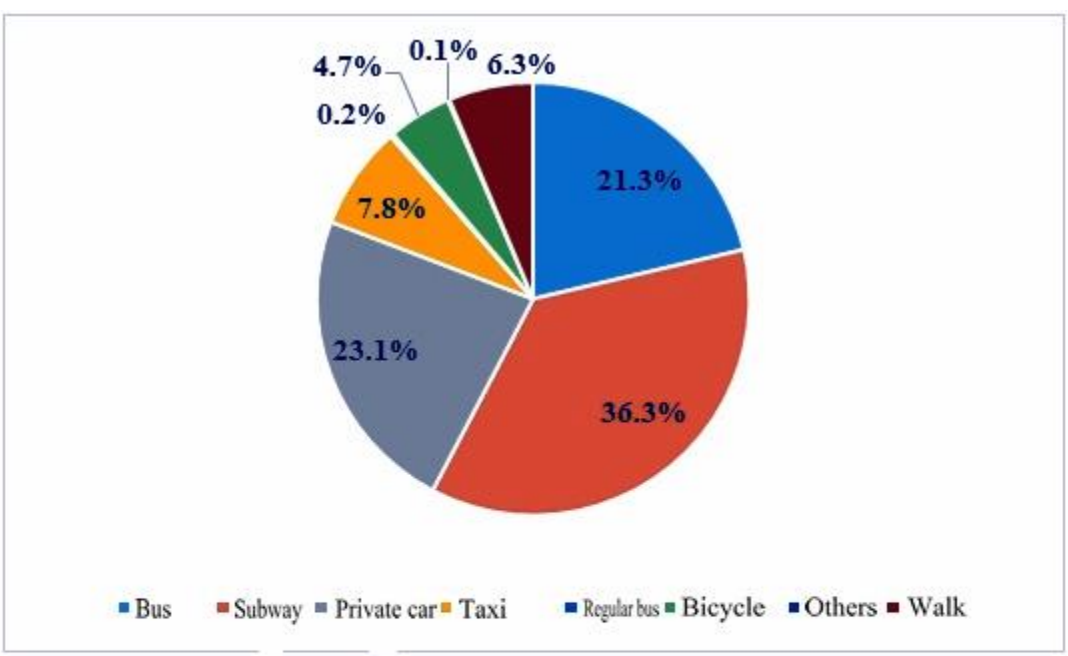


Figure 2-23 Travel Structure of CBD Employment Center

Data source: The Traffic Survey Data of Beijing

(2) Employment Center in Financial Street

Average travel time of Financial Street Employment Center is 58.4 minutes; travel time distribution is as shown in the following figure; travel time of 50-60 min has the highest percentage of 15.4%, which is followed by 15% and 13% for 30-40 min and 40-50 min respectively. Viewing from commuting traffic means, the metro has the highest percentage of 32%, which is followed by 28.2% and 21.3% for car and bus respectively; percentage of public traffic is up to 54.2%.

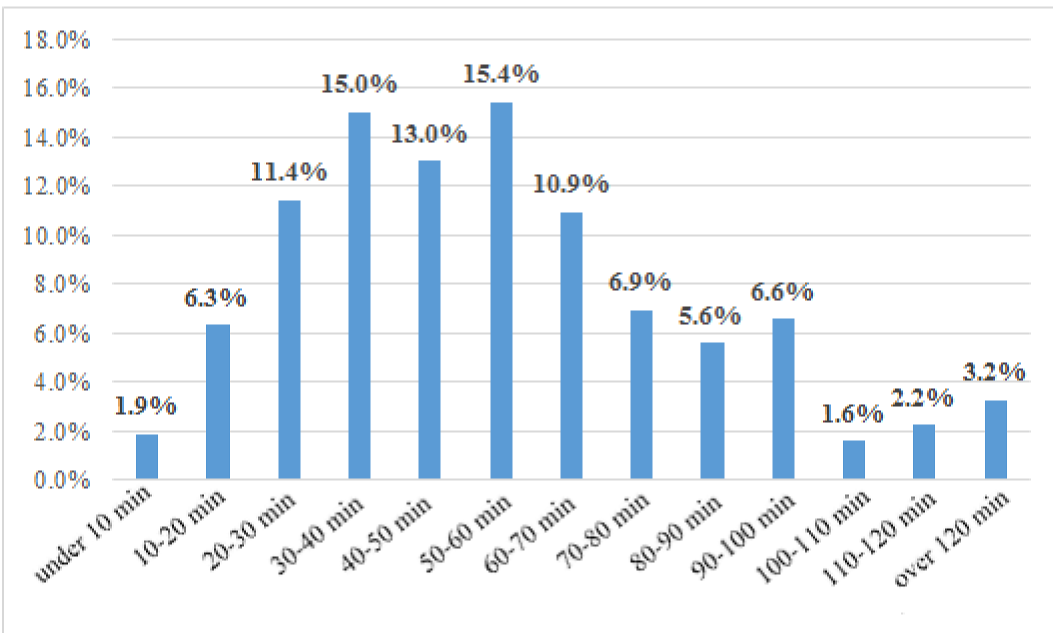


Figure 2-24 Travel Time Distribution of Financial Street Employment Center

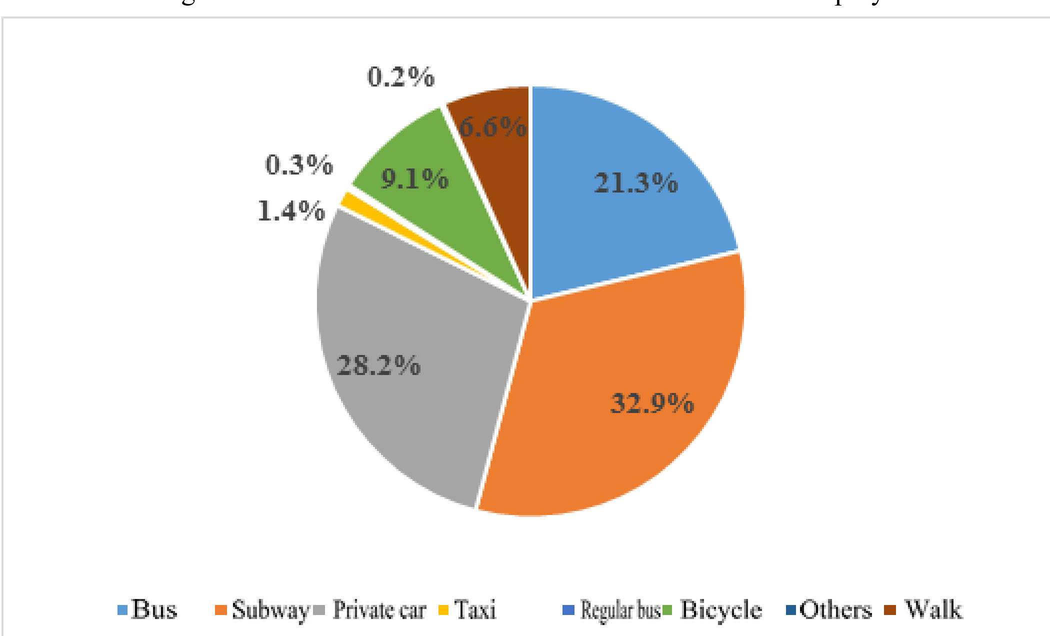


Figure 2-25 Travel

Structure of Financial Street Employment Center

Data source: The Traffic Survey Data of Beijing

(3) Zhongguancun Employment Center

Average travel time of Financial Street Employment Center is 56.7 minutes; travel time distribution is as shown in the following figure; travel time of 50-60 min has the highest percentage of 12.7%, which is followed by 11.4% and 11.1% for 40-50 min and 20-30 min respectively. Viewing from commuting traffic means, the metro has the highest percentage of 30.3%, which is followed by 25% and 21.9% for car and bus respectively; percentage of public traffic is up to 52.2%.

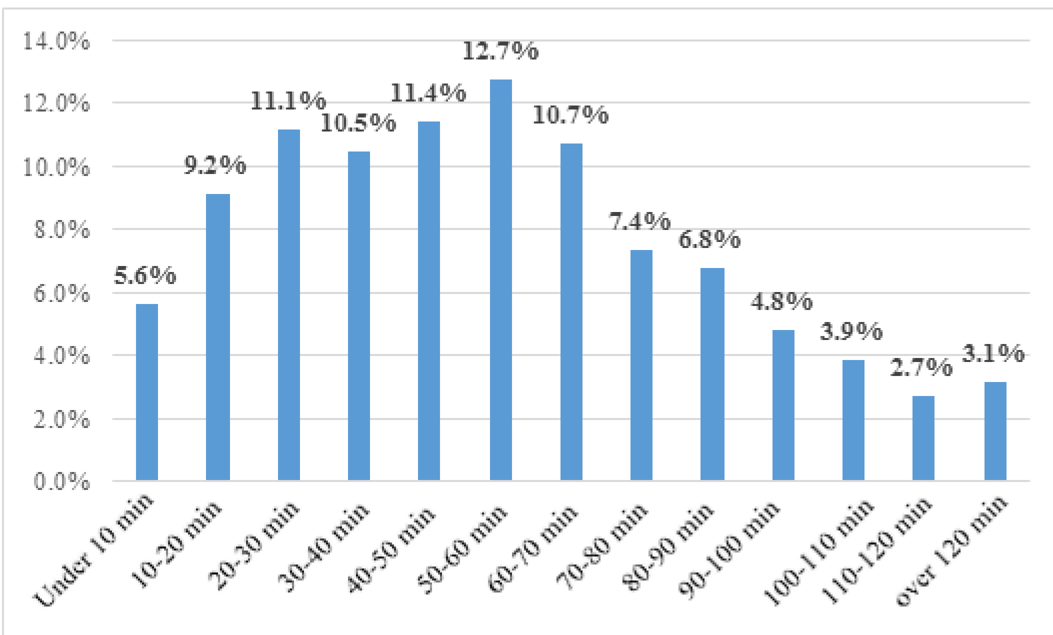


Figure 2-26 Travel Time Distribution of Zhongguancun Employment Center

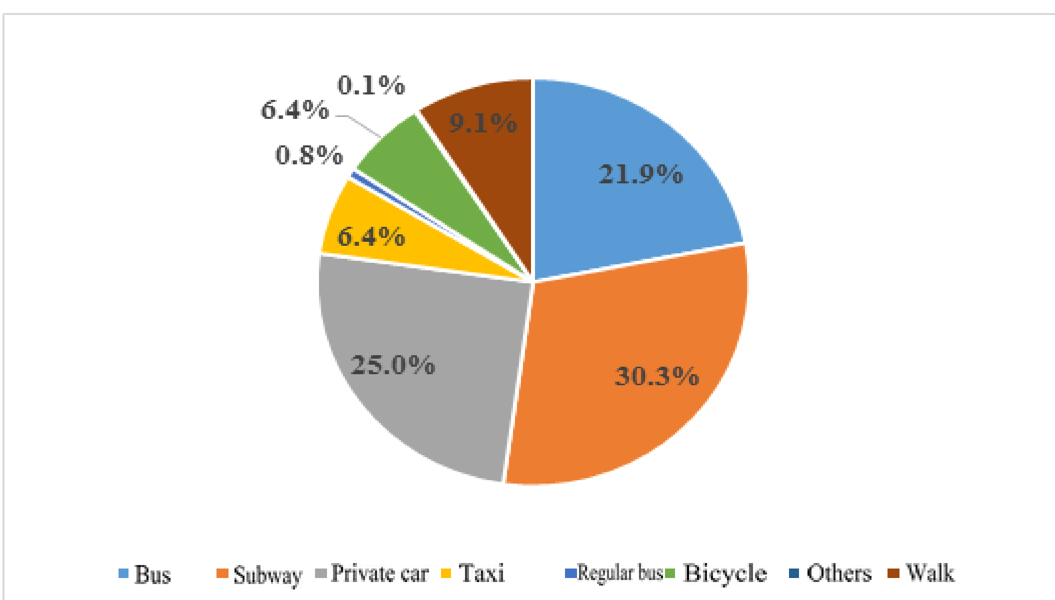


Figure 2-27: Travel

Structure of Zhongguancun Employment Center

Data source: The Traffic Survey Data of Beijing

2.3.3 Job Accessibility Analysis

The assumption for minimization of traffic jam and improvement commuting efficiency through job-housing balance within the area is unlikely to be realized under the background polycentric urban structure. The key link for improvement of overall efficiency of the city is to improve accessibility of job-housing space, and select traffic facility supply and commuting organization mode applicable to the polycentric urban structure.

Evaluation indicator most frequently used during discussion on reasonability of urban job-housing structure is commuting time or distance; for a mass of empirical studies, variation to commuting time and distance serves as the key factor for evaluation of operation efficiency of mono-centric or polycentric structure as well as an important content for evaluation of land planning, utilization and implementation effect of traffic policies (Giuliano, 1991; Gordon, 1991; Cervero, 1996; Newman, 1997; Michael Mallen, 2003; Bannester, 2004;). However, for analysis of commuting time and distance data and analysis of variation to spatial structure of the city as obtained on macro aspect, such indicators are unlikely to describe specific conditions of spatial job-housing evolution based on individualized features of travelers. For instance, it is discovered that the same spatial analysis of Los Angeles can result in a contrary conclusion on increase and decrease of commuting time in the polycentric urban structure. Many researchers are doubtful of objectiveness and limitation of commuting time samples, and thereby propose that there are numerous factors for variation to commuting time; for instance, if both husband and wife are employed, it will be difficult to use a single commuting time indicator to interpret job-housing space of a two-earner family; meanwhile, variation to commuting time is also affected by such issues as complicated selection of traffic means and traffic cost.

Some other researchers manage to evaluate urban spatial structure and accessibility through establishment of gravity model (Hansen, 1987; Shen Qing, 1998). Such study method was accepted quickly after that, and traffic factors were introduced into the model as impedance condition to examine urban structure and traffic supply conditions in a complete and systematic space. The study makes use of job accessibility evaluation model as established by Shen Qing (2000) to select data from Beijing Municipal Bureau of Statistics and comprehensive traffic survey data of Beijing through calculation; In reference to division of population with working ability in foreign countries, the study defines persons15 to 60 years old as working population; population age percentage is in reference to statistics on population age as issued by Beijing Municipal Bureau of Civil Affairs. Commuting flow refers to OD spatial relationship between the family and unit of an employee; commuting time data refers to actual working hours of an employee (morning peak: 7:00am-9:00am); commuting time of public transit travelers includes waiting and interchange time.

The study scope covers urban area of Beijing, especially major concentration area of working population, inside the 6th Ring road. As data obtained is based on division of administrative street units, the uniform data on population, employment and commuting in street units during estimation of accessibility.

According to the method provided by this model, formula for evaluation of job accessibility of traveler by means of car and public traffic means is stated as follows:

$$A_{\mathrm{i}}^{\mathrm{auto}}=\sum_{\mathrm{j}}\frac{E_j f(C_{ij}^{auto})}{\sum_k[\alpha_k w_k f(C_{kj}^{auto})+(1-\alpha_k)w_k f(C_{kj}^{trans})]} \quad (1a)$$

$$A_{\mathrm{i}}^{transit}=\sum_{\mathrm{j}}\frac{E_j f(C_{ij}^{trans})}{\sum_k[\alpha_k w_k f(C_{kj}^{auto})+(1-\alpha_k)w_k f(C_{kj}^{trans})]} \quad (1b)$$

$$A_{\mathrm{i}}^{G}=\alpha_i A_{\mathrm{i}}^{\mathrm{auto}}+(1-\alpha_i)A_{\mathrm{i}}^{transit} \quad (2)$$

A_i^{auto} and $A_i^{transit}$ refer to job accessibility value of commuters by car and public transport respectively, i=1,2,…,N;

E_j refers to number of jobs at the place where the commuter works, j=1,2,…,N;

$f(C_{ij}^{auto})$ and $f(C_{ij}^{trans})$ refer to traffic impedance of commuters going from area i to area j to work by car and public transport respectively; $f(C_{ij})$ can be calculated based on threshold value and parameter estimation;

w_k refers to working population at residential place of employees in area k, which is defined in this study as 15-60 years old permanent population within street units at the residential place, k=1,2,…,N;

α_k refers to the percentage of commuting by car within the street units, k=1,2,…,N;

A_i^G refers to the overall job accessibility of working population in area i;

α_i refers to the percentage of commuting by car in area i;

Reasonability for evaluation with this job accessibility indicator lies in the fact that as an endogenous factor for evaluation of job-housing spatial distribution, supply factor of different traffic means can reflect job-housing matching conditions, describe possibility for residents to have an access of job opportunities in an objective and practical manner, and reflect inherent relationship with urban job-housing space and overall operation conditions of the city. Main purpose of the study is to analyze job-housing relationship; therefore, traffic impedance $f(C_{ij})$ is calculated based threshold value; for street unit, average commuting time in area i-j is set as threshold value; impedance function inside and outside of the threshold value is 1 and 0 respectively.

As indicated by comprehensive traffic survey data of Beijing, the average commuting time of car and public traffic inside the 6th Ring Road is 30-40 min and 60 min respectively in 2005, 2010 and 2015. Therefore, the study of job accessibility mainly aims at analysis and comparison of spatial distribution of job accessibility corresponding to threshold value of 30min and 60min for commuting by means of car and public traffic respectively.

According to ArcGIS spatial analysis, distribution of job accessibility inside the 6th Ring Road is as shown in the following figure. Firstly, viewing from job-housing spatial distribution, job accessibility at urban center is obviously higher than that at suburbs. Viewing from orientation, job accessibility in the west and north of the city is better than that in the east and south respectively. Viewing from commuting mode, job accessibility of car commuters in the east and north of the city is in a trend of increase; whereas job accessibility of public traffic commuters has witnessed a decrease to some extent; job accessibility of both car and public traffic commuters in the northwest of the city is satisfactory.

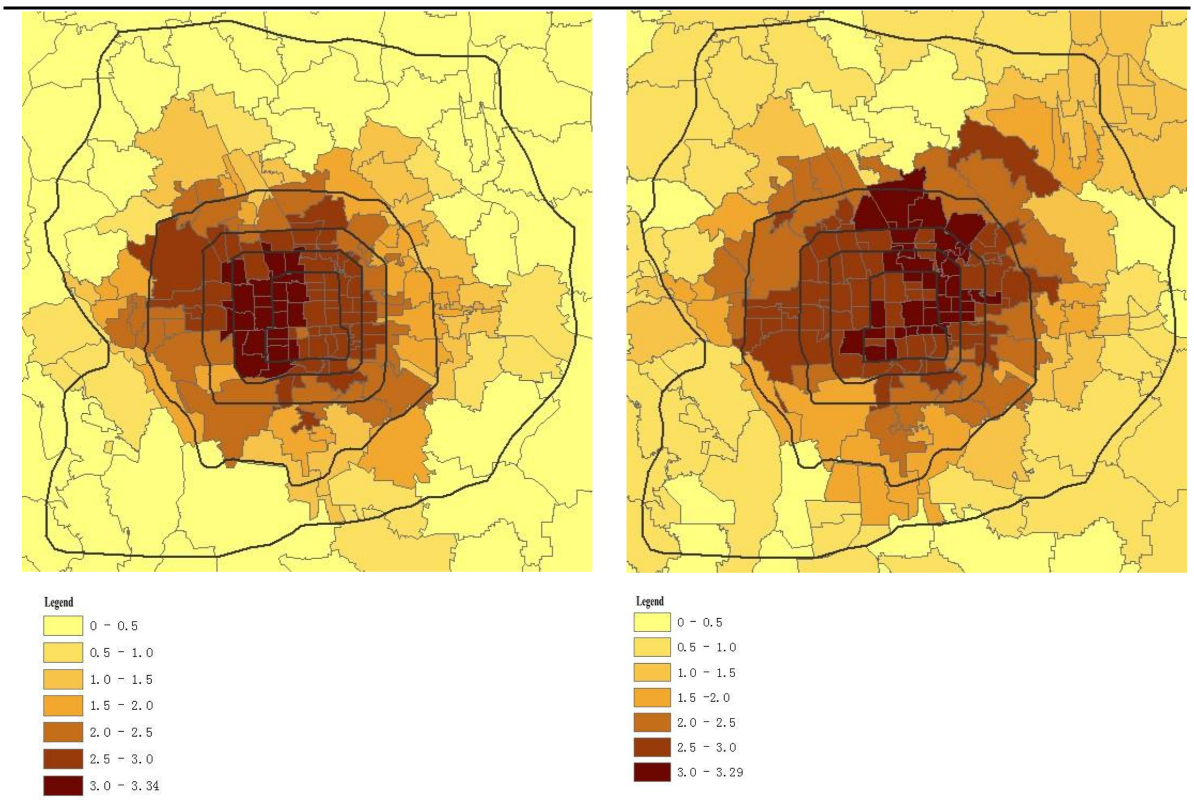


Figure 2-28 Spatial Distribution of Job Accessibility Based on Car Commuting Pattern in 2010-2015 (30 min)

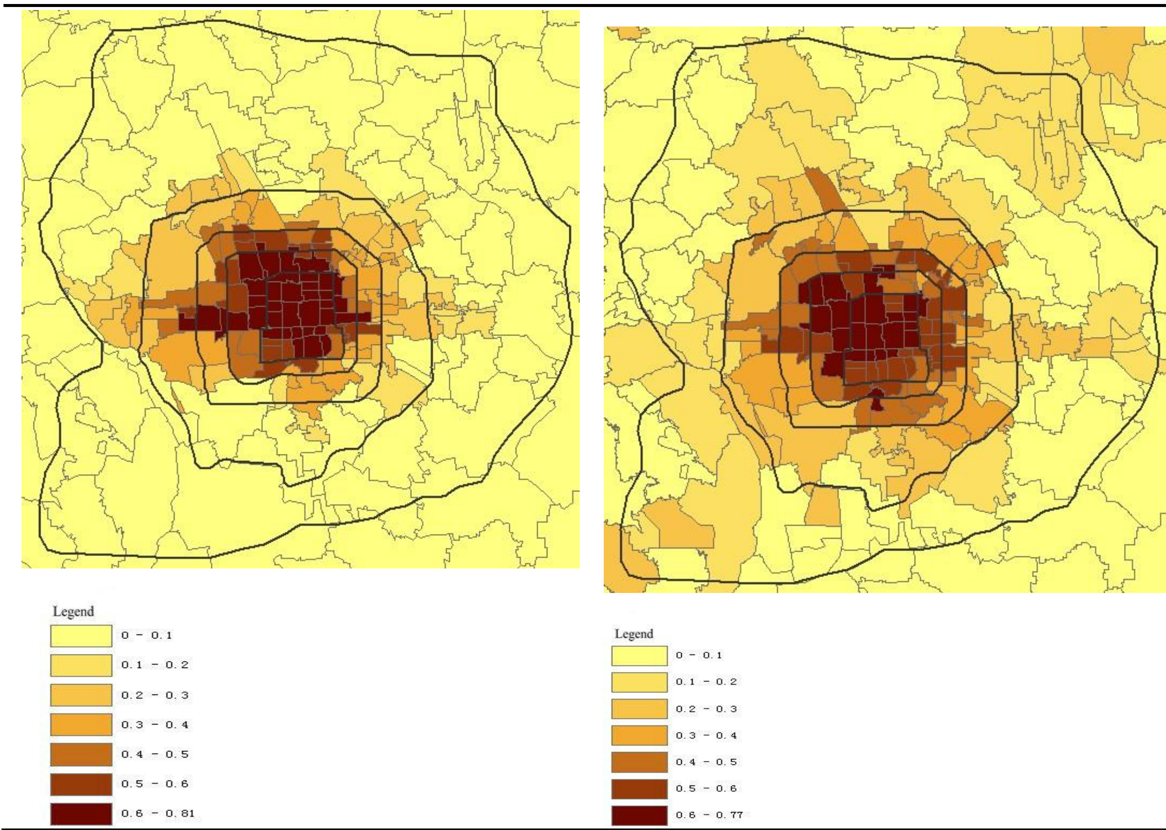


Figure 2-29: Spatial Distribution of Job Accessibility Based on Public Traffic Commuting Pattern in 2010-2015 (60 min)

Data source: The Traffic Survey in Beijing

2.3.4 Development of public transport and employment accessibility

M1, the first metro line in Beijing, was put into operation in 1969, while the mass construction of rail transit lines in the city began since 2000. As of 2010, there were 14 rail transit lines, with total operation length of 336 km. From 2010 to 2015, additional 9 lines were commissioned (Table 2-5), adding the total operation length to 554 km. Then, the network of rail transit lines was basically shaped. In this period of five years, the annual passenger volume increased by 1.8 times from 1,846,450,000 to 3,323,810,000.

Table 2-5 Composition of the rail transit lines in Beijing

Metro line	Initial operation time	Origin – terminal	Operation length (km)	Number of stations	
				Total	Transfer stations

Metro line	Initial	Origin – terminal	Operation	Number of stations	
M1	Jan. 1969	Pingguoyuan – Sihui East	31	23	10
M2	Sep. 1984	Loop line (Xizhimen – Jishuitan)	23	18	10
M13	Sep. 2002	Xizhimen – Dongzhimen	41	16	8
BT	Dec. 2003	Sihui – Tuqiao	19	13	2
M5	Jan. 2007	Songjiazhuang – Tiantongyuan North	28	23	10
M8	July 2008	Nanluoguxiang – Zhuxinzhuang	29	18	6
M10	July 2008	Loop line (Bagou – Huoqiying)	57	45	15
JC	July 2008	Dongzhimen – T2	28	4	2
M4	Sep. 2009	Gongyixiqiao – Anheqiao North	28	24	10
M15	Dec. 2010	Qinghuadongluxikou – Fengbo	43	20	4
CP	Dec. 2010	Xi'erqi – Nanshao	31	12	2
DX	Dec. 2010	Gongyixiqiao – Tiangongyuan	22	11	0
FS	Dec. 2010	Suzhuang – Guogongzhuang	23	11	1
YZ	Dec. 2010	Songjiazhuang – Ciqu	23	13	1
M9	Dec. 2011	National Library – Guogongzhuang	17	13	7
M6	Dec. 2012	Haidian Wuluju – Lucheng	43	26	9
West section of M14	May 2013	Zhangguozhuang – Xiju	12	7	2
M7	Dec. 2014	Beijing West Railway Station – Jiaohuachang	24	19	4
East section of M14	Dec. 2014	Shangezhuang – Beijing South Railway Station	31	20	7

Source: Beijing Transport Annual Report.

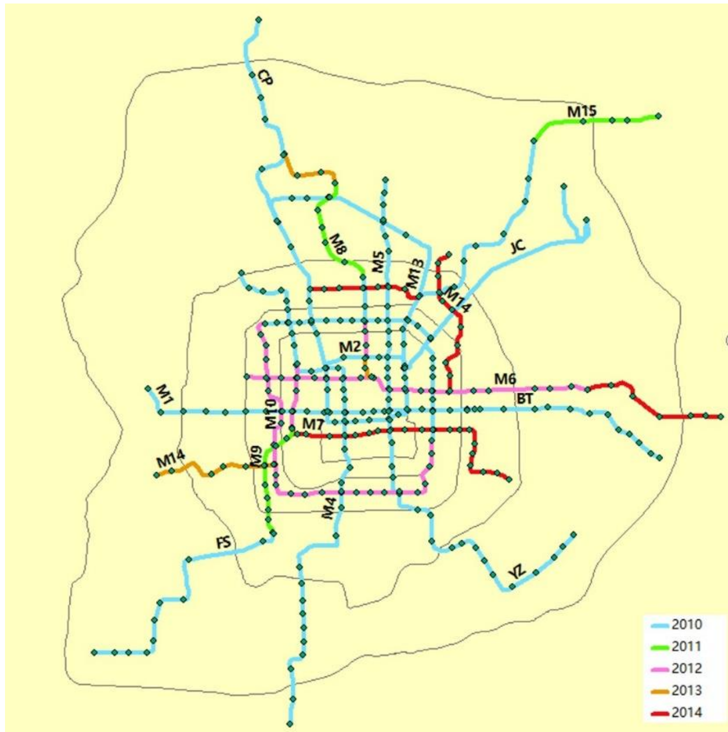


Figure 2-30 Beijing rail transit lines in 2015

2.3.4.1 Impacts of Rail Transit Lines on Growth of Population and Employment

(1) Growth of population along rail transit lines

Total urban population in Beijing has been growing. In 2015, the resident population in Beijing was 21,705,000, up 10.7% from 19,612,000 in 2010. The population suburbanization progressed in a circled manner, and the total population grew and extended outwards from the urban center in respect of spatial distribution. The resident population declined slightly within the 2nd Ring Road, climbed gently within the range from the 2nd Ring Road to the 4th Ring Road, and grew rapidly within the range from the 4th Ring Road to the 6th Ring Road.

The network operation of rail transit lines has stimulated the population proportion around the stations. The population proportion in 500 m and 1000 m radius of stations within the 6th Ring Road increased to 30.4% and 62.3% respectively in 2015 from 12.8% and 34.3% in 2010. The construction of rail transit lines has also accelerated the population suburbanization. We investigated the total population and density in major residential communities within the 6th

Ring Road in 2010 and 2015, as shown in Figure 3-18 and Figure 3-19, where red represents the communities with population grown significantly, yellow represents the communities with population grown slightly, and green represents the communities with population declined sharply.

Clearly, the total population and density in major residential communities along new lines have grown apparently. For example, outside the 5th Ring Road, the CP line and the north section of M8 were put into operation, in addition to M13 and M5, providing more transfer stations. As a result, the resident population in major residential communities like Huilongguan, Tiantongyuan and Beiyuan along these lines reached 1,201,000 in 2015, which is 162,000 more than that in 2010, representing a year-on-year increase of 32,000. In the southwestern urban areas, M7, M9, M14 and the west section of M10 were put into operation successively after 2010 to connect existing FS and M4 lines, providing additional 7 transfer stations. Thus, the resident population in the communities such as Lugouqiao, Huaxiang and Huangcun along these lines has grown swiftly – to 799,000 in 2015, which is 70,000 more than that in 2010, representing a year-on-year increase of 14,000. The formal commissioning of the loop line M10 has triggered a higher density of population along the line, which was 17,900 persons/km2 in 2015, up 9.7% from 16,300 persons/km2 in 2010. Meanwhile, the average passenger volume of M10 in working days of 2015 was 1,590,000 passengers/day, which is 4 times of that in 2008 when the line was initially put into operation.

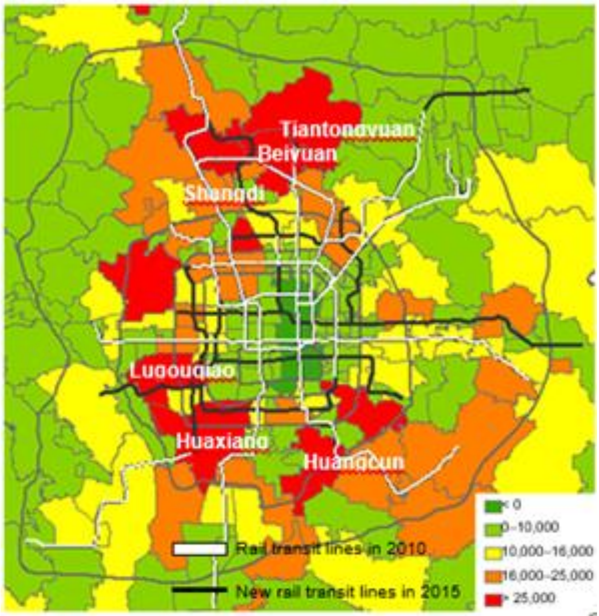


Figure 2-31 Difference value of total population in 2015 and 2010(within the 6th Ring Road)

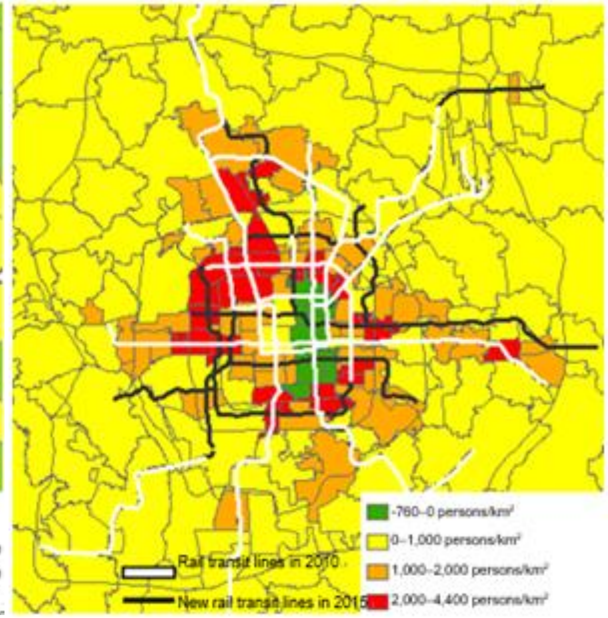


Figure 2-32 Difference value of population density in 2015 and 2010(within the 6th Ring Road)

Data Source: Beijing Statistical Yearbook

(2) Growth of employment along rail transit lines

Total employment quantity in Beijing was 11,861,000 in 2015, up 15.0% from 10,316,000 in 2010. In view of spatial distribution, the employment growth has dual features. One is centralized growth in urban center – 71.8% of jobs or employment positions in Beijing are concentrated in the six major urban districts. The other is fast growth in suburban centers – the employment growth is much faster in the suburban districts including Fangshan, Tongzhou, Shunyi, Changping and Daxing. The employment space presents a multi-center pattern. Its growth is triggered by the rail transit lines. The employment proportion in 500 m and 1000 m radius of stations within the 6th Ring Road increased to 35.3% and 68.5% respectively in 2015 from 18.2% and 36.5% in 2010.

The network operation of rail transit lines facilitates the accessibility to employment centers and boosts the centralized growth of employment (Figure 2-33 and Figure 2-34). In 2015, the total employment quantity in CBD, Finance Street and Zhongguancun increased by 64.2%, 37.4% and 41.4% respectively, with the employment density up to 43,000–74,000 persons/km2.

Moreover, the radial layout of rail transit lines accelerates the employment growth in suburban areas. In the past five years, the employment quantity grew outstandingly in such centers as Shangdi, Yizhuang, ABP (Huaxiang) and Beijing International Airport. In the Yizhuang National Economic Development Zone, for example, the employment quantity in 2015 was 350,000, doubled compared with that in 2010. The passenger volume of the YZ line has soared since 2010 when it was put into operation – by 2.6 times to 171,000 passengers/day in 2015 from 50,000 passengers/day.

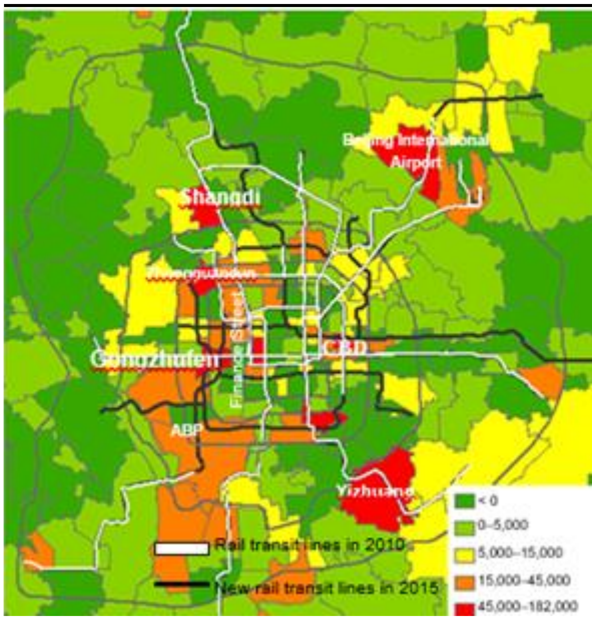


Figure 2-33 Difference of total employment quantity along rail transit lines in 2015 and 2010 (within the 6th Ring Road)

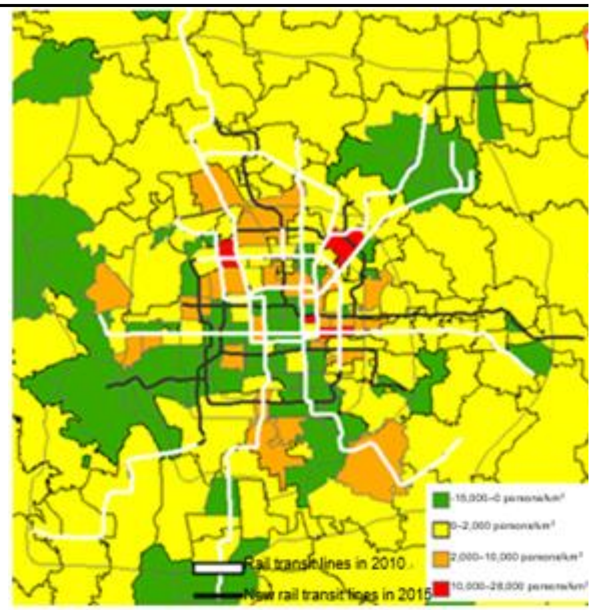


Figure 2-34 Difference of employment density in 2015 and 2010 (within the 6th Ring Road)

Data Source: Beijing Statistical Yearbook

2.3.4.2 Impacts of Rail Transit Lines on Employment Accessibility

(1) Employment accessibility supported by rail transit lines

We adopted the measurement of employment accessibility proposed by Shen Qing (2001). This method can be used to calculate the weighted commuting time from the start point to each part of the entire employment space under different transport modes. Compared with traditional accessibility calculation methods, Shen Qing's method introduces the share rate and impedance (commuting time) of each transport mode as weights, thus allowing the effective measurement of multi-center employment space.

By using the Beijing Traffic Model, we simulated the commuting time (including onboard duration and connecting time) and share rate of cars and public transport modes (including both railway system and routine bus) under different rail transit lines in 2015 and 2010, and calculated the employment accessibility for communities on the basis of 2015 population and employment data.

The comparison results show clearly that, under the condition of 2015 rail transit lines, the urban employment accessibility in Beijing improved greatly, and the average employment accessibility for communities grew by 0.6% from 2010 to 2015.

(1) The employment accessibility in the northern and eastern areas is much higher than other areas of the Beijing city, and tends to further extend outwards. For example, the employment accessibility for Huilongguan increases by 5%, and that for Tongzhou increases by 7%.

(2) Construction and development of rail transit lines help improve the employment accessibility in the western and southwestern areas. For example, in Area A (covering Lugouqiao Community, Taipingqiao Community and Lugu Community), due to the formal operation of the west section of M14 and M9, the employment accessibility grew by 4% from 0.815 in 2010 to 0.818 in 2015 and the average commuting time via public transport modes in the six major urban districts reduced from 79.9 minutes in 2010 to 68.7 minutes in 2015. In Area B (covering Tiancunlu Community, and Balizhuang Community), by virtue of the west section of M10 and M6, the employment accessibility increased by 7% from 0.816 in 2010 to 0.822 in 2015, and the average commuting time via public transport modes reduced from 78.6 minutes in 2010 to 66.5 minutes in 2015.

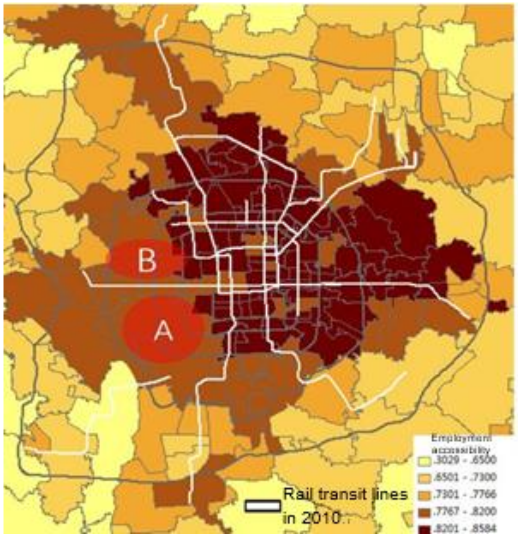


Figure 2-35: Distribution of employment accessibility under 2010 rail transit lines

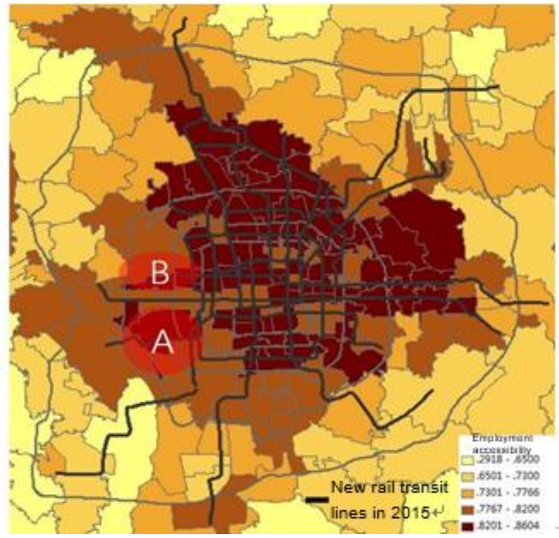


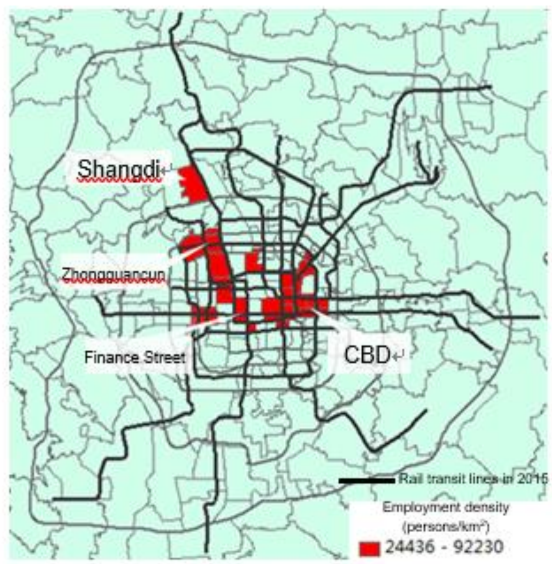
Figure2-36: Distribution of employment accessibility under 2015 rail transit lines

Data Source: Beijing Statistical Yearbook, Beijing Urban Comprehensive Transportation Survey.

(2) Suggestions on future construction of rail transit lines

We investigated and compared the spatial distribution of top 20 communities in respect of employment density and employment accessibility, with consideration to the traffic construction investment and adaptability of job markets in Beijing. It is found that the areas with high employment density mainly include the pan-CBD between the East 2nd Ring Road and the East 3rd Ring Road, the Finance Street and Zhongguancun between the Northwest 2nd Ring Road and the 4th Ring Road, and the Shangdi area emerging around the North 5th Ring Road (Figure 2-37). In view of employment accessibility (Figure 2-38), the areas from the East 2nd Ring Road to the East 3rd Ring Road demonstrate good accessibility, especially CBD which has the highest accessibility. For Zhongguancun and Shangdi in suburban areas, the employment accessibility has improved slightly but far behind the fast-growing demand of job markets. Typically in Shangdi, the employment quantity grew significantly in the past five years and it is about 300,000 now; CP and M13 are the major transit lines, with the load factor up to 140% in this area, where certain measures must be taken to limit the passenger volume in peak hours.

In summary, these areas with fast employment growth should be given the top priority in future construction and improvement of traffic facilities. Especially, the accessibility to suburban employment centers should be improved, so as to effectively adapt to and support the rapid changes in urban employment space.



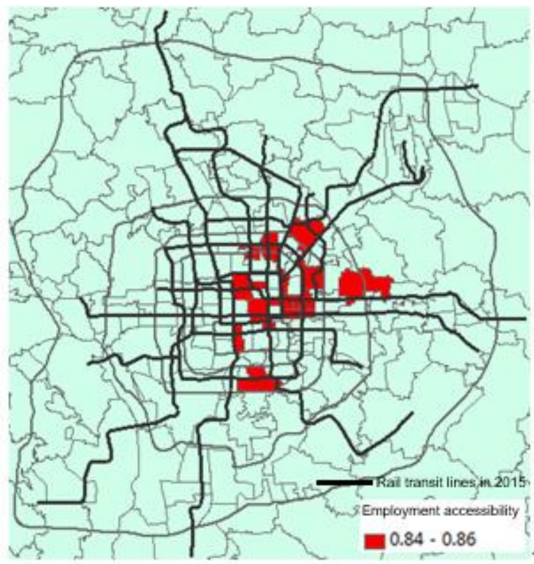


Figure 2-37: Top 20 communities with high employment density in 2015

Figure 2-38: Top 20 communities with high employment accessibility in 2015

Data Source: Beijing Statistical Yearbook, Beijing Urban Comprehensive Transportation Survey.

3 Regression Analysis Based on Traffic Investigation Data

3.1 Basic Situation of the Survey

3.1.1 Survey Scale, Time and Method

A total of 1000 households were surveyed in this survey. Among them there are 500 households involved in job satisfaction issues.

Survey period: March 2016 to May 2016

During the survey mission, each interviewed household selects one day from Monday to Friday on weekdays as the survey time and the survey period is all the 24-hour trips during the investigation day. The number of weeks of appointment between different households in each community is about the same.

In-home survey time: after 17:00 pm from Monday to Friday, all day for Saturday and Sunday.

3.1.2 Survey Sampling

In this survey, a two-stage sampling method was adopted. First, communities in the six urban districts of Dongcheng, Xicheng, Chaoyang, Haidian, Shijingshan and Fengtai were sampled and urban households were drawn from each community. Specific steps are as follows:

(One) Community Extraction

1. Principles of Community Extraction

Communities were extracted from the surveyed communities in the traffic survey in Beijing in 2015. Table 3-1 shows the list of communities involved in the survey and their corresponding administrative regions.

Table 3-1 List of the Communities in the survey and their administrative regions

Administrative Region	The total number of sample frames		
	Community committees	Village committee	Total
Dongcheng District	205	0	205
Xicheng District	255	0	255
Chaoyang District	369	154	523
Fengtai District	271	69	340
Shijngshan District	139	0	139
Haidian District	584	84	668

2. Methods to Extract Communities

(1) Number and District of Communities to be Sampled

The total sample size of the survey is 1000. Taking into account of factors such as investigation time and funding requirements, it is planned to visit 10 households in each community, so a total of 100 communities will be sampled for survey.

In the six districts of the city, according to the number of permanent residents in each urban area, the number of communities that need to be extracted in each urban area should be prorated according to the specific amount as follows:

Table 3-2 The number of permanent residents in each urban area and the number of communities to be extracted

No.	District	Permanent Residents		Number of Communities Extracted
		Number (10,000 people)	Proportion (%)	
1	Xicheng District	129.8	10.12%	10
2	Dongcheng District	90.5	7.05%	7
3	Chaoyang District	395.5	30.83%	31
4	Fengtai District	232.4	18.12%	18
5	Shijingshan District	65.2	5.08%	5
6	Haidian District	369.4	28.80%	29
Total		1282.8	100.00	100

(2) Specific Steps to Extract Community Samples

a. Sort out the list of the six districts in the city and ensure that there is no overlap or omission;

b. Number each community within the city in unity from 1;

c. According to the number of communities that need to be investigated in each urban area, random sampling should be carried out. The community corresponding to the extracted serial numbers is the community of the survey, prepare a spare community list;

d. Organize the list of the selected communities, find and mark their corresponding geographical locations and the corresponding number of households and the number of people in the city map.

(Two) Household Sampling

1. Track Samples

Give 10 addresses per community (based on the principle of isometric distance from the 50 samples surveyed by the Traffic Survey), the interviewer must follow the order of the address given by each household one by one and complete the “Tracking Sample Contact Table” until the sample size is completed.

Address Source: The source of the survey is the address of Bureau of Statistics’ travel survey. The original address was tracked this year. At the same time, interviewers also provided interviewers' badges. If any respondents are suspicious of this survey, they may dial for consultation to prove the authenticity of this survey.

(Three) Selection of Home Interviewee

All family members are interviewed, including temporary residents.

(Four) Sample Replacement Principles

First of all, knock on the door of a sample of 10 sample households, truthfully record the address table in detail. If the withdrawn family households are not at home, or there are empty buildings or they refuse to visit, and then select eligible households in accordance with the left and right shocks.

3.2 Investigation Data Sample Analysis

Based on the above in-home survey, 2112 pieces of effective data of the commuting sample are screened out. The research made the clustering analysis describing the commuting characteristics of different types of people. The correlation of different factors and job satisfaction was investigated by the regression analysis of quantified data as well.

3.2.1 Basic information analysis of investigation samples

As seen from the statistical analysis of the genders of the investigation samples, the ratio of the male is slightly higher than that of the female, reaching 54.02% and 45.98% respectively. Please see Table 3-3 for the specific data.

Table 3-3 Statistical Stable of Genders of Investigation Samples

Gender	Proportion
Male	54.02%
Female	45.98%
Total	100.00%

As seen from the statistical table of occupations of the investigation samples, most of the respondents are the employees of the enterprises and companies, accounting for 48.06%, followed by commercial and service personnel, and employees of public institutions, accounting for 10.13% and 10.84% respectively. This is consistent with the overall condition of Beijing.

Table 3-4 Statistical Table of Occupations of Investigation Samples

Occupation	Proportion
Non-occupation	0.43%
Worker	1.66%
Employees of enterprises and companies	48.06%
Commercial service industry personnel	10.13%
Public servants	3.08%

Employees of public institutions	10.84%
Agriculture, forestry, animal husbandry, fishery personnel	0.62%
Community worker	6.06%
Individual proprietary or self-employed	9.56%
Full-time driver	0.99%
Teaching and administrative staff	4.17%
Medical staff	2.89%
Soldiers / policemen	1.09%
Professionals	0.43%
Others	0.00%
Total	100.00%

As seen from the statistics of the types of the buildings, most of the residential buildings are the commercial residential buildings, accounting for 59.33%. Please see Table 3-5 for the specific data.

Table 3-5 Statistical Table of Types of Buildings of Investigation Samples

Type of Building	Proportion
Commercial residential building	59.33%
Organization’s self-managed/directly-managed building	14.06%
Lodged building	1.18%
Leased building	13.35%
Low-rent housing / public rental housing	1.37%
Economically affordable housing	2.79%
Rural residential land	6.11%
Others	1.80%
Total	100.00%

As seen from the statistical table of annual household income, the majority of families are with the income in the amount of RMB 100,000 to RMB 150,000, accounting for 35.23%, followed by the families with the income in the amount of RMB 150,000 to RMB 200,000, accounting for 25.47%. Please see Table 3-6 for the specific data.

Table 3-6 Statistical Table of Annual Household Income of Investigation Samples

Annual household income (RMB Yuan)	Percentage
Less than 50 thousand	2.32%
50(included)-100 thousand	19.79%

100(included)-150 thousand	35.23%
150(included)-200 thousand	25.47%
200(included)-250 thousand	10.98%
250(included)-300 thousand	4.97%
300(included)-500 thousand	1.14%
Over 500 thousand	0.09%
Total	100.00%

3.2.2 Analysis of Travel Characteristics

In the investigated transport modes (walking is not included), public transport accounts for 49.3%, of which the transit mode accounts for 27% and bus accounts for 22.3%. The percentage of trips by car, taxi, regular bus, bicycle and others is 32.3%, 2.9%, 1.8%, 13.5% and 0.2% respectively. Comparing with the data of in-home commuting survey in 2015, the share of the transit and bicycle are slightly increased.

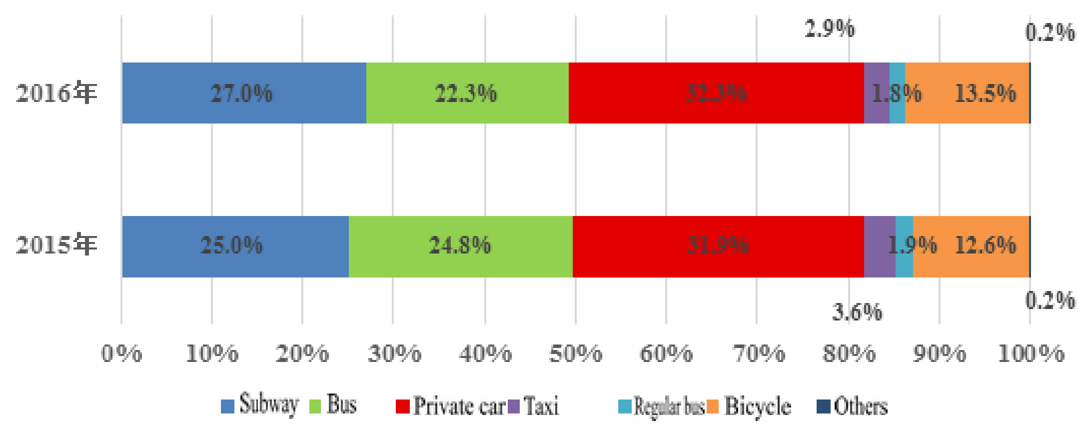


Figure 3-1 Statistical Chart of the Travel Mode of Investigation Samples

As seen from the statistical chart of the travel duration, the travel duration is mainly concentrated on the range of 0~60min, accounting for 83.95%; the overall average travel duration is 39.4 minutes. Please see Figure 3-2 for the specific data.

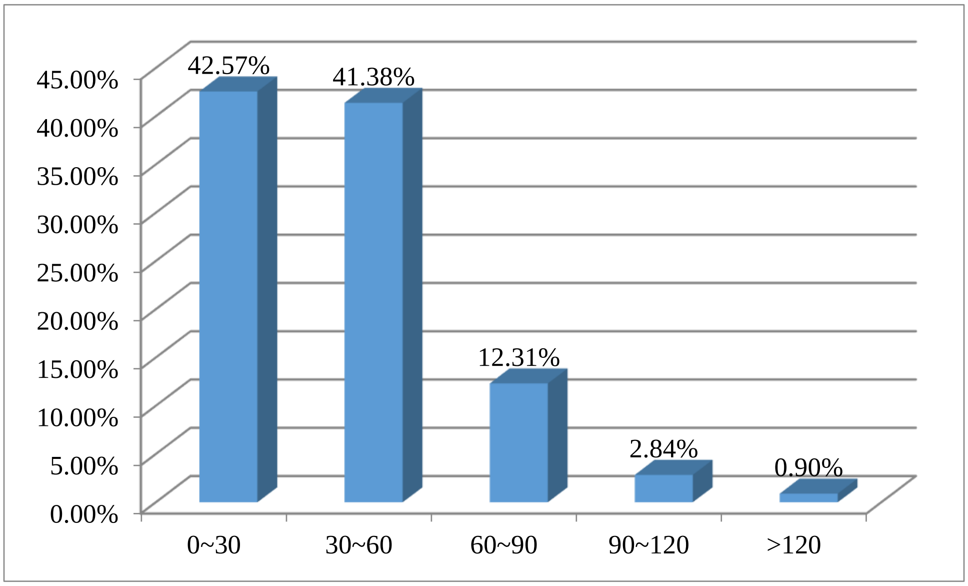


Figure 3-2 Distribution Diagram of Travel Duration of Investigation Samples

According to the statistical table of the travel distance, the travel distance is less than 5km in most cases, accounting for 50.90%; the overall average travel distance is 7.5km. Please see Figure 3-3 for the specific data.

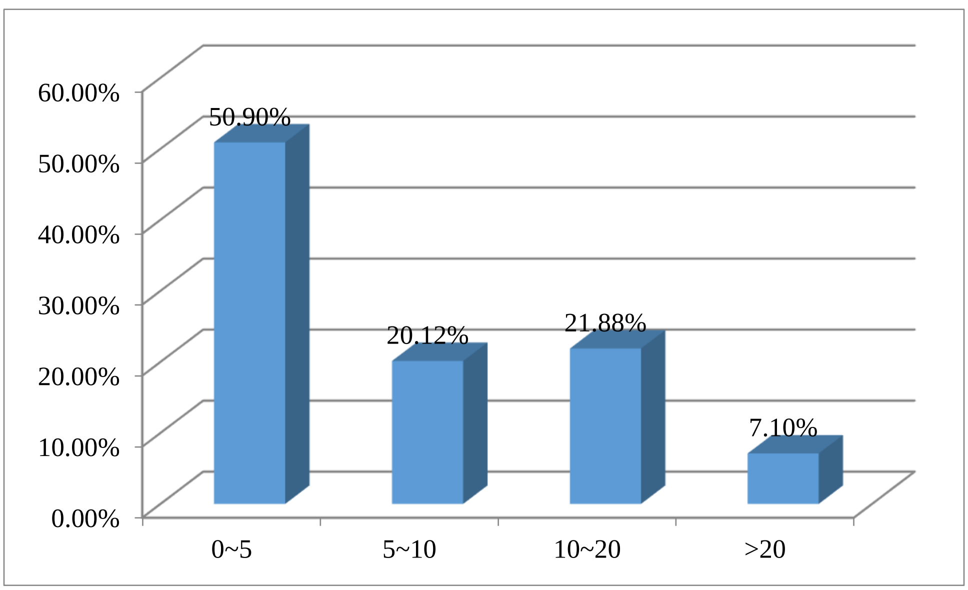


Figure 3-3 Distribution Diagram of Travel Distance of Investigation Samples

As seen from the statistical table of the monthly transport expense, most of the people will spend the monthly transport expense in the amount of RMB500 ~ RMB1,000, accounting for 52.89%. Please see Figure 3-4 for the specific data.

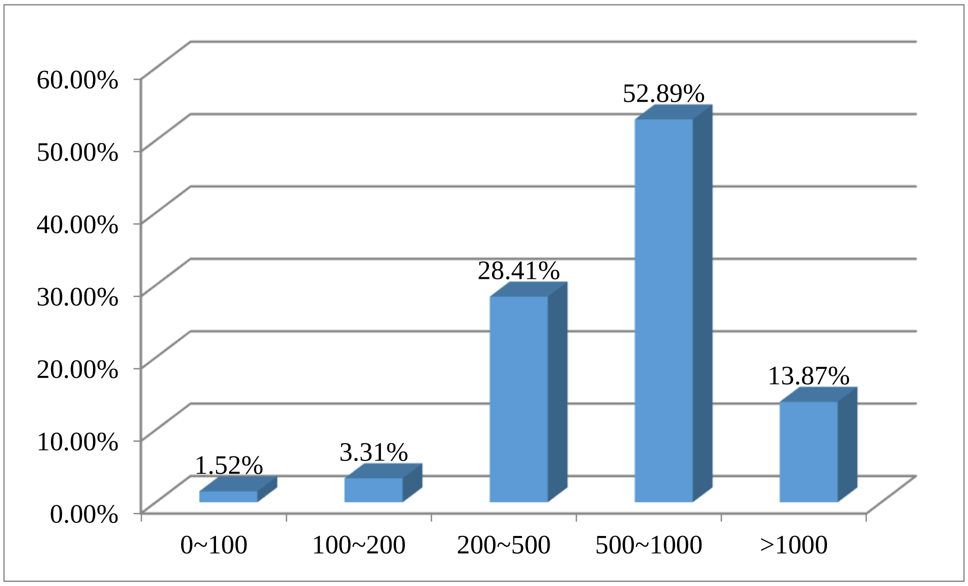


Figure 3-4 Distribution Diagram of Monthly Transport Expense of Investigation Samples

3.2.3 Analysis of Work Satisfaction

In the questionnaire, we added three questions related to the job satisfaction, including the satisfaction evaluation of their current job, the tolerant longest commuting duration (one way) and the corresponding activity when the commuting duration exceeds the tolerant duration under the change of working place.

As seen from the satisfaction shown in the questionnaire, most of the commuters are satisfied with the current commuting conditions, accounting for 78.6%. Only 0.6% of the commuters express the dissatisfaction.

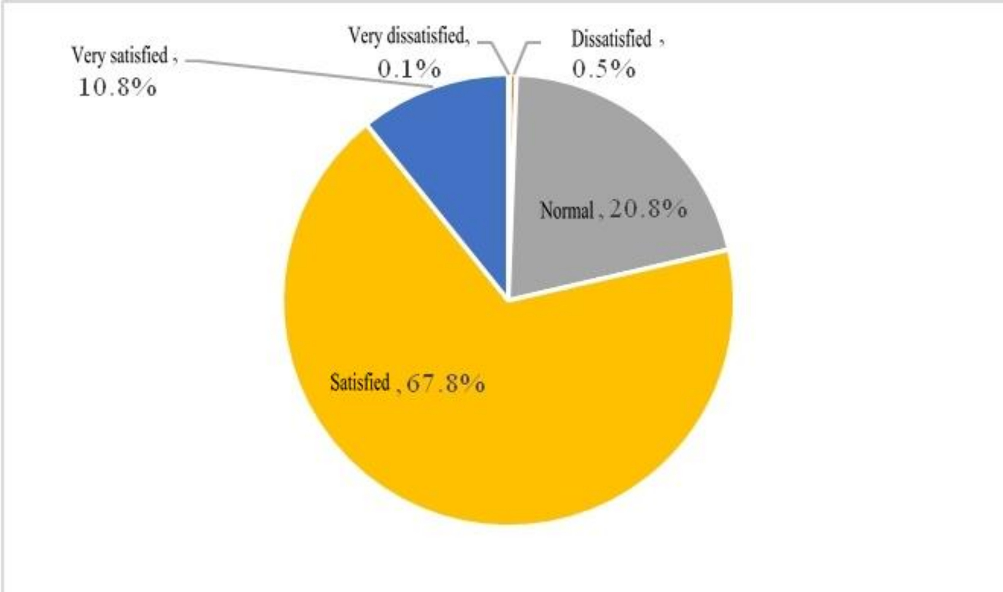


Figure 3-5 Satisfaction of Residents

From the questionnaire, it is known by enquiring the commuters about the maximum commuting duration acceptable to the commuters that approximately more than 50% of the commuters can tolerant the maximum commuting duration more than 50 minutes (see Figure 3-6), which is close to the average travel duration of 56 minutes by commuting modes (walk not included) within the Sixth Ring Road under the Beijing Traffic Survey in 2015.

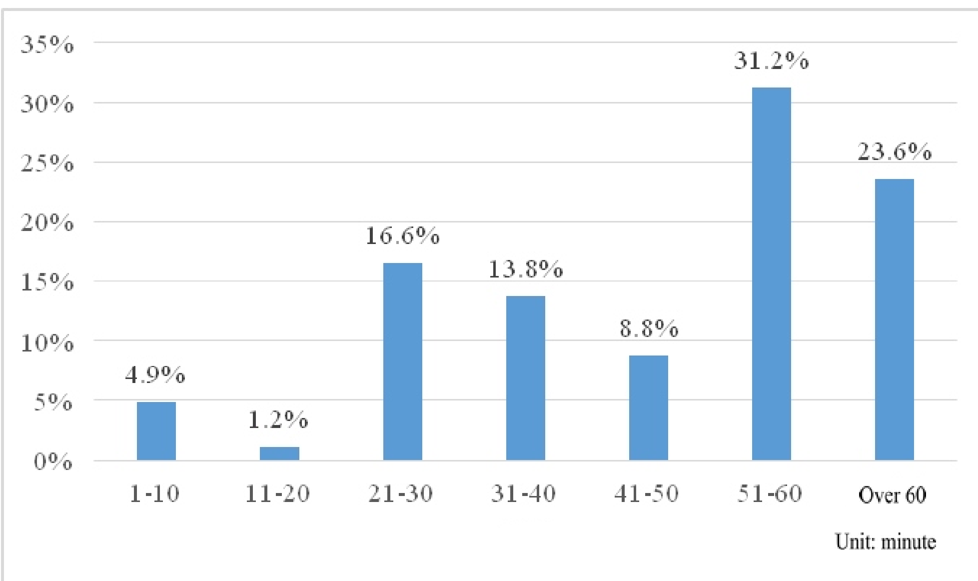


Figure 3-6 Distribution Diagram of Residents' Travel Duration

In case of the job change, if the commuting duration is more than the maximum commuting duration acceptable to the respondents, more than 50% of the respondents will maintain the current status and make no change. However, 16.4% of the respondents will not apply for the job with the long commuting distance (see Figure 3-7), which to some extent indicates that factors influencing the choice of residential job and housing location are complicated and the commuting duration is not the determinant factor for residents to change job and housing location. In the questionnaire, about 14% of residents will change the housing location when the commuting duration exceeds the tolerant duration. This group of residents is mainly house-renters. Besides, about 14.4% of residents choose to change the transport mode, who currently mainly adopt the passenger car (42%) or bus (11%) for commuting trips.

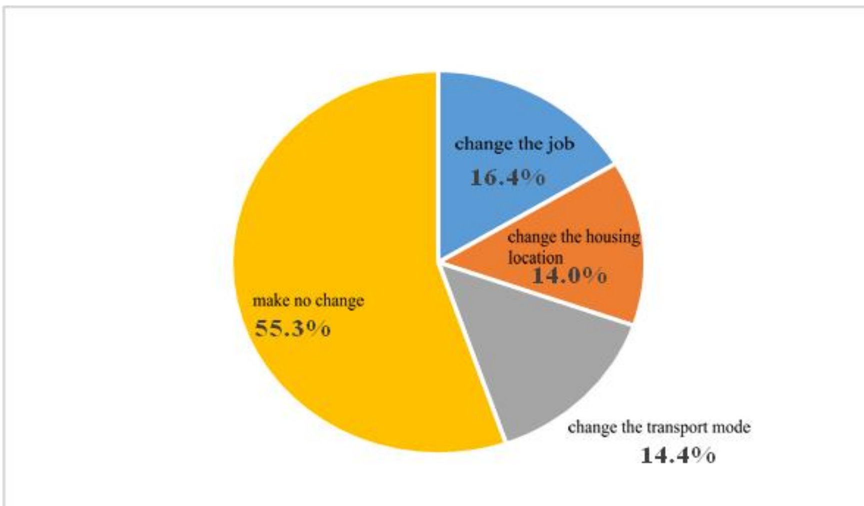


Figure 3-7 Diagram of Residents Intention with commuting duration longer than the tolerant duration after the job change

We made the cross statistical analysis for the job satisfaction of people with different level of income and found that with the higher income level, the proportion of people with very satisfied and satisfied status will increase significantly.

Table 3-7 The job satisfaction of people with different income level

Unit: RMB	Very satisfied	Satisfied	Average level	Not very satisfied	Very Dissatisfied
Under 100 ,000	5.3%	54.9%	39.2%	0.6%	0.0%
100,000-200,000	10.3%	71.7%	17.5%	0.4%	0.2%
Over 200,000	20.1%	71.4%	8.5%	0.0%	0.0%

We made the cross statistical analysis for the job satisfaction of people with different level of commuting duration and found that most people being investigated evaluated the job satisfaction level as very satisfied and satisfied. However, for people whose commuting duration is over 60 minutes, their evaluation of job satisfaction is going down (see Table 3-8).

Table 3-8 The job satisfaction of people with different commuting duration

Duration	Very satisfied	Satisfied	Average level	Not very satisfied	Very Dissatisfied
0-30 minutes	24.4%	54.2%	19.3%	1.4%	0.7%
30-60 minutes	8.1%	77.5%	14.2%	0.1%	0.0%
Over 60 minutes	3.2%	58.3%	38.5%	0.0%	0.0%

We made the cross statistical analysis for the income level of people with different commuting modes and found that people with higher income have a higher proportion of choosing passenger car for commuting trips. While low income people have a higher proportion of choosing bicycle for commuting trips. Generally, the proportions of choosing passenger car, subway and bus for commuting trips are uniformly distributed (see Table 3-9).

Table3-9 The income level of people with different commuting modes

Unit: RMB	Under 100,000	100,000-200,000	Over 200,000
Passenger car	19.12%	57.69%	23.19%
Subway	13.19%	69.79%	17.02%
Bus	12.94%	70.98%	16.08%
Bicycle	34.70%	57.07%	8.23%
Walk	29.97%	57.73%	12.30%

3.3 Study Methods for Regression Analysis

The regression analysis is a kind of statistical method by which a set of predictive variables (Independent variables) is used to predict one or more response variables (Dependent variables). It is also used to assess the effect of the predictive variables on the response variables. In most practical problems, there are more factors affecting the dependent variables. Generally, such problems are referred to as the multiple regression analysis problems. Among other methods for multiple statistical analyses, the regression analysis is used in the widest range. The multiple regression analysis is a common method for economic prediction. By establishing the mathematical model between the economic variables and explanatory variables, the R test, F test, and t test will be carried out on the mathematic model so established, and the values of the given explanatory variables are substituted into the regression model if the determination requirements are complied with, so as to work out the future value of the economic variable, i.e. the predicted value.

Logit Regression Model is not only the earliest discrete choice model and the model used in the widest range at present, but also the common method of empirical analysis for sociology, clinical medicine, bio-statistics, econometrics, quantitative psychology, and marketing management.

Aiming at the categorical variables, we commonly use Logit Regression Model, which is a particular case of the generalized linear model. If there are three or more types of categorical dependent variables and there is no ordering relation between such categories, it is possible to adopt the Multinomial Logit Model, which is the natural expansion of the Logit Regression Analysis. For some dependent variables between which the ordering relation cannot be determined, we still choose the Multinomial Logit Model, because the model with the minimum or least strict assumptions shall be chosen if it is impossible to determine whether the data can satisfy all the assumptions of the substitute model.

The data of the Logit Model can link up the attribute variables in the form of probability, and the value of the probability p ranges from 0 to 1; therefore, it is not appropriate to directly establish the function relationship directly between the probability $p = \pi(x)$ and x, i.e. $\pi(x) = \alpha + \beta x$.

In practice, $\pi(x)$ will increase continuously or decrease continuously along with x, and its intuitive curve pattern is in the S-shape.

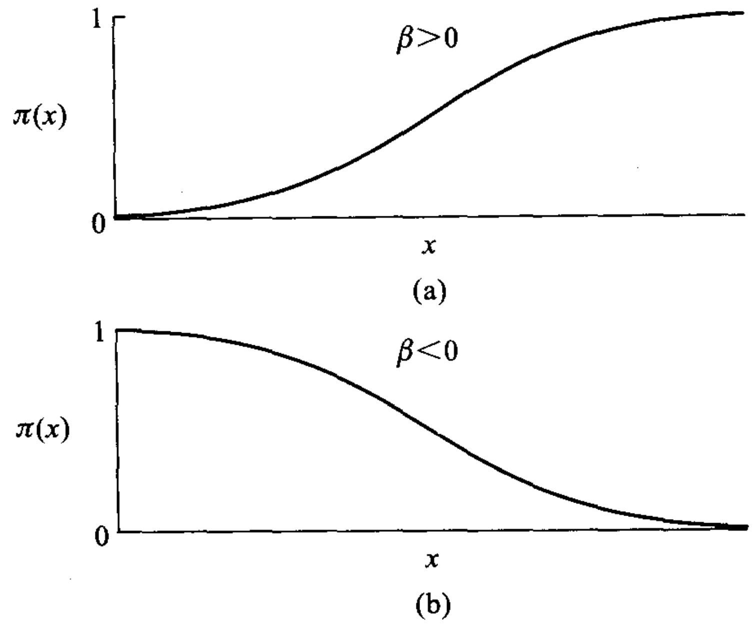


Figure 3-8 $\pi(x)$ Function Curve

In general, the mathematic function in such shape shall be in the following form:

$$\pi(x) = \frac{\exp(\alpha + \beta x)}{1 + \exp(\alpha + \beta x)}$$

This formula is referred to as Logit Regression Function. By linearizing the aforesaid function, we can get:

$$\ln\left(\frac{\pi(x)}{1 - \pi(x)}\right) = \alpha + \beta x$$

The function f(p) of p is assumed as the functional form of the variable, and take:

$$f(p) = \ln\frac{\pi(x)}{1 - \pi(x)} = \ln\frac{p}{1 - p}$$

Such conversion is referred to as the Logit Function or the Logit Transformation. Therefore, the Logit Transformation takes the log odd in the contingency table. If the value of the probability ranges from 0 to 1, Logit may be any real number, so as to avoid the structural defect in the linear probability model.

Assume that the response variable Y is a dichotomous variable, set $p = P(Y = 1)$, and there are k factors affecting Y including $x_1, \cdots x_k$, so:

$$\ln \frac{p}{1-p} = g(x_1, \cdots, x_k)$$

It is known as the Logit Regression Model of the dichotomous data, or Logit Regression Model for short. Such k factors are known as the covariants of the Logit Regression Model.

The most important Logit Regression Model is the Logit Linear Regression Model. The multiple Logit Model is in the form of:

$$\ln \frac{p}{1-p} = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k$$

According to the above formula, we can get:

$$\frac{p}{1-p} = e^{\beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k}$$

$$p = \frac{e^{\beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k}}{1 + e^{\beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k}}$$

If there are three or more response variables, i.e. the attribute variables in multiple categories, the Multinomial Logit Model shall pair up each category with one baseline category; generally, the final category is selected for reference, so as to form the baseline-category Logit.

The baseline-category Logit Model with the predictive variable of x is:

$$\ln(\frac{\pi_j}{\pi_J}) = \alpha_j + \beta_j x, \; j = 1, \cdots, J-1$$

In this model, there are J-1 equations in total, each of which has different parameters. Such effects will vary with the category paired up with the baseline. No matter what category is used as the baseline, there is the same parameter estimation for the same pair of categories; that is to say that the category of the baseline is selected arbitrarily.

3.4 Regression Analysis of Commuting Duration

Although the aforesaid analysis is made to simply analyze the residents' travel characteristics as well as the relevant impacts of the commuting duration and distance and the other factors; however, it is impossible to embody the impact degree of each factor on the commuting duration and commuting distance in detail; therefore, in order to study the impact degree of the different variables on the commuting duration and the commuting distance, the regression analysis is made against such questionnaire.

In this regression, screen and select the travel Start-To-End as H-W commuting sample data; in total, there are 2069 pieces of the data samples. In order to improve the precision of regression, and facilitate the analysis of the impact of the main variables concerned on the commuting duration and satisfaction, the samples of the secondary factors are eliminated artificially; finally, 1598 pieces of data samples are regressed.

On the basis of the questionnaire, screen and select the travel Start-To-End as H-W commuting sample data; in total, there are 2069 pieces of the data samples. In order to improve the precision of regression, and facilitate the analysis of the impact of the main variables concerned on the commuting duration and satisfaction, the samples of the secondary factors are eliminated artificially; finally, 1598 pieces of data samples are regressed.

The multiple linear regression shall be made while taking the passenger car (X), subway transit (X2), bus (X3), bicycle (X4), medium income (X5), high income (X6), housing attributes (X7), gender (X8), employees of enterprises and companies (X9), commercial service industry (X10), public institutions (X11), self-employed (X12), job-housing ratio (X13) , aggregate job accessibility (X14), and age (X15) as the independent variables, and taking the travel duration (Y1) and travel distance (Y2) as the dependent factor. The regression models include:

$$Y_1 = C + A_1X_1 + A_2X_2 + A_3X_3 + A_4X_4 + A_5X_5 + A_6X_6 + A_7X_7 + A_8X_8 + A_9X_9 + A_{10}X_{10} + A_{11}X_{11} + A_{12}X_{12} + A_{13}X_{13} + A_{14}X_{14} + A_{15}X_{15}$$

$$Y_2 = C + A_1X_1 + A_2X_2 + A_3X_3 + A_4X_4 + A_5X_5 + A_6X_6 + A_7X_7 + A_8X_8 + A_9X_9 + A_{10}X_{10} + A_{11}X_{11} + A_{12}X_{12} + A_{13}X_{13} + A_{14}X_{14} + A_{15}X_{15}$$

Table 3-10 Instructions to Variables

Variable	*Instructions to Variable*	*Unit*
Independent variable: Transport mode		
Passenger car (X_1)	Whether traveling by passenger car	Categorical variable
Subway transit (X_2)	Whether traveling by passenger car	Categorical variable
Bus (X_3)	Whether traveling by passenger car	Categorical variable
Bicycle (X_4)	Whether traveling by passenger car	Categorical variable
Independent variable: Level of income		
Medium income (X_5)	Whether at the medium level of income	Categorical variable
High income (X_6)	Whether at the high level of income	Categorical variable
Independent variable: Type of housing		
Housing attributes (X_7)	1 indicating private housing, 0 indicating leased housing	Categorical variable
Independent variable: Gender		
Gender (X_8)	1 indicating male, 0 indicating female	Categorical variable
Independent variable: Occupation		
Employees of enterprises and companies (X_9)	Whether is the employee of enterprises and companies	Categorical variable
Commercial service industry (X_{10})	Whether is the employee of commercial and service industry	Categorical variable
Public institutions (X_{11})	Whether is the employee of public institutions	Categorical variable
Self-employed (X_{12})	Whether is the self-employed	Categorical variable
Independent variable: Job-housing space		
Job-housing ratio (X_{13})	Number of jobs in sub-district / number of permanent resident population(data from the traffic survey in 2015)	Scale variable
Aggregate job accessibility (X_{14})	Aggregate job accessibility to the sub-district where people work	Scale variable

Independent variable: Age		
Age (X_{15})	20-30 years old: X_{15}=2; 30-40 years old: X_{15}=3; 40-50 years old: X_{15}=4; 50-60 years old: X_{15}=5; 60-70 years old: X_{15}=6; 70-80 years old: X_{15}=7	Ordinal variable
Dependent variable:		
Travel duration (Y_1)	One-way commuting duration for working (min)	Scale variable
Travel distance (Y_2)	Commuting distance from residence place to work place (km)	Scale variable

By comparison of the regression results, the effect of the travel duration is more significant than that of the travel distance, the regression result is more credible; therefore, the travel duration is selected as the dependent variable for the purpose of the multiple linear regression.

Table 3-11 Regression Results

	Model 1	**Model 2**	**Model 3**	**Model 4**
Dependent variable	Y_1	Y_1	**(In log of Y_1)**	**(In log of Y_1)**
(Constant)	365.369	107.052***	8.26	3.541***
Transport mode				
Passenger car (X_1)	25.154***	25.744***	1.021***	1.036***
Subway transit (X_2)	39.699***	40.026***	1.319***	1.329***
Bus (X_3)	42.157***	42.418***	1.341***	1.347***
Bicycle (X_4)	7.332***	7.656***	0.448***	0.457***
Annual household income				
Medium income (X_5)	4.022**	4.181**	0.09**	0.09**
High income (X_6)	3.262*	3.516*	0.098*	0.1**
Type of housing (X_7)	5.143**	4.858**	0.154***	0.146***
Gender (X_8)	1.172		0.036	
Type of occupation				
Employees of enterprises (X_9)	10.676***	11.083***	0.614***	0.629***
Commercial service industry (X_{10})	6.768*	7.124*	0.531***	0.542***

Public institutions (X_{11})	5.344	5.499	0.480***	0.487***
Self-employed (X_{12})	1.503	2.078	0.339***	0.364***
Job-housing ratio	-3.007		-0.042	
Aggregate Job accessibility（X_{14}）	-94.19**	-101.705**	-1.396*	
Age（X_{15}）	-0.521		-0.018	
Job-housing ratio squared	0.756		0.011	
R^2	0.481	0.473	0.640	0.638
Corrected R^2	0.473	0.468	0.635	0.635
F	63.924***	93.613***	122.743***	169.566***
Number of samples	**1598**	**1598**	**1598**	**1598**

According to the model results, the corrected R^2=0.635 in Model 3# is the maximum value; therefore, it is recommended to make use of the Model 3# to make the regression of the commuting duration impact factors. According to the results of the regression analysis, the following explanation and interpretation are made:

(1) Personal attributes

1) Gender

As seen from the regression results, the gender has the insignificant linear relationship with the commuting travel duration of the residents, which remains robust performance in different models.

In case of the other variables under control, taking the female as the reference group, the average commuting travel duration of the male is more than that of the female by 1.1 minutes.

2) Occupation

As seen from the regression results, the occupation type has the significant linear relationship with the commuting travel duration of the residents, and remains robust performance in different models.

In case of the other variables under control, select the community worker as the reference group, the change in the type of occupation leads to the great change in the commuting duration, and the employees of the companies spend the maximum time in commuting, which is longer than that spent by the community worker by 10.7 minutes, followed by the commercial service industry, public institutions,and self-employed, which are longer than that of the community worker by 6.8 minutes, 5.3 minutes, and 1.5 minutes.

3) As seen from the regression results, the relationship between age and commuting travel duration is not statistically significant, which is the same case in different models.

(2) Economic factors

1) Annual household income

As seen from the regression results, the level of income has the significant linear relationship with the commuting travel duration of the residents, and remains the robust performance in different models.

By selecting the low income people as the reference group, it is discovered that there is the significant positive correlation between the annual household income and the commuting travel duration. People in the medium income group have the longest commuting duration, followed by people in the high income group. Since people in the low income group have a higher proportion of renting houses, the commuting duration is therefore short.

2) Type of housing

As seen from the regression results, the housing has the significant linear relationship with the commuting travel duration of the residents, which remains the robust performance in different models.

In case of the other variables under control, select the housing lessee as the reference group, the shift from the leased housing to the private housing will lead to the increase in the commuting duration by approximately 5.1 minutes on average, which is related to the principle that the leased housing shall be neighbored to the work place.

(3) Commuting mode

As seen from the regression results, there is the significant positive correlation between the transport modes and the commuting duration of the residents; both the regression equation and parameter have the higher level of significant, and remain robust performance in different models.

In case of the other variables under control, select the transport mode of walk as the reference group, the commuting duration spent by the transport modes of the passenger car, subway transit, public transport, and bicycle is more than that spent by the transport mode of walk by 25.2 minutes, 39.7 minutes, 42.2 minutes, and 7.3 minutes respectively. Among transport modes, buses make the greatest contribution to the increase in the travel duration.

(4) Spatial factor

1) Job-housing ratio

As seen from the sample regression results, the job-housing ratio has the negative correlation with the commuting duration of residents at a insignificant level of significance, which remains the robust performance in different models. The model regression results indicate that the increase in the job-housing ratio by 0.1 will lead to the decrease in the average commuting duration of the residents by 0.3minute.

2) Transport accessibility

As seen from the regression results, the regional accessibility has the significantly negative correlation with the commuting duration of residents, which remains the robust performance in different models.

The higher the aggregate job accessibility of district where people live is, the shorter the commuting duration is shorter. The increase in the aggregate job accessibility by 0.1 will lead to a decrease in the commuting duration by 9.4 minutes.

(5) Main conclusions

Through the statistical analysis and regression analysis of the survey data, the trend of commuting characteristics and the correlation between commute time and social factors and individual attribute factors were investigated from two dimensions. Combining with the trend of changes in job-and-residence space,the following main conclusions can be drawn:

1) The increase of commuting time is the inevitable result of the expanding urban space

The increase of commuting time is related to many influencing factors, which is essentially caused by the increase of working distance. With the expansion of urban real estate development to the periphery of the city, the suburbanization of population and the increase of employment aggregation have accelerated the separation of employment and residence. From the regression analysis, it is found that the correlation between commuting time and family income level and housing type is more significant. With the increase of family income, families' newly purchased housing move to the periphery of the city and people work in the center city. This factor is positively correlated with commuting time. In addition, housing type has a significant impact on commuting time, mainly reflected in that renters have a negative correlation with commuting time, renters have a more flexible choice of places to live and fewer commuting times than home buyers.

2) Cross-regional traffic volume in urban area is increased and the influence of regional static job-housing ratio on commuting time is not very significant

From the changes of the distribution characteristics of urban space and commuting traffic, it can be found that suburbanization of employment poly-centricity and residential population form a significant increase in cross-regional traffic flow. In this study, the static job-housing ratio is based on street units. The regression results show that due to the high degree of segregation of work and residence in urban residents in Beijing, the cross-regional commuting traffic flow distribution is presented. The influence of static occupancy of street units on commuting time is not significant.

3) The choice of mode of transport shows a significant positive correlation with commuting time

The investment direction of urban traffic construction has a profound impact on residents' choice of transportation modes. The different commuting efficiency and comfort of different modes of transportation have big differences in the attractiveness of residents. With Beijing's "bus priority" policy, rail transit mileage rose from 336 km in 2010 to 554 km. The Traffic Survey of Beijing in 2010 and 2015 show that the proportion of subway trips increased from 18% to 24% during the commuters' travel.

Different modes of transportation have slightly different impacts on commuting time. The choice of ground mode of bus commuting time has made the greatest contribution, followed by rail transit and passenger cars, which is because the bus commuting duration being the longest

4) There is a significant correlation between occupational type and commuting time

Different occupational types have a significant impact on commuting time, which is mainly because job distribution characteristics for different professionals are significantly different. For example, community workers are working in the vicinity of their place of residence, so this part of the population has shorter commuting times. Those who work at companies, businesses or the service sector have relatively long commuting time.

In addition, gender differences are not significant in regression analysis, which is partially due to the fact that there are no significant differences in employment opportunities due to gender differences. Gender differences have little effect on commuting time.

3.5 Regression Analysis of Residents' Work Satisfaction

In this regression, screen and select the travel Start-To-End as H-W commuting sample data and the sample data involved in the satisfaction scoring; in total, there are 1037 pieces of the data samples.

In order to study the impact of different factors on residents' work satisfaction, by establishing the regression model, the following variables are added respectively and gradually, so as to investigate the impact of personal attribute and traffic factor on the residents work satisfaction.

The multinomial logit regression analysis shall be made while taking the classification of travel duration (X1), transport mode (X2), income level (X3), housing type (X4), occupation (X5), gender (X6), job-housing ratio (X7), aggregate job accessibility (X8) and age (X9) as the independent variables, and taking the satisfaction (Y) as the dependent factor. The regression models include:

$$\text{Logit}\left(P(Y_i)/P(Y_j)\right) = C + A_1X_1 + A_2X_2 + A_3X_3 + A_4X_4 + A_5X_5 + A_6X_6 + A_7X_7 + A_8X_8 + A_9X_9$$

Table 3-12 Instructions to Variables

Variable	*Instructions to Variable*	*Unit*
Independent variable: Classification of travel duration (X_1)	travel duration	Scale variable
Independent variable: Transport mode (X_2)	Walk taken as 1, passenger car taken as 2, subway transit taken as 3, bus taken as 4, bicycle taken as 5	Categorical variable
Independent variable: Level of income (X_3)	Low income taken as 1, medium level taken as 2, high level taken as 3	Ordinal variable
Independent variable: Type of housing (X_4)	Private housing taken as 1, leased housing taken as 2	Categorical variable
Independent variable: Occupation(X_5)	employee of enterprises and companies taken as 1, employee of commercial and service industry taken as 2, employee of public institutions taken as 3, community worker taken as 4, self-employed taken as 5.	Categorical variable
Independent variable: Gender(X_6)	Male taken as 1, female taken as 2	Categorical variable
Independent variable: Job-housing space		
job-housing ratio (X_7)	Number of jobs in sub-district / number of permanent resident population (data from the traffic survey in 2015)	Scale variable
Independent variable: Aggregate job accessibility (X_8)	The job accessibility of sub-district where people work	Scale variable
Independent variable: Age (X_9)	20-29 years old taken as 2, 30-39 years old taken as 3, 40-49 years old taken as 4, 50-59 years old taken as 5, 60-69 years old taken as 6, 7-79 years old taken as 7	Ordinal variable
Dependent variable:		
Satisfaction (Y)	Questionnaire: 5 indicating highest degree, ……, 1 indicating lowest degree	Ordinal variable

By multiple comparative tests, the method of adding variables gradually is used to make the logit regression analysis; however, the factors affecting the satisfaction are not just such social factors such as personal attributes and traffic characteristics; the perception at the deeper level of the gap with the reality, and the personality difference in the satisfaction are the most important causes. Therefore, the maximum value of the coefficient R^2 determined by the regression result is 0.513, which is not a high value in generally, and the model is not so highly capable to explain the dependent variables. Moreover, the sample size of people who evaluate the job satisfaction level as 2 and 1 is very small which has no statistical significance. Therefore, we only made the regression analysis on the samples with value of 3, 4, and 5. The specific results of model 1 are shown as follows:

Job satisfaction[a]		B	Exp(B)		B	Exp(B)
4.0	Intercept	-.455		5.0	-30.487	
	Travel duration	-.004*	.996		.018	1.018
	Aggregate job accessibility	.324	1.383		-13.350	1.593E-6
	Job-housing ratio	.372*	1.451		-.013*	.987
	Longest tolerant travel duration	-.027***	.973		-.138***	.871
	[age=2.00]	.280	1.323		-17.128	3.641E-8
	[age=3.00]	1.447	4.251		.983	2.672
	[age=4.00]	1.826	6.208		1.798	6.038
	[age=5.00]	1.679	5.359		.401	1.493
	[age=6.00]	1.802	6.060		.357	1.430
	[age=7.00]	0b	.		0b	.
	[transport mode=walk]	.254	1.289		-.021	.979
	[transport mode=passenger car]	.444	1.558		.766	2.151
	[transport mode=subway/commuting train]	1.135*	3.112		1.153	3.168
	[transport mode=bus]	1.322**	3.752		.660	1.935
	[transport	0b	.		0b	.

	mode=bicycle]					
	[income level=low level]	-1.233**	.291		-1.300	.273
	[income level=medium level]	-.792*	.453		-.079	.924
	[income level=high level]	0b	.		0b	.
	[housing type=private housing]	.058	1.060		-.367	.692
	[housing type=leased housing]	0b	.		0b	.
	[gender=male]	-.657**	.518		-1.009*	.365
	[gender=female]	0b	.		0b	.
	[occupation=employee of enterprises and companies]	.377	1.457		-1.162	.313
	[occupation=employee of commercial and service industry]	-.435	.647		-1.029	.357
	[occupation= employee of public institutions]	.742*	2.100		.306	1.357
	[occupation=community worker]	1.328*	3.775		-17.410	2.749E-8
	[occupation=self-employed]	0b	.		0b	.

After deleting statistically insignificant variables, we made the regression analysis again. The maximum value of is 0.483 which is significant。The specific results of model 2 are shown as follows:

Job satisfactiona		B	Exp(B)		B	Exp(B)
4	Intercept	3.538***		5	6.407***	
	Job-housing ration	.389*	1.476		-.0.17*	1.017
	Longest tolerant travel duration	-.029***	.972		-.134***	.874
	[income level=low level]	-1.232**	.292		-1.559*	.210
	[income level=medium level]	-.823*	.439		-.330	.719

	[income level=high level]	0b	.		0b	.
	[gender=male]	-.673**	.510		-.838*	.433
	[gender=female]	0b	.		0b	.
	[occupation=employee of enterprises and companies]	.230	1.259		-1.147*	.318
	[occupation=employee of commercial and service industry]	-.525	.591		-1.199	.301
	[occupation= employee of public institutions]	.620*	1.860		.130	1.139
	[occupation=community worker]	1.259*	3.522		-20.069	1.924E-9
	[occupation=self-employed]	0b	.		0b	.
	[transport mode=walk]	.243	1.275		-.261	.771
	[transport mode=passenger car]	.415	1.514		1.383*	3.985
	[transport mode=subway/commuting train]	1.051*	2.860		1.730*	5.643
	[transport mode=bus]	1.149**	3.154		1.415*	4.116
	[transport mode=bicycle]	0b	.		0b	.

Based on the regression results of model 1 and model 2, the following explanation and interpretation are made:

(1) Personal attributes

1) Gender

With regard to the regression results, the gender is significantly related to the work satisfaction, which remains robust performance in different models.

a. Group with satisfied/average level: the probability of male with satisfied level is 0.51 times of that of female. In other words, the probability of female satisfied with their current job is higher than that of male by 49%.

b. Group with very satisfied/average level: the probability of male with very satisfied level is 0.43 times of that of female. In other words, the probability of female very satisfied with their current job is higher than that of male by 57%.

The above results indicated that in the case of other variables under control, taking the female as the reference group, the average satisfaction of the male is lower than that of the female.

2) Occupation

As seen from the regression results, there is the significant relationship between the occupation and the work satisfaction, which remains robust performance in different models.

a. Group with satisfied/average level: the probability of employees of public institutions with satisfied level is 1.86 times of that of the self-employed. In other words, the probability of employees of public institutions satisfied with their current job is higher than that of the self-employed by 86%.

The probability of community worker with satisfied level is 3.52 times of that of the self-employed. In other words, the probability of community worker satisfied with their current job is higher than that of the self-employed by 252%.

b. Group with very satisfied/average level: The probability of employees of enterprises and companies with very satisfied level is 0.31 times of that of the self-employed. In other words, the probability of employees of enterprises and companies satisfied with their current job is lower than that of the self-employed by 69%.

3) Age

As seen from the model regression results, there is no significant linear relationship between the age and the satisfaction, indicating that the age has no impact on the satisfaction basically.

(2) Economic factors

1) Annual household income

As seen from the regression results, the level of income has the significant linear relationship with the work satisfaction, which remains the robust performance in different models.

a. Group with satisfied/average level: The probability of low income households with satisfied level is 0.29 times of that of high income households. In other words, the probability of high income households satisfied with their current job is higher than that of low income households by 71%.

The probability of medium income households with satisfied level is 0.43 times of that of high income households. In other words, the probability of high income households satisfied with their current job is higher than that of medium income households by 57%.

b. Group with very satisfied/average level: The probability of low income households with satisfied level is 0.21 times of that of high income households. In other words, the probability of high income households satisfied with their current job is higher than that of medium income households by 79%.

2) Type of housing

As seen from the regression results, the housing has the insignificant linear relationship with the residents' work satisfaction, which remains the robust performance in different models, indicating that the type of housing has no effect on the job satisfaction

(3) Commuting characteristics

1) Travel modes

As seen from the regression results, the transport modes have significant relationship with the satisfaction, which remains the robust performance in different models.

a. Group with satisfied/average level: The probability of people taking subway with satisfied level is 2.86 times of that of people taking bicycle. In other words, the probability of people taking subway satisfied with their current job is higher than that of people taking bicycle by 186%.

The probability of people taking bus with satisfied level is 3.15 times of that of people taking bicycle. In other words, the probability of people taking bus satisfied with their current job is higher than that of people taking bicycle by 215%.

b. Group with very satisfied/average level: The probability of people taking passenger car with very satisfied level is 3.98 times of that of people taking bicycle. In other words, the probability of people taking passenger car very satisfied with their current job is higher than that of people taking bicycle by 298%.

The probability of people taking subway with very satisfied level is 5.64 times of that of people taking bicycle. In other words, the probability of people taking subway very satisfied with their current job is higher than that of people taking bicycle by 464%.

The probability of people taking bus with very satisfied level is 4.11 times of that of people taking bicycle. In other words, the probability of people taking bus very satisfied with their current job is higher than that of people taking bicycle by 311%.

2) Classification of travel duration

As seen from the regression results, the travel duration has insignificant correlation with the work satisfaction, which remains the robust performance in different models indicating that the travel duration has no effect on the job satisfaction.

3）The longest tolerant travel duration

As seen from the regression results, the longest tolerant travel duration has a significant correlation with the work satisfaction, which remains the robust performance in different models.

a. Group with satisfied/average level: With the increase of 1 minute of the longest tolerant travel duration, the probability of people with average level moving to satisfied level will decrease by 3%.

b. Group with very satisfied/average level: With the increase of 1 minute of the longest tolerant travel duration, the probability of people with average level moving to very satisfied level will decrease by 13%.

The above results indicate that in the case of other variables under control, the satisfaction will decrease gradually with the tolerant duration increasing.

(4) Spatial factor

1）Job-housing ratio:

As seen from the regression results, the job-housing ratio has a significant correlation with the work satisfaction, which remains the robust performance in different models.

a. Group with satisfied/average level: With the increase of 0.1 of the job-housing ratio, the probability of people with average level moving to satisfied level will increase by 4.7%.

b. Group with very satisfied/average level: With the increase of 0.1 of the job-housing ratio, the probability of people with average level moving to very satisfied level will increase by 0.17%.

2）Transport accessibility:

As seen from the regression results, the transport accessbility has an insignificant correlation with the work satisfaction, which remains the robust performance in different models, indicating that the transport accessibility has no effect on the job satisfaction.

(5) Main conclusions

In order to study the impact of traffic infrastructure improvement on residents' job satisfaction, a small sample survey of residents' households was used in the study to raise questions about residents' job satisfaction. In terms of the salience of satisfaction, several factors, such as income level, gender, maximum commuting time that can be endured and job-housing ratio, significantly affect job satisfaction; job and traffic modes partially affect job satisfaction; others including housing type, age, traffic accessibility and travel time consumption are not significantly associated with job satisfaction.

Combined with statistical analysis and regression analysis, the following conclusions are obtained:

1) Income level is the most important factor in the evaluation of job satisfaction

Regression analysis shows that income level is a significant factor in the evaluation of job satisfaction. Under the same conditions, the job satisfaction of high-income groups is high, the chance of "more satisfied" is 71% higher than that of low-income families, and the rate of "very satisfied" is 79% higher than that of low-income families.

2) 60 minutes is the commuting time that most people can accept, exceeding this level of

patience will significantly reduce the job satisfaction of residents

In the survey, "commuting time" and "the longest commuting time that can be endured" were asked at the same time. Statistics show that three-quarters of people can tolerate the commuting time within 60 minutes; most people are relatively satisfied with the current work status. Although the "commuting time" factor has no significant effect on job satisfaction in regression analysis, the degree of job satisfaction will be significantly reduced if the maximum endurance time limit is exceeded.

3) In areas where there is a high degree of job-residence mix, people’s job satisfaction is high

The regression results showed that the job-housing ratio of the interviewed population was positively correlated with job satisfaction, and job satisfaction increased when the mix of job and residence increased. The odds of shifting from "normal" to "more satisfied" increase by 4.7% for each 0.1 increase in job-housing ratio.

4) Improving the service level of rail transit and ground transportation will improve residents' job satisfaction

Statistics of survey data show that people with different incomes have no obvious tendency in choosing different modes of transportation. Regression data show that subway and bus commuter traffic has the most significant impact on job satisfaction. Therefore, improving urban public transport construction and service levels can significantly improve residents' job satisfaction.

5) Gender differences have an impact on the evaluation of job satisfaction

Under the same conditions, women's job satisfaction is higher than that of men. Women are 49% more likely to be relatively satisfied than men and 57% more likely to be much satisfied than men.

4 Main Conclusions and Suggestions

4.1 Main Conclusions of the Subject

This study is carried out in order to identify the characteristic line of the urban development in Beijing in the recent years, analyze the matching and evolution trend of the urban job-housing space; investigate the impact of the traffic investment and public transport construction on the employment market in the recent years, and provide the reference and supporting for the policy guidance by the government. The main conclusions as well as the measures and suggestion include:

(1) The population in Beijing presents a trend of suburbanization, and the employment presents a characteristic of dual-directional driving with agglomeration and enhancement of career center and diffusion to urban periphery.

The suburbanization trend in the urban space development in Beijing emerged in 1980s. Along with the increase in the urban population, more and more residents become desirable to live in the peripheral area of the city. Compared to 2005, the proportion of the population living within the Second Ring Road decreases from 12% to 9% in 2014. The proportion of the permanent resident population living between the Fourth Ring Road and the Sixth Ring Road increases continuously; the area between the Fifth Ring Road and the Sixth Ring Road suffers from the highest population increment, and the number of the permanent resident population in such area increases by 2.27 million persons. The main growth region covers the area of North Fifth Ring Road, the area outside South Fourth Ring Road, and outside the East Fifth Ring Road.

By the end of 2014, the total number of the jobholders in Beijing reaches 11.567 million persons, increasing by 2.787 million persons compared to that in 2005. 71% of the jobs are concentrated in the downtown. There is no significant change in the pattern that the distribution of the jobs is agglomerated to the center; however, due to the urban industrial adjustment and the rising of the modern service industry in Beijing, the spatial distribution of the jobs presents a number of career centers with the high intensity and density and the distinctive industrial characteristics while the aggregate employment is rising, so as to form the urban spatial layout including one main career center (CBD business district) and many career sub-centers. The career centers, such as Yizhuang Economic Development zone, CBD Business District, Zhongguancun Hi-Tech Park, Financial Street, and Airport Economic Zone (Capital Airport), achieve the fastest increase in the aggregate employment. In conclusion, in addition to the rapid growth, the urban aggregate employment in Beijing presents the dual directional driving characteristics of spatial agglomeration and enhancement of the career center and the diffusion to urban periphery.

(2) Both the urban population and the employment density in Beijing are highly concentrated within the Sixth Ring Road, the spatial agglomeration intensity and growth trend of employment are slightly higher than population density, and urban space presents a "cone" shape.

With the conditions of job-housing space in Beijing, the maximum value of the employment density in the downtown is approximately 150% of the population density; compared to the urban form of the other metropolises in the world in the development phase of employment suburbanization, the job-housing space structure in Beijing as a whole is relatively well-balanced. However, as seen from the interior, the organizations, enterprises and institutions are likely to be concentrated in the Dongcheng District and Xicheng District; furthermore, with the Financial Street and Wangfujing, there are abundant job resources with the job-housing ratio up to 1.0-1.4; most of the urban population and the aggregate employment are concentrated in Chaoyang District, Haidian District, Fengtai District, and Shijingshan District at the periphery of the downtown, amounting to approximately 1/2 of the aggregate in the whole city with the average job-housing ratio ranging from 0.3 to 0.6; in the suburbs of Beijing, the job-housing ratio is generally lower; except for the job-housing ratios of Shunyi District and Daxing District which are slightly higher than 0.4, the job-housing ratios of the other districts are lower than 0.4; in Changping District and Fangshan District, the housing industry has been developing rapidly in recent years, so as to attract a great number of employees in the urban center to purchase housing and reside in such districts, so that the job-housing ratios of such areas are lower than 0.3.

(3) The distribution of commuting OD attracted by the employment center presents the characteristics of imbalance, same direction, and crossing

1) The comparison of the comprehensive transport investigation data in Beijing in 2005, 2010, and 2015 shows that from the viewpoint of the distribution of the jobholders' place of residence, the distribution range of the residence place of the working people attracted by the career centers are expanding gradually, and the ratio of the long-distance travel to the commuting travel is increasing gradually.

2) The impact area of different career centers to the place of residence presents a characteristic of distribution differentiation, which is mainly due to the different scales and industrial characteristics of the career centers and the different social attribute characteristics of the employment population. For example, the residence places of the employees in CBD are almost distributed within the whole Fourth Ring Road, and extending outside the Fifth Ring Road; with regard to Yizhuang Economic Development Zone, the working people are mainly concentrated nearby the East and South Fourth Ring Road.

3) The career center is highly attractive to the residential centers in the same direction, and the difference in the spatial distribution of the residence places of the working people presents a regional characteristic. At a generally lower level of the urban transportation cost, the duration of the commuting becomes the important constraint condition to the residence places of the working people. Therefore, the spatial distribution of the commuting flow from the career center presents a regional characteristic, and the career center is highly attractive to the neighboring communities and the residence groups in the same direction.

4) The investment in and construction of the transport facilities have the impact on the

distribution of the residence places of the people from the career center; in particular, as the large-capacity express passenger transport system, the rail transit is highly attractive to the employment and the selection of the residence place.

（4）Under the impact of the rail transit, both the population and the employment present the trends of suburbanization and centralization; with the construction of the rail network, the employment accessibility presents the obvious trend of progressive decrease from the downtown to the urban periphery, while the opening of the new line will increase the employment accessibility of the area in the same direction to a significant extent.

The construction and operation of the urban rail transit enhances the accessibility to the suburbs; due to the extension of the urban rail transit, both the population and the employment show the trend of suburbanization, and the population density and the employment density in the areas surrounding the rail transit transfer station further increase, showing the trend of concentration; in addition, the extreme imbalance position of the job-housing space (Job-housing ratio) is usually the place suffering from the passenger flow pressure.

Due to the construction of the rail transit network, the employment accessibility presents obvious trend of progressive decrease from the downtown to the urban periphery, while the opening of the new line will increase the employment accessibility of the area in the same direction to a significant extent. By comparison of the employment accessibility under the rail transit network condition in 2010, the accessibility in southeast area within the Sixth Ring Road is improved significantly, which is closely related to the opening of the Line 6# and Line 7# as well as the connection of the Loop Line 10#; the improvement in the southwest area is mainly due to the opening of the Western Section of the Line 14# and the connection between Fangshan Line and Line 9#; the improvement in the west area within the Fifth Ring Road is mainly due to the connection of the Loop Line 10# and the opening of the Line 6#; the improvement of the public transport accessibility in the whole northwest area outside the Fifth Ring Road is mainly due to the development and construction of Shanhou Region in Haidian District in recent years and the layout and arrangement of the well-developed public transit network.

（5）As seen from the impact factors on the commuting duration, occupation, level of income, type of housing, mode of transportation and the transport accessibility of the residence area have the significant impact on the commuting duration, and the age, gender and job-housing ratio have the insignificant impact.

There is the significant difference in the commuting duration between different types of occupation. The company personnel will spend the longest time on commuting, followed by commercial service personnel, public institution personnel, self-employed abd community worker; people in the medium income group have the longest commuting duration, followed by people in the high income group. Since people in the low income group have a higher proportion of renting houses, the commuting duration is therefore short; with regard to the type of housing, due to certain flexibility in the selection of space by the housing leaseholder, the commuting duration for the leased housing is less than that for the privately-owned housing; compared to the commuters by walk, the commuters by public transport, rail transit, passenger car, and bicycle spend more commuting time by 42.2 minutes, 39.7 minutes, 25.2 minutes, and 7.3 minutes respectively. The average commuting duration of the male is more than that of the female by 1.41 minutes. The better the job accessibility of where people live is, the shorter the commuting duration will be, Which means an increase of 0.1 for the job accessibility will lead a reduce of 9.4 minutes for the commuting duration.

（6）As seen from the impact factors on the work satisfaction, gender, occupation, level of income, mode of transport, the tolerant longest travel duration and the job-housing ratio have significant impact on the work satisfaction, and the age, type of housing, and transport accessibility have insignificant impact

The regression results show that The satisfaction degree of male is lower than that of the female. The probability of female with very satisfied response is 57% higher that that of male. In terms of the occupation, the community worker has the highest satisfaction degree and the probability of community worker with satisfied level is 3.52 times of that of the self-employed. The probability of employees of public institutions with satisfied level is 1.86 times of that of the self-employed. Employees of enterprises and companies have a lower satisfaction degree, whose probability of very satisfied level is only 0.31 times of that of the self-employed. The level of income has a positive correlationship with the work satisfaction. The probability of high income households satisfied with their current job is 57% higher than that of medium income households and 71% higher than that of low income households. In terms of the satisfaction degree of different transport modes, the satisfaction degree of people taking subway, bus and cars is 5.6 times, 4.1 times and 3.9 times higher than that of people taking bicycle respectively. Also, the effect of commuting duration on satisfaction degree is not significant. However, the satisfaction degree will decrease sharply when the duration is over the tolerant longest commuting duration.

4.2 Measures and Suggestions of the Subject

（1）Constructa rapid commuter network coordinated with the multi-center employment pattern, in particular, accelerate the construction of rapid commuter passage in employment centers and large residential groups outside the city, and establish a multi-level and differentiated large-capacity rapid system.

（2）Continue to promote the "bus priority" policy to speed up the construction of rail transit and ground transport has a very positive role to improve the overall urban commuting efficiency and enhance residents' job satisfaction.

（3）Continue to promote the TOD land development model, increase the development density of residential buildings around the MTR station, grasp the timing of ongoing urban functions and spatial adjustments, and strive to solve functional disruptions and job-housing balances and optimize the allocation of public service resources.

（4）Build a one-hour fast commuting network in Beijing to enhance the convenience of public transport connections, in particular, speed up the connection of walking, cycling and public transport, and increase the coverage of public transport in large-scale residential areas in employment centers so as to further improve employment accessibility.

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北京城市职住空间与就业可达性研究

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