*Research Paper*

# Urban Regeneration and Sustainable Urban Development from Polycentric Spatial Structure Traffic Performance

## Take Harbin, China as an example

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### Abstract

*Traffic congestion has become the main phenomenon of agglomeration dis-economy in urban. Adjusting spatial structure to improve traffic efficiency and reduce traffic pollution has become an important issue of urban sustainable development. The study adopts the social survey method to test the traffic performance of Harbin polycentric spatial structure. Combine with the co-location hypothesis, the paper analyzes the influencing factors of polycentric commuting distance and commuting time. The results show that the average commuting distance of centers is greater than that in the city, and the proportion of long-distance commuting is higher, but the faster commuting speed in the fringe area subcenters makes average commuting time shorter than that in the city. The importance of commuting costs is insufficient, the employment and residential location resources are extremely unbalanced, and they influence location selection of residence and employment and makes long-distance commuting economically reasonable. The fundamental ways to improve the traffic performance of polycentric spatial structure are to face up to the rationality of long-distance commuting and traffic demand,  in urban renewal, adjusting commuting cost and the  spatial layout of residential and employment resources, improving the balance between occupation and housing, promoting sustainable urban development.*

### Keywords

*Urban Regeneration, Sustainable Development, Polycentricity, Traffic performance, Location re-selection, Harbin*

## 1. Introduction

The increase of commuting cost and air pollution caused by urban traffic congestion have become the main manifestation of agglomeration diseconomy. Improving the efficiency of urban transportation has become an important issue for sustainable urban development.  In many countries and regions, single-center cities are often accompanied by agglomeration dis-economy such as land and labor competition, traffic congestion, and environmental pollution, polycentricity is considered to be an effective way to solve the above problems(Fujita et al. 1997), and become a key tool for environmental sustainability(Commission of the European Communities 2014). However, the research conclusions of traffic performance of polycentric spatial structure are not uniform. In terms of the impact on

transportation modes, most studies believe that compared with single-center cities, the travel modes of polycentric cities tend to be decentralized, relying more on private cars, and the proportion of public transportation and non-motorized travel modes decreases accordingly. In Oslo, Hanssen(1995) showed that car use rose from 25 percent to 41 percent and public transport use fell from 61 percent to 46 percent under the impact of job fragmentation. Cervero and Wu(1998) analyzed the influence of decentralization on travel modes in the San Francisco bay area, and found that the proportion of commuting by car alone increased, the proportion of driving in partnership decreased from 17.3% to 13.8%, the proportion of public transportation decreased from 19.3% to 15.4%, and the travel mode shifted from public transportation to private transportation. On the contrary, decentralization does not necessarily reduce public transportation. From 1971 to 1989, the motorization of transportation in Paris increased significantly, but the market share of public transportation remained at around 31%. The continued high investment of the Paris government in public transportation infrastructure played an important role(Bolotte 1991). Compared with the single-center structure, the divergence in whether the polycentric structure can shorten commuting distance and time is more obvious. Respondents in the San Francisco bay area were divided into two categories based on whether or not they moved following a job. Residents who continue to live in the city become commuters, and their commuting distance has increased significantly. Residents who move to the suburbs are in better condition, but their commuting distance is longer than before the decentralization of employment centers(Cervero and Landis 1992). Since then, a survey of 22 job centers in the San Francisco metropolitan area showed that a 12% increase in the average one-way commute distance and a 5% increase in the average one-way commute time, with job decentralization increasing both the distance and time of the commute(Cervero and Wu 1998). The positive view is that polycentric spatial structures have the potential to reduce commuting times(Giuliano and Small 1993). The transformation from a single-center city to a polycentric city produces subcenters. Employees who previously lived outside the city and worked in the central area can move to a nearby subcenter to reduce the commuting distance and time(Aguilera and Mignot 2004). Gordon and Wong(1985) compared the growth scale of cities in the northeastern and western United States with the average commute distance, they found that the average commuting distance in the northeastern cities increased with the growth of the size of cities, while the growth of the size of western cities did not cause the increase of travel distance, which was caused by the polycentric development of western cities. Gordon et al.(1991) used the co-location hypothesis to explain the mechanism of polycentric structure to shorten commuting distance, they argue that households and businesses periodically adjust their spatial location to achieve resident-employment balance, reduce traffic volume, average commuting distance and time. The core of residential and corporate location selection is the trade-off between benefits and costs. Polycentric structure is not a necessary and sufficient condition for shortening commuting distance and time, only a polycentric structure with a balanced employment and residence has the potential to save commuting time and distance(Sun and Pan 2008). In view of this, two purposes of the research work arose. Firstly, test the traffic performance of the polycentric space structure in Harbin. Secondly, this paper analyzes the benefit-cost balance in the employment and residential location selection of Harbin residents, reveals the factors influencing the traffic performance of polycentric spatial structure, and provides development basis for urban Regeneration.

## 2. Materials and Methods

### 2.1. Study City and Data

Harbin is a central city in northeast China. The urban master plan of Harbin(2011) considers polycentricity as a spatial structure development policy, the spatial structure is undergoing a polycentric transformation to deal with the agglomeration diseconomy that urbanization may bring. Polycentric spatial structure traffic performance needs to be tested, the main urban area of Harbin is taken as the research area, covering 571 communities in 7 districts(Figure 1). The research data include the employment data of 2008 and 2013 Harbin economic census, land use data of built-up areas and urban community zoning data in 2013, the above data comes from the official agencies such as the Statistics Bureau, Planning

Bureau and Civil Affairs Bureau of Harbin. Through social investigation, the author obtained the information of working place and living place, commuting mode and time, subjective feeling of commuting, factors influencing the choice of employment and living place.
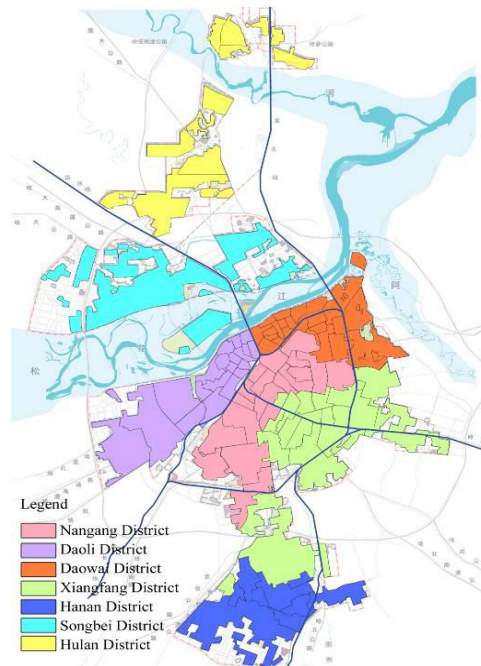


**Figure 1. Districts zoning of Harbin built-up area. Source: painted by the author.**

## 2.2. Research Methods

### 2.2.1. Urban center identification method

The centers are identified by fracture point zoning method and dual employment density standards method. Firstly, the fracture point zoning method divides the low-density fringe area and high-density core area. Drawing the trend chart of the distance from the district to the highest point of urban employment density and the district's employment density, the vertical axis represents the district's employment density after standardization, the abscissa represents the shortest road distance from the districts to the highest density point of employment, the fracture point refers to the point where the change trend of employment density and distance drops abruptly, and the density remain stable after the mutation. The districts before the fracture point is high-density core area, and these after the fracture point is low-density fringe area. Secondly, developing candidate community density standards, According to McMillen and Smith (2003), a subcenter is defined as an area with significantly higher employment densities than surrounding areas. Greene (1980) argues that a subcenter can be defined when the employment density is twice that of the surrounding area. Giuliano and Small (1991) identify subcenter as a set of contiguous tracts that each have at least 10 employees per acre and together have at least 10,000 employees. The community density standards of the two density area are three times of the average employment density of each. Thirdly, determine the centers range, the communities that meet density criteria determine the basic range of center, combining with the actual situation in the city center，when the adjacent community outside the basic range has a close functional relationship with the centers, the  density of adjacent community is two times higher than the average density, and not less than 60% of the adjacent community density in centers, and the community can be included in the center. Finally, the city centers are determined, if the employment scale of the centers exceed 40,000.

### 2.2.2. Measurement of Traffic Performance

An active polycentric space structure should have three aspects of traffic performance. First, shortening the commuting distance, reducing excessive commuting, traffic congestion, the ratio of the average commuting distance between centers and the city should less than 1. Second, shortening the commute time and reducing the time cost, the ratio of the average commuting time between centers and the city should less than 1. Third, changing urban traffic structure, increasing the proportion of green travel.

### 2.2.3. Survey Procedures

The survey takes employees in urban centers as the objects of investigation. The survey process and methods are as follows(Figure 2). First, designing the survey framework and formulating the questionnaire questions. Second, talking with interviewees and experts to simplify and adjust the contents of the questionnaire, and improving the construct validity and face validity. Third, pre-survey, analyzing the construct validity, revising the questionnaire, grouping the respondents according to the information of the pre-survey, and calculate the proportion of each group to determine the sample size. The construct validity was calculated by formula 1.
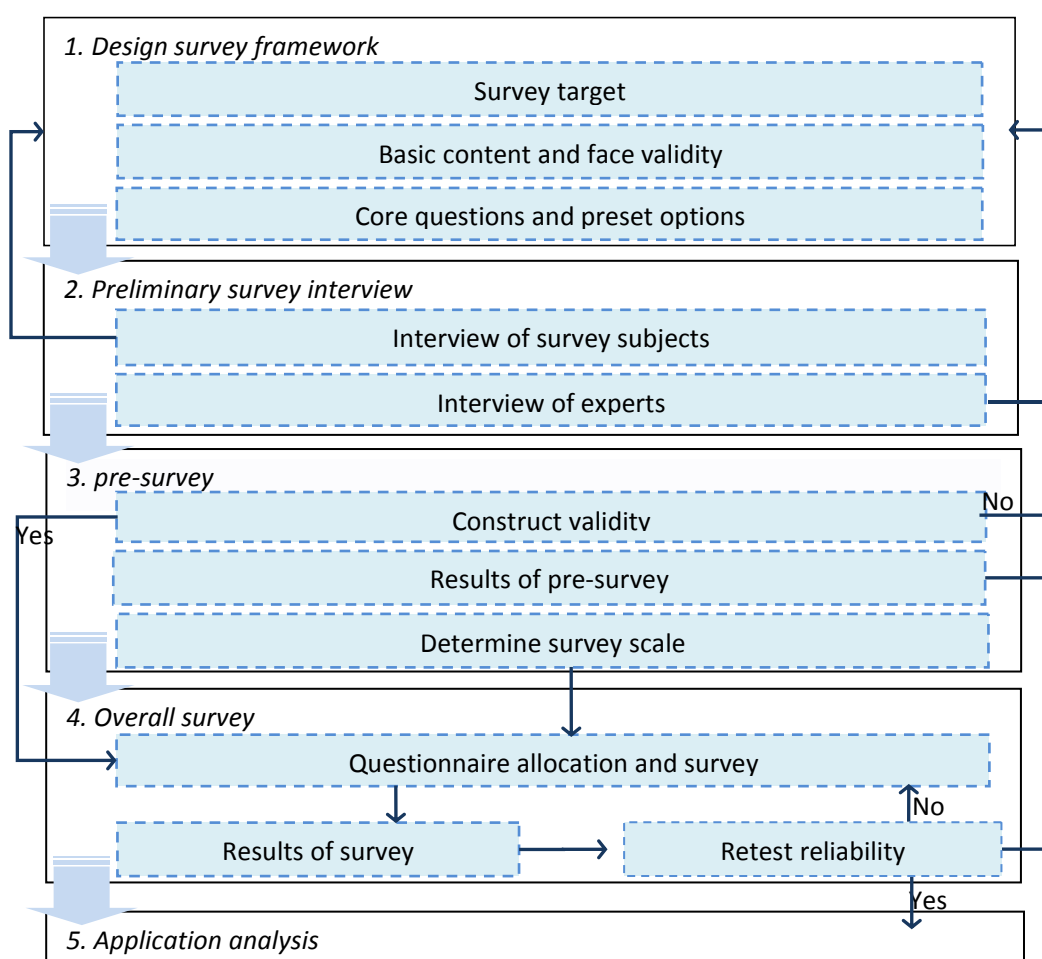


**Figure 2. Social survey process. Source: painted by the author.**

$$KMO = (\sum\sum r_{ij}^2)/(\sum\sum r_{ij}^2 + \sum\sum a_{ij}^2) \qquad (1)$$

The $r_{ij}$ means correlation coefficient; $a_{ij}$ means partial correlation coefficient. KMO value is best when it is around 0.9 and acceptable when it is above 0.7. The variance contribution rate of 6 factors is ≥35%, and the construct validity meets the requirements(Meng 2010). The KMO test result of the preliminary survey is 0.74, and the variance contribution rate of the first 6 factors is 42.32%, the construct validity of the questionnaire meets the requirements. The sample size is determined by formula 2, the n means sample size; t means probability degree; p means proportion of a particular category of respondents; Δ means

allowable error of sampling. Take confidence level is 0.95, corresponding to the probability of t = 1.96, take Δ=0.02, sampling permissible error within 2%. Enter the proportion of respondents into the formula (Table 1). The 25-40 age groups require the largest sample size.

$$n = \frac{t^2 p(1-p)}{\Delta^2}$$  (2)

**Table 1. The proportion of different age groups in the preliminary survey**

| Group | Pre-survey proportion | Group characteristics | Sample size |
|-------|----------------------|----------------------|-------------|
| 18-25 | 15.17% | Unstable job, no house, single, willing to buy a house. | 1224 |
| 25-40 | 39.28% | Married, stable income, home ownership, children need compulsory education, high rate of private car ownership. | 2305 |
| 40-50 | 29.30% | Higher income, greater affluence, stronger willingness to improve living conditions. | 2017 |
| 50-60 | 16.25% | Work stable, with certain family wealth, the demand for comfort of living environment increases. | 1307 |

Fourth, based on the employment scale of the center, the questionnaire was distributed and investigated. Retest reliability was calculated by formula 3, the *x* means first measurement of score; $\bar{x}$ means average of the first measurement score; *y* means second measurement score; $\bar{y}$ means average of the second measurement score. The retest reliability was calculated by pre-survey and comprehensive survey, and the reliability value was 0.812, the survey data had consistency and stability.

$$r = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2 \times \sum(y - \bar{y})^2}}$$  (3)

### 2.2.4. Commuter Distance Acquisition

Through questionnaire to obtain center practitioners working and living location, according to the respondents commuting mode, using the urban traffic navigation map to obtain path between job and living, for car travelling, the commuting distance is the vehicle mileage with shortest travel time, for bus travelling, the commuting distance is the bus route distance that takes the shortest time.

## 3 .Results

### 3.1. Identification of Polycentric Space Structure

The relationship between distance and employment density of districts shows that (Figure 3), the employment density decrease rapidly between Xiangfang and Songbei District, and the employment
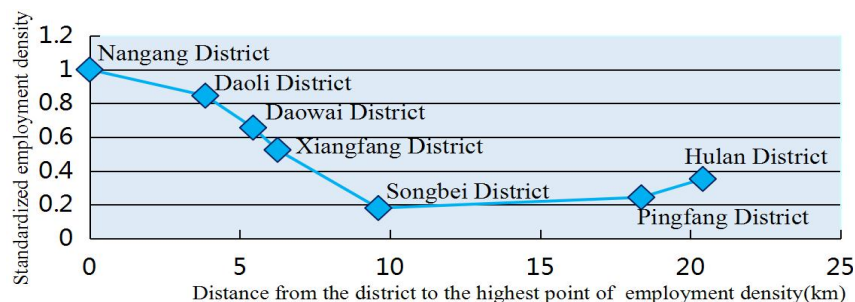


**Figure 3. Relationship between distance and employment density. Source: painted by the author.**

density of Songbei, Pingfang and Hulan District are stable at the same level, there is a fracture point between Xiangfang District and Songbei District, therefore, Songbei, Pingfang and Hulan District are low-density fringe area, and the others are high-density core area. Screening communities and identifying candidate centers, mapping the distribution of community employment density (Figure 4),  Museum center, Central Avenue center and Development Zone center in high-density core area, and Hanan and Hulan center in low-density fringe area, were identified(Table 2). The size of  Songbei and Limin employment are more than 40,000, but the employment density is slightly lower than the standard. As they are the main functional areas of Harbin new area, and the employment growth is fast, they will soon reach the standard (Figure 5), so they are incorporated into the polycentric system as quasi-centers (Table 3).

**Table 2. Identification standard of urban center**

| Density in high-density areas (10,000 people / km$^2$) | Density in low-density areas (10,000 people / km$^2$) | Community standard in high-density areas (10,000 people / km$^2$) | Community standard in low-density areas (10,000 people / km$^2$) | Total employment (10,000) |
|---|---|---|---|---|
| 0.62 | 0.20 | 1.86 | 0.60 | 4 |

**Table 3. Urban centers list (2013)**

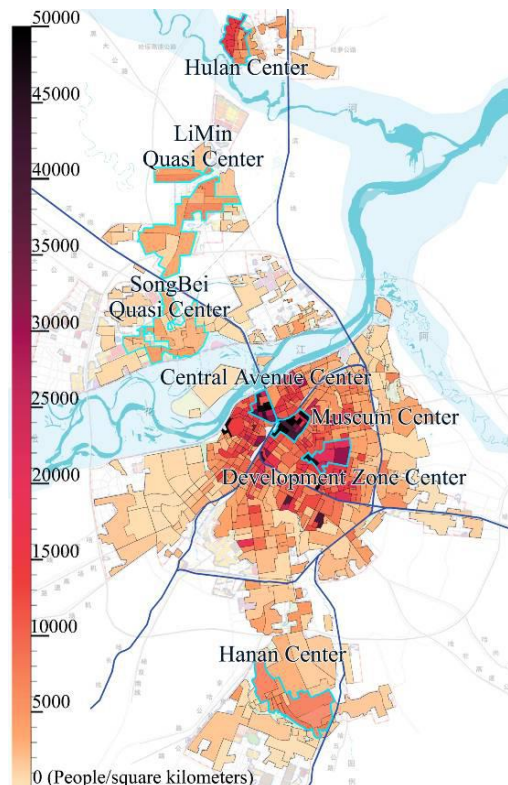| Location | Name | Communities | Area (km$^2$) | Employment (people) |
|---|---|---|---|---|
| High density areas | Museum center | 12 | 2.63 | 135578 |
| | Central Avenue center | 13 | 2.19 | 78257 |
| | Development Zone center | 5 | 3.60 | 93772 |
| Low density areas | Hanan center | 14 | 9.08 | 58747 |
| | Hulan center | 20 | 4.04 | 46425 |
| | Songbei quasi center | 19 | 9.29 | 50310 |
| | Limin quasi center | 9 | 10.13 | 48619 |



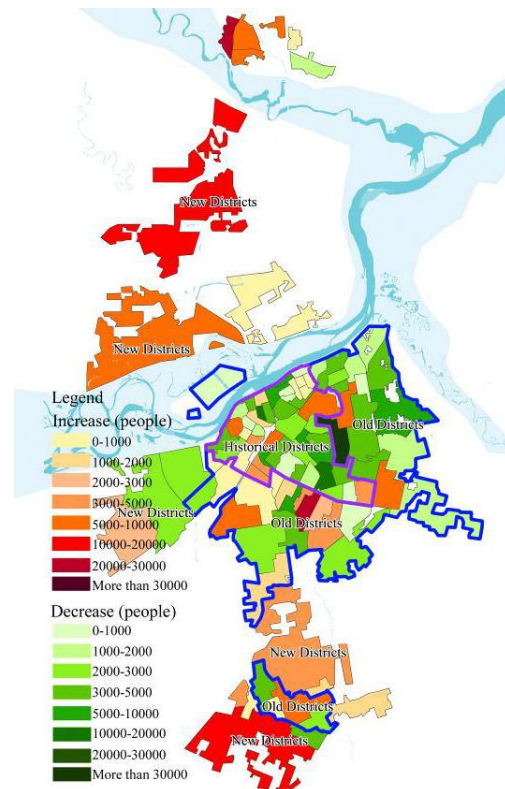**Figure 4. Community employment density (2013)**     **Figure 5. Changes in employment (2008-2013)**

## 3.2. Traffic Performance of Polycentric Spatial Structure

The average one-way commuting distance of the centers is 8.51km, which is larger than 7.46km of the city(Baidu maps 2017), the ratio is 1.141, and the polycentric space structure extends the commuting distance of the city. The relation between commuting distance of centers and distance of the main center and subcenters is inverted U curve, with the distance from the main center; the commuting distance of subcenters keep increasing, at the Songbei quasi center, the commuting distance reaches the highest 14km, Later, as the distance between the main center and subcenters increases, the commuting distance of subcenters decreases continuously. 2km is the main distance to walk, beyond which the intention to walk is greatly reduced(Chen et al. 2006), in core area, the proportion of commuting within 2km of centers remains between 10-15%, in marginal area, with the increase of the distance between the main center and subcenters, the proportion of commuting within 2km of the center increases with a linear trend(Figure 6). The relationship between the average center commute distance, the commute proportion within 2km, and the main center and subcenters distance can be explained as, the increased distance between the main center and subcenters reduces the accessibility of the center in fringe areas, living locally or commuting long distance become the only two options, under the restriction of transportation cost, living nearby has economic rationality, so the proportion of living within 2km increases and commuting distance decreases.
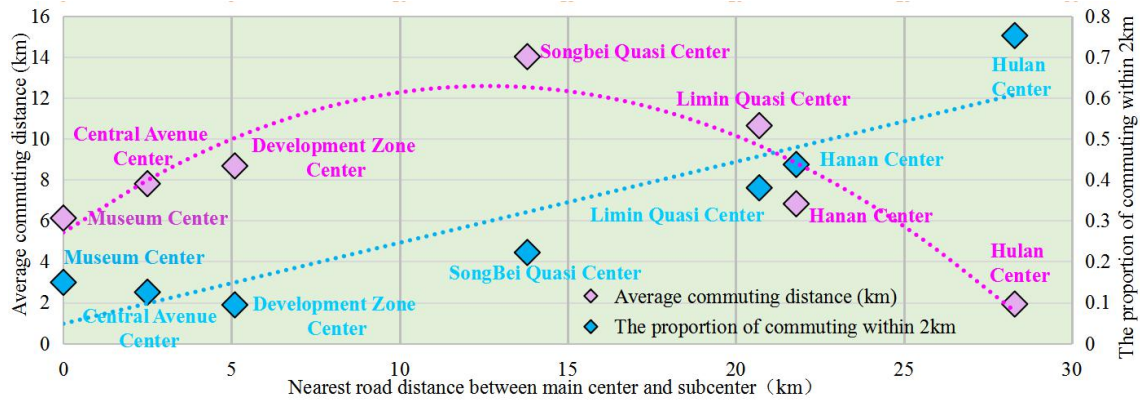


**Figure 6. Commuting distance and proportion of commuting within 2km. Source: painted by the author.**

The average one-way commuting time of centers is 31.2min, which is smaller than 33.3min of the city(Baidu maps 2017), the ratio is 0.937, the polycentric space structure shortens the urban commuting time. The commuting time of subcenters decreased significantly with the increase of distance between the main center and subcenters, the commuting time of centers and quasi-centers in fringe area is significantly better than that of centers in core area(Figure 7). The average commuting speed of vehicles in centers is 23.51km/h, higher than 21.39km/h of urban in rush hour(Amap 2017), the ratio is 1.099, the polycentric space structure increases the speed of motor vehicle commuting slightly, the commuting speed of centers and quasi-centers in fringe areas are significantly better than that of centers in core
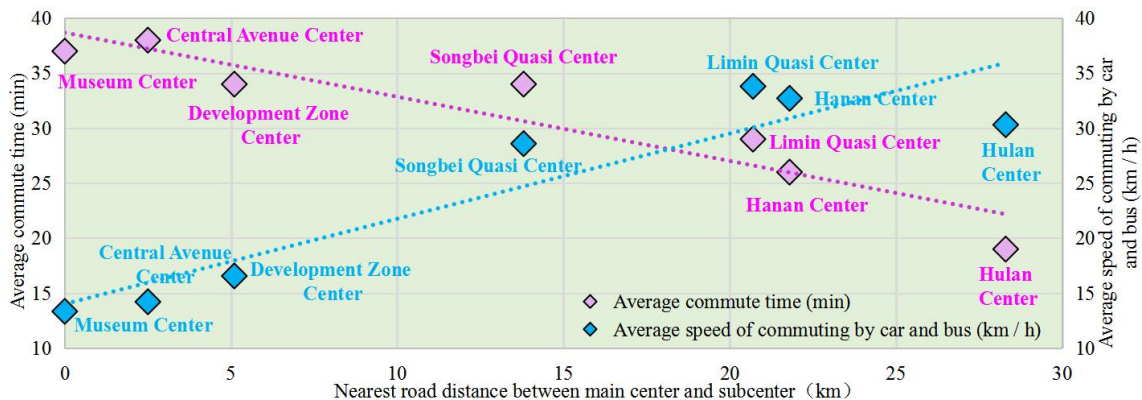


**Figure 7. Average commute time and speed of motor vehicle commute.  Source: painted by the author.**

areas (Figure 7), this is the reason Songbei and Limin quasi-center have long commute distance but short commute time.

In terms of commuting modes, the proportion of buses decreases gradually with the distance from the main center, then drops again after increase in Hanan center. The proportion of buses in the core area is much higher than that in fringe region centers and quasi-centers. As the distance between main center and subcenters increases, the proportion of cars and commuter buses increases, while after Limin quasi-center, the proportion of cars and commuter buses decrease with the increase of distance, the proportion of bicycle and moped rises slowly(Figure 8). On the whole, the proportion of non-motor vehicle commute is lower, but in Hanan and Hulan centers, more environmentally friendly modes of transportation, such as walking, bicycles and buses, dominate, which is related to the higher ratio of living nearby and the shorter commuting distance.
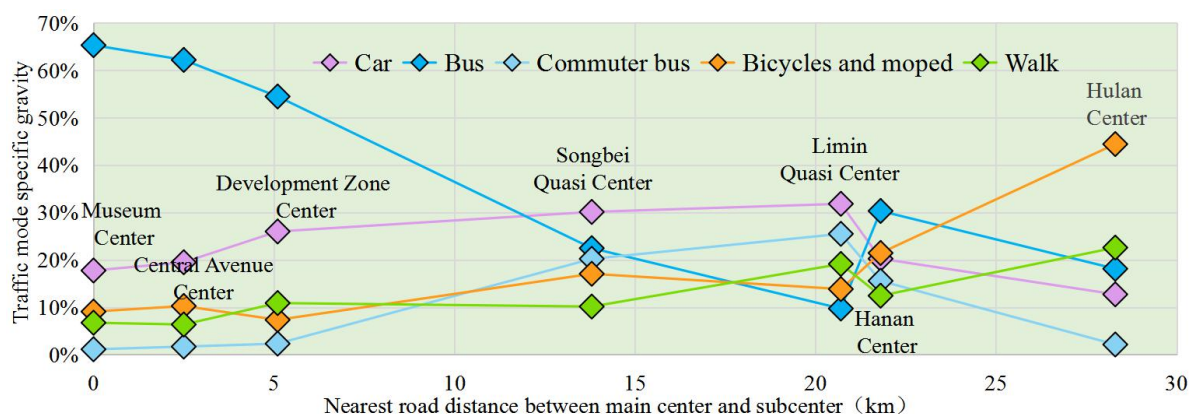


**Figure 8. Traffic mode specific gravity of centers.  Source: painted by the author.**

## 4. Discussion

### 4.1. Factors Affecting Commuting Distance

The co-location hypothesis holds that households and enterprises adjust their positions periodically to achieve the residence-employment balance and shorten the commuting distance(Gordon and Richardson 1997). The paper analyzes the reasons why workers who are not satisfied with their commute do not change their jobs and residential areas. There are commonalities and differences in the reasons why practitioners who are not satisfied with the commuting distance do not change their address. The reasons such as high housing price, commuting of family members, tolerable degree of commuting, and shuttle bus have a wide influence on the change to jobs. High housing prices in urban centers have restricted residents from moving in, especially for young people. For a family with multiple employees, the commuting distance of family members must be considered in a balanced way, It is difficult to consider the personal commuting distance. In addition, long commutes are tolerable despite people's dissatisfaction with the distance to work. Free shuttle buses also make long commutes more acceptable. Unstable work hinders the relocation of 18 to 25 year-old to the vicinity of the workplace, it's an arbitrary decision to rent or buy a house around an unstable workplace, and it's wiser to wait or ignore the commute and focus on other living factors. The demand for children's education affects the relocation of 26 to 40 year-old to the vicinity of workplace(Figure 9). Analysis why people who are not satisfied with the commuting distance do not change jobs. Welfare, salary, job attribute and employment field are the common factors to prevent job changing of the four groups. High wages and benefits offset the cost of long commutes. Jobs in administrative agencies, public institutions and state-owned enterprises are stable and have high welfare benefits, they are good jobs worthy of a lifetime. At the same time, professional job skills lead to a narrow range of employment, making it difficult to reduce commuting distance by changing jobs. In addition, the difficulty of re-employment, job development prospects and other factors also prevent job changes(Figure 10).
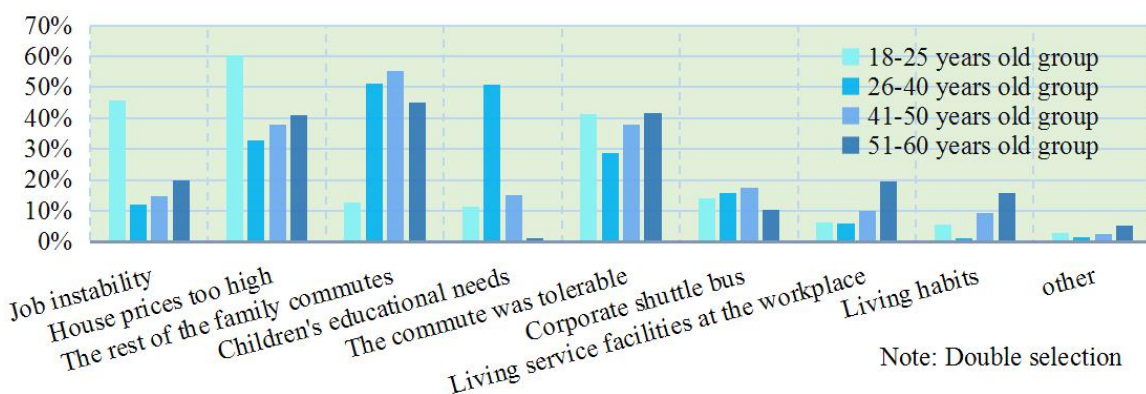
**Figure 9. Reasons for not changing address who are not satisfied with commute. Source: painted by the author.**
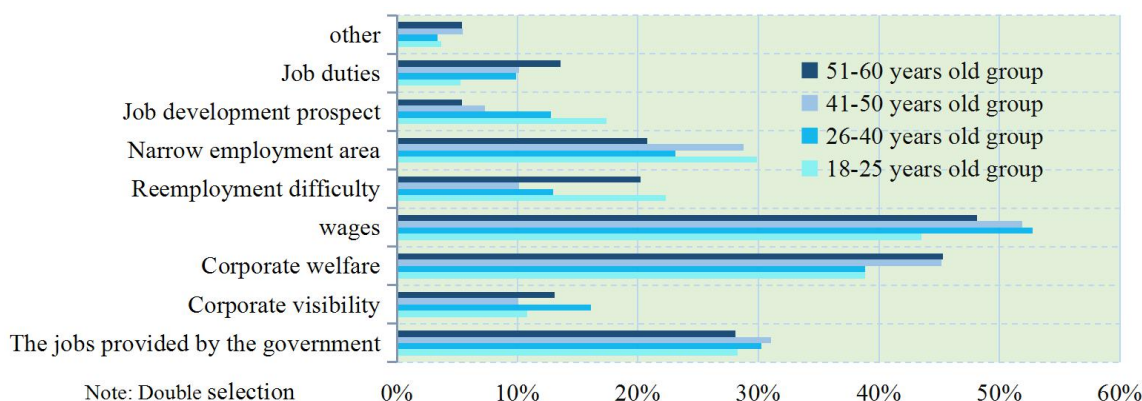


**Figure 10. Reasons for not changing job who are not satisfied with commute. Source: painted by the author.**

The core of the Co-location hypothesis is the re-balancing of the commuting cost with the location benefits of employment and residence. When the cost of commuting is greater than the benefit of the current employment and residential location, location re-selection occurs. Residents can reduce the commuting distance and time by changing their work and residence. There are two important prerequisites for the above process. First, commuting cost is important enough and has enough weight in location selection to compete with location benefits of residence and employment. Secondly, the dynamic balance between residence and employment in European and American cities is often realized under the condition that employment and living space resources are relatively fair. When employment and housing resources are extremely unbalanced, such as unbalanced education quality and employment benefits, the loss of benefits from changes in employment and residential location may far outweigh the reduced cost of commuting, with long-distance commuting becoming the most lucrative option. On the one hand, compared with the specific location benefits of work and residence, the importance of commuting cost is insufficient.

● The weights of residential location selection factors for different groups were assigned by AHP. The weights of commuting distance of the four groups were between 0.1 and 0.25, far lower than the decisive position of housing price and school quality, and similar to the other factors(Figure 11).

● The cost of long-distance commuting is far lower than the employment benefits such as salary and welfare, which are the main reasons to prevent those who are not satisfied with the commuting distance from changing jobs.

● Commuter buses transform personal commuting costs into enterprise costs benefits. For individuals, the importance of commuting costs is reduced, while commuter bus is often the standard configuration of large enterprises in outer suburbs.
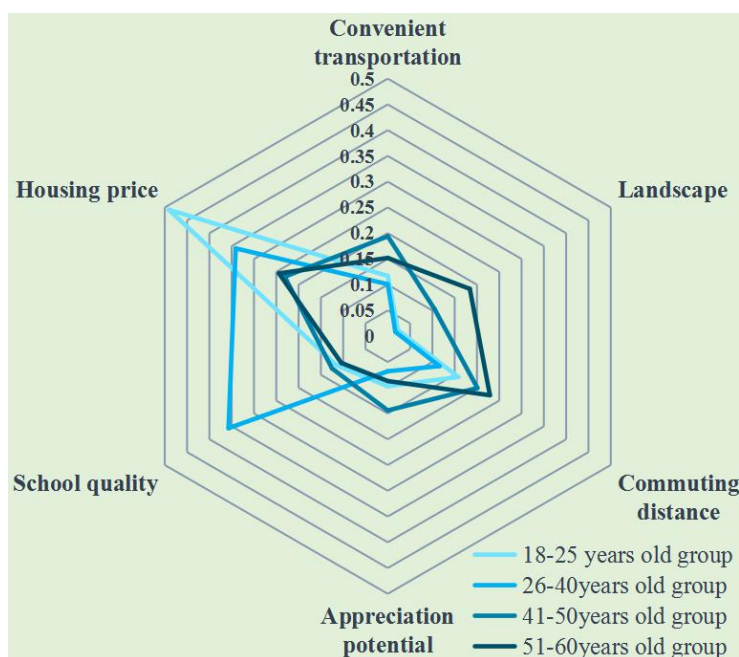
**Figure 11. Weight of Housing Choice.  Source: painted by the author.**

In the cost-benefit trade-off, commuting cost plays a secondary role, which makes the location selection aiming at shortening the commuting distance lack of development motivation. On the other hand, the location benefits of employment and residence are extremely uneven, which hinders the balanced process of location re-selection.

● Education and other residential resources are unevenly distributed(Figure 12). Chinese families attach great importance to children's education, while the school district system of basic education resources closely combines residential location with school quality, thus narrowing the range of choices for families with heavy educational weight in residential location selection.
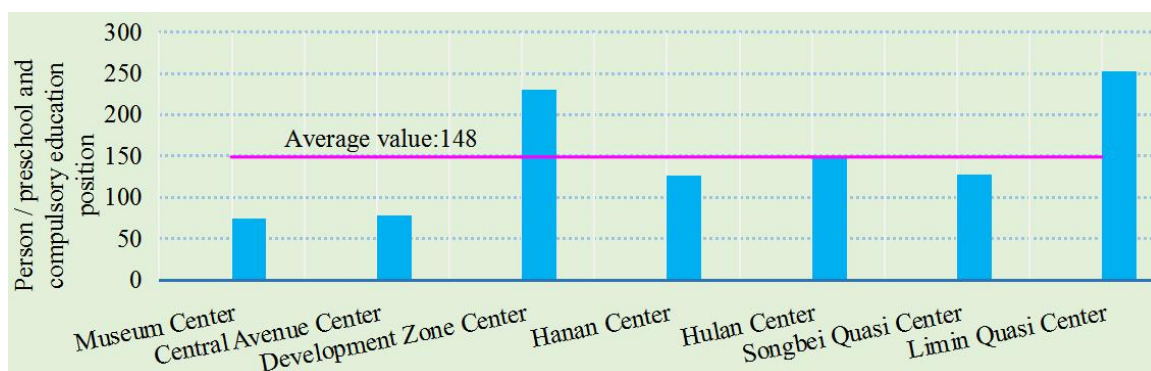


**Figure 12. Analysis on the intensity of basic education service.  Source: painted by the author.**

● Unbalanced work welfare, high welfare level of state organs, public institutions and state-owned enterprises, scarcity of jobs, "lifetime" work reduces the mobility and selectivity of employment. These units often act as catalysts for the growth of new areas, be relocated to urban fringe areas by policy, such as the city government.

● The spatial distribution of various enterprises is uneven, such as university towns. The more professional the working skills of practitioners are, the smaller range of employment options will be, and the lower the feasibility of changing jobs to adjust the commuting distance will be.

● Housing prices vary widely. House prices and rents have become important factors restricting location choices.

The above situations are not isolated, and they are likely to occur at the same time. In combination with the common dual-career families in China, it is difficult to reduce the commuting distance by re-choosing the location of employment and residence. Long-distance commuting has economic rationality and may become the rational choice with the largest comprehensive benefit.

## 4.2. Factors Affecting Commute Time

Commuting time is affected by the distance and speed of the journey, while the speed of the journey is mainly affected by the mode of travel and road accessibility. Road accessibility refers to the method of calculating accessibility by chance accumulation(Black and Conroy 1977), the ratio of the isochronous area in commuting flat hump period to that in commuting peak period is the commuting congestion index. If the value is close to 1, the accessibility of the center in different periods is similar, and there is no commuting congestion in the city center. The commuting congestion index of centers was measured with 20 minutes, and the isochronous area of the commuting peak period in centers of the core area shrank significantly. The impact of commuting peak on the speed of vehicles in centers of fringe region is relatively weak (Table 4).

**Table 4. Traffic congestion index of the centers**

| 20 min（km$^2$） | Museum center | Central Avenue center | Development Zone center | Hanan center | Hulan center | Songbei quasi center | Limin quasi center |
|---|---|---|---|---|---|---|---|
| Isochronous area in commuting peak period | 85.22 | 50.79 | 89.99 | 77.43 | 29.09 | 85.44 | 67.73 |
| Isochronous area in commuting flat hump period | 42.08 | 37.68 | 69.78 | 74.72 | 27.97 | 75.57 | 64.84 |
| Commuting congestion index | 2.03 | 1.35 | 1.29 | 1.04 | 1.04 | 1.13 | 1.05 |

## 4.3. Urban Regeneration based on traffic performance

In recent years, with the development of urbanization, Harbin land scale will continue to increase in the future(Guo and Huang 2016), the suburbanization of employment is significant(Figure 5), and the growth potential of the number and employment scale of fringe area centers is huge, urban Regeneration based on traffic performance of Polycentric spatial structure has the following focus.

● Facing up to the economic rationality of long-distance commuting, as the rate of car ownership rises, the commuting speed advantage of centers and quasi-centers in fringe areas will decline, and the commute time will increase rapidly, rapid public transportation such as subway and light rail can be used to respond to the demand of long-distance commuting and squeeze the space of car commuting.

● when residential sub-urbanization fails to keep pace with the rate of employment sub-urbanization, it will inevitably aggravate the separation of employment and residence in the fringe, and the commuting distance of the fringe center and the quasi-center will continue to increase. adjusting the balance of residential and employment location resources, and improving the relationship between work and housing, it is the fundamental way to improve the traffic performance of polycentric space structure.

● In fringe center and the quasi-center, developing life service functions and improving the quality of educational, medical and life service facilities, it should on the same level as the main urban area.

● Housing supply is diversified, and housing products with different characteristics are provided for different groups of people to meet the rigid demand and improvement demand of housing.

# 5. Conclusions

Harbin polycentric spatial structure increases the city commuting distance, but with the increase of the main center and subcenters distance, in fringe area center, proportion of commuter within 2km rise and driving speed is higher, they result in shorter commute time. Overall, the polycentric spatial structure improves the urban traffic efficiency, to be exact, it is the peripheral centers and the quasi-centers that improve the traffic performance of Harbin polycentric spatial structure. Analysis of long-distance commutes suggests that, the traffic performance of polycentric spatial structure is not a simple problem of space or land planning, but a complex social problem. The commuting cost corresponding to the traffic performance is only one of the living costs of urban residents. The importance of commuting cost is not enough, and the space resources represented by employment and residential location are not equal, making it difficult to location re-selection based on the cost-benefit trade-off. With the sub-urbanization of jobs, the development of fringe centers and the increase of cars, the commuting speed advantage of fringe centers may be lost, and the traffic performance of polycentric space structure may be reduced. Polycentric spatial structure is only a necessary condition to improve the traffic performance of megacities, the balance between employment and residence, the spatial balance between employment and residence resources is the necessary condition to promote the performance of polycentric transportation, and is also the core goal of continuous resource allocation in urban regeneration.

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