Accessibility of the Urban Poor in Metropolitan Areas: Case Study of Beijing

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Preamble

The project ‘Development scenarios for Wuhan: indicators for urban-rural accessibility’ is funded by The World Bank. The work in this project is carried out by a consortium of Chinese and American partners led by Peking University-Lincoln Institute Center for Urban Development and Land Policy, Peking University in China.

With Beijing as our case study, we use the counting job approach and average commuting time approach to evaluate the job accessibility of people living in affordable housing as urban poor. By creating scenarios, also analyze the accessibility change for affordable housing projects before 2004 and built in year 2005 and 2006; whether the accessibility is improved after the subway and light rail developed in year 2011 and 2020; and whether the accessibility is improved if the job centers relocate to suburban area in 2020. The results of these metrics illustrate that Chinese cities is in contrast with the classical job-housing relation in Western cities. In Beijing, affordable housing residents have low accessibility to major job opportunities which are still concentrated in the city center, while the affordable housing is increasingly located further in suburban area. Ultimately, city planning projects designed using these metrics can help the urban poor in accessing more employment opportunities, basic urban services and amenities, and skill training activities in city centers, by placing an emphasis on a reasonable travel time by public transport, and thus improving their economic prospects.

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1. Introduction

1.1 Project Background
As Chinese cities continue growing and land prices in central urban areas increase, many large-size low-income housing projects and job opportunities are being moved to peripheral urban locations. However, current public transport services concentrate on connections to downtown areas, and public transport service between different peripheral locations is limited. This lack of public transport service impairs the employment prospects of the urban poor who are dependent on transit. Although anecdotal evidence exists that this is true, this project seeks to measure, quantify, map, and develop sharable tools to evaluate this problem.

Through the development of these tools, it will be possible to design and evaluate projects based on the impact they have on providing job accessibility to low income groups (in conjunction with other evaluation metrics).

1.2 Spatial Mismatch
The concept of spatial mismatch is originally from North American cities, describing the imbalance relation between residence and job opportunity. It is an important issue not only because it induces a long distance commute, but implies that there is limited access to job opportunities, urban facilities, and resource. This nexus creates an environment will deprive future growth and development opportunity especially for already disadvantaged groups within the city (Blumenberg and Ong, 1998; Holzer, 1991; Kain, 1992).

In the field of urban economy, there is a long standing debate about the spatial mismatch hypothesis (SMH). In 1968, John Kain first described of firms moving out of the city center to the suburban rings of American cities. However, disadvantaged groups like African-American had restricted mobility due to housing segregation and remained in the city center (Kain, 1968). As a result, African-Americans had limited access to “good” jobs that were relocated outside of the city, depriving them of future development opportunities (Kain, 1992, p.394).

Other scholars, on the other hand, questioned whether space really mattered or not in the realm of economy and society. Their focus was turned toward the role of race, as race was an important factor to residential segregation in American cities (Ellwood 1986; Raphael, 1998). Moreover, while the prevailing theory was limited to unemployment in inner city in the U.S., the amount of empirical researches from these scholars provided a more detailed explanation to the mismatch in the metropolitan context. Other than distance, the accessibility to jobs is weighted according to race, ethnicity, age and even the mastery of the English language (Alramson and Fix 1993; Mattingly 1999; Ley 1983, 95-131).

Meanwhile, the dichotomy between inner city and suburban areas became more complex. Accumulative analyses reveal that not only do inner city or suburbs matter, but deep historical residential patterns also influence accessibility. After World War II, African Americans had limited ability to afford homes and cars in the suburbs of the U.S. (Warner, 1978). However, later on they
were able to afford homes in suburban White communities, but were discriminated against by the local residents (Brooks, 2002). This discrimination toward African American residents made the mismatch more severe in the 1950s to 1960s, but later with the 1968 fair housing legislation, African Americans were allowed the opportunity to move to suburban areas (Boustan and Margo, 2009). As such, the spatial mismatch has turned out to be much more complicated, when the simple division between inner city and suburban area is not enough to depict the whole picture in the metropolitan context (Grengs, 2010).

If the accessibility to jobs is a racial mismatch rather than a spatial mismatch, this will result in a degradation of urban transportation policies advocating social-mixed and gentrification of the inner city. This is because even if these policies have the ability to move African American out of an occupation declining area, it does not work on solving the unemployment problem. Moreover, although the social and racial characters are attached as drivers in the job-housing mismatch issue, we cannot ignore that distance is still one of the key factors in shaping the job-housing pattern. In other words, the over emphasize on societal factors distort the concept of spatial mismatch.

In the ambiguous definition of spatial mismatch, some scholars shift the attention to the transportation variable. They argue that despite the location of housing and jobs, transportation is important because it is the link connecting the two factors together. Distance does matter, but it should be measured and controlled in an urban transportation network context. In the case study on Los Angeles, San Francisco and Boston, Scholars come to similar findings that the geographical distance itself does not bring on a disadvantage but that the choice of transportation has a much larger influence (Shen, 2000; Kawabata, 2003). More important car ownership as it provides the flexibility to access jobs (Taylor and Ong, 1995). Even in the case study of Detroit, which had a long history of public transit investment, people still depended more on travelling by cars especially for who work in the suburban areas (Grengs, 2010). Besides the travel mode, the urban land-use arrangement, zoning code and layout of facilities also relates to the mismatch issues of American cities (Handy and Niemeier, 1997; Hansen, 1959; Wachs and Kumagai, 1973).

In conclusion, the spatial mismatch hypothesis is continuously challenged in the United States. Is the growing distance making African Americans more disadvantaged in accessing job opportunities? Although empirical studies find that social factors do matters, it cannot neglect the role of distance and it is just one other way to define distance depending on road network, travel mode and urban land-use arrangement.

1.3 Spatial Equality
When approaching the spatial match phenomenon, researches have placed more importance on whether distance or other social characters influence job accessibility, while to the importance of spatial equality is neglected. In the perspective of spatial equality, urban services, facilities and amenities should be equally distributed among the residents, especially among the disadvantage groups such as the minority, the poor, and the elderly (Omer, 2006). In other words, social inequality happens when the residents in a particular area have limited access to urban resources such as education, health, recreational, and cultural activities. (Apparicio and Seguin, 2005).
Researchers have long discussed social equality from different perspectives. Scale is very important in the study of social equality as results may differ depending on the level of analysis, be it a study on the region, city or neighborhood. As intensively discussed as a Geography topic, modifiable areal unit problem (MAUP) is one of the key points to judge whether urban resources are equally distributed (Cao and Lam, 1997; Fotheringham and Wong, 1991; Sheppard and McMaster, 2004). Due to data availability, most of the case studies are conducted in a larger scale or zonal data in a certain area (census tract, TAZs or zip code). However, these types of data may be inadequate to analyze social equality for a much localized facility, such as daycare, playground or convenience store (Hewko, Smoyer-Tomic and Hodgson, 2002). Current research focuses more on two scales, regional level and local level (Kuan, 2008). In the regional level research, scholars are more focused on the change of spatial pattern of employment and housing, such as the job sprawl from the central business district (CBD) to suburban area (Handy, 1993). In the local level, with the rising of new urbanism movement, scholars are paying more attention on the relation between the physical environment around neighborhoods and individual travel behavior (Bookout, 1992). For example, the new urbanists advocate mix-used land use and grid road network, and prefer walking distance to major service facilities to reduce the dependence on cars.

Besides scale, some researchers illustrate the difference in social equality and its implications among a board range of urban resources. Many of them consider health to be crucial in urban life especially for the disadvantaged groups, such as the residents’ access to clinics and other health services (Luo and Wang, 2003) like the poor and the elderly’s access to fresh and organic food (Apparicio et al., 2007). Others researchers have talked about the access to neighborhood facilities such as parks, shops, green spaces and education services (Knox, 1987:327-329; Coutts, 2008; Witten et al., 2008). The access to local facilities can be used as a measurement of life quality.

In this sense, spatial inequality can be recognized as the outcome of spatial mismatch, which will deprive future development opportunity for urban residents. Its policy implication lies in that jobs may not only guarantee a good quality of life, but the access to healthy food, educational services, hospitals and other urban resources are also important.

2. Case Study

2.1 Study Area and Background
Beijing is the large, sprawling, northern capital of China. The city’s population has been growing steadily and has reached to over 17 million in 2011 (Beijing Statistical Yearbook 2011). Since the economic reforms of 1979, China has rapidly urbanized changing the urban landscape of cities such as Beijing. Beijing, today, not only needs to expand to accommodate the growing population, but needs to develop a unique urban form to respond to new economic incentives coupled with new administrative policies. The process has brought major changes to the city’s demographics and has implications for urban development patterns that shape people’s lifestyles in the city.

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2.1.1 Urbanization, Migration, Income Inequality, and Access to Services

China’s urban population is expected to grow from 572 million in 2005 to 926 million in 2025 (McKinsey Report, 2007). This rapid expansion is due to China’s rural-urban migration. This is because not only are rural residents attracted to cities due to increased economic opportunities, but government restrictions on internal migration have greatly loosened since the end of the 1970s. Classifying and measuring migrants can be tricky, but Chinese government statistics cite more than 252 million people are living at least semi-permanently outside of their hometown (National Statistics Bureau of China, 2011).

While China has made immense progress bringing down the number of people living in poverty, the last 30 years has also seen a growth in income inequality. Income inequality between regions increased, with a growing proportion of wealth residing in costal, urban areas (Sinclair, Yue et al, 2007). The gap between the rich and the poor is also wider in urban areas than in the countryside (Benjamin et al, 2008).

In Beijing, the income gap has been accompanied by the development of urban poverty (Fang and Zhang, 2002). Despite a long history of government policies favoring urban areas, economic reforms also brought instability to urban life. The promise of permanent employment and universal welfare was sacrificed as state-run enterprises were dismantled, creating new risks for urban residents (Fang and Zhang, 2002). This was exacerbated in the 1990s when the city government redeveloped Beijing’s city center, driving many of the city’s urban poor to affordable housing projects now located at the city’s periphery (Huang, 2005).

The low-income resident can be defined as those whose average family monthly income is lower than 740 Yuan (Beijing Municipal Government, 2011). However, low-income residents are spread all over the city and they are very hard to trace. This can be commonly illustrated by urban migrants without Hukou, or resident permit, who make up a large proportion of the urban poor. It is reported that the number of China’s floating population living in Beijing increased from 170,000 in 1976 to more than 4 million in 2007 (Zhu and Li, 2008). But unlike the city’s permanent residents, urban migrants lack official statistics which state their housing information or living location. Moreover, urban villages where the migrants tend to congregate disappear rapidly making data collecting for this group notoriously difficult.

In order to obtain a reliable data source, this project selects affordable housing residents as the source of where the city’s urban poor are living. This is because to live an affordable housing complex, families undergo strict property investigations,¹ making this route to be, a solid source

¹ According to the qualification of applicant, the annual family income and family total property will be lower than certain standard depends on family size in the study area of Beijing (central six administrative districts). For example, for only one-person family, the annual family income should be lower than 22.7 thousand Yuan and the total property (includes cars and other valuable capital asserts) should be lower than 240 thousand Yuan. For two-person family, annual family income and total property limitation increase to 36.3 thousand and 270 thousand. For three-person family, annual family income and total property limitation increase to 45.3 thousand and 360 thousand. For four-person family, annual family income and
for transparent and accessible data of the urban poor (Ministry of Housing and Urban-Rural Development, 2012).

2.1.2 Land-Use Development Patterns
Beijing has seen major changes in its urban development in the last 30 years, creating the urban landscape that is at the root of the city’s accessibility conditions. Pre-reform Beijing was defined by the development of self-contained work units, or danwei. Each unit included business operations (offices or factories), housing, schools, shops, and recreation for danwei workers. As a result the city’s urban space was divided into mostly autonomous, self-segregated blocks. The redevelopment of these spaces since reform and their opening is a large part of Beijing’s modern landscape. Danwei units became less self-contained as the government closed down state-owned companies and opened housing markets. This led to more diverse communities, but also distanced people from work locations as industries moved out of the city center and homes were no longer tied to jobs (Wang and Song, 2011).

The redevelopment of the danwei system also accompanied major changes in Beijing’s land-use patterns. As the city become more prosperous, commercial activity shifted from industry to services. This meant that big factories gave way to office blocks in the city(Zhou, 2000). In addition, privatization of the housing market in 1994 further broke the link between housing and jobs, and led to the development of large apartment blocks on the city’s borders. Authors such as Huang and Feng, have conducted studies on Beijing’s housing development has led to the city’s urban sprawl and suburbanization.

2.1.3 Transportation Network Development
Transit systems both define and respond to urban growth. Beijing has seen major development in both its road network and public transportation system over the last 30 years. This factor is a fundamental element in the city’s accessibility problems.

Beijing is perhaps most famous for its road network, which now extends out to the sixth ring road. Government investment in infrastructure is reflected in a massive increase in car ownership starting in the 90s. In 2005, of the six central districts, 52.8 % of local residents travel by walk and bike, 29.4% travel by public transit (bus, minibus, subway and taxi), and only 7.1% travel by car (Shen, 2007). However, in 2008 Beijing had increased to 3.25 million registered private cars, and the number is predicted to increase 15% annually (Zhao, 2009). As a measure of the city’s growing dependence on motorized transportation, in the period from 2000-2005, trips by car in Beijing increased twice as fast as trips by public transit, while trips by bicycle shrunk (Zhao, 2009). While the road network has expanded very quickly, and Beijing’s car-centered growth has helped drive sprawl and single-use development, the road network is also highly congested, facing regular traffic jams and slow travel speeds (Wang and Chai, 2008; Cervero, 2009).

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2 It were eight central districts before the administrative adjustment in 2009, including Chongwen and Xuanwu districts which later belong to Dongcheng and Xicheng districts.
Growth in the road system has been paralleled by growth in public transportation. Beijing’s subway system opened in 1969 with two lines, followed by 9 lines before the city’s Olympic events in the summer of 2008. Today the city’s subway system has 14 lines, and a total track distance of 323 km. In addition, there are currently 7 lines under construction, with a plan of phasing in 21 lines over 10 years (Beijing Subway, 2012). Ridership has also been substantial, with 5,100 commuters everyday (Beijing Subway, 2012).

Despite the huge investment in subway expansion, because of its size and sprawl, Beijing also relies on a massive bus network. The bus system includes nearly as many as 678 lines and 174.2 thousand km. The bus system is also inexpensive, costing as little as 0.4 Yuan a trip using the public transit smart card. Beijing has also invested in Rapid Bus Transit, connecting several Northeast suburbs to the city center via a limited access bus lane and 3 BRT lines currently (Beijing Bus, 2012).

2.2 Data Sources

2.2.1 Study Area
Administratively, Beijing encompasses an area far larger than the city’s built-up area and includes several neighboring towns. In an attempt to focus on Beijing as a city, not as an administrative entity and due to the lack of quality data in outlying areas, this study is confined to the six districts which make-up Beijing’s core: Dongcheng, Xicheng, Haidian, Chaoyang, Fengtai and Shijingshan district. This area roughly encompasses the area within the 6th ring road. While this approach has the advantage of excluding residents of outlying towns that are not truly members of Beijing’s conceivable travel-shed, it risks excluding some low-income residents that have been forced to lower rent housing in the extreme urban periphery (Figure 2-2-1).
2.2.2 Population Data
The Chinese government takes population data as part of their regular ten year census, and they take household surveys every 10 years. The population data for this study come from the 2000 household survey, provided by the Population Serve in 2000. They supplied statistics at the level of neighborhood districts, *jiedao*, of which there are 136 in the study area (Figure 2-2-2).
2.2.3 Road Network

The road network used for the study was as it was in 2004 (based on google map in 2004). By 2004, the 5th ring road was completed and the 6th ring road was already under construction (Figure 2-2-3). While data on individual road segment travel speeds are unavailable, this study uses estimates taken from observation at locations throughout the city during peak and non-peak hours. As a result, the study uses an estimate of 25 km/h for peak times, and 40km/h at non-peak times for most locations with adjustments made for areas of high and low congestion (Table 2-2-3).
2.2.4 Economic Data
Economic data for the study comes from Basic Economic Unit Survey in 2001, which reports on businesses registered in Beijing. Business addresses and employment numbers from the survey were used to create the GIS maps of employment for this study.

In addition, further information about employment can be obtained from the Beijing Land-Use Map. By identifying the location of commercial land plot, the data shows the distribution of employment by job type.

2.3 Data Preparation

2.3.1 Identifying Low-Income Residences
This study focuses on accessibility of Beijing’s low-income residents. Because the population survey does not include accurate income data, information on the location of affordable housing is used as a means to identify the housing location of poor Beijing residents. By using a map of 72 government funded affordable housing development before 2004 (Beijing Housing and Construction Bureau, 2012), we are given a picture of the conditions that low-income residents holding a Beijing hukou registration are likely to face. Many migrant workers are ineligible for these apartments due to their lack of a hukou.
2.3.2 Identifying Job Centers

Using employment data from the 2001 Basic Economic Unit Survey, several methods were used to create GIS maps of employment locations in Beijing. As accurate geo-coding data for Beijing addresses is unavailable, this study maps employment data by zip-code. By checking the zip-code of registration address of company and adding up employees of companies under the same zip code, the employment density within each zip-code can be calculated (Fig 2-3-1).

However, zip-code density cannot be directly used as a basic unit for analysis for the following reasons four reasons. First, the registration address is not necessary the actual address of the company’s office. This can neglect the land use characters of the registration address. Second, the zip code zone is too large in Beijing for the data to be used for accessibility analysis since the variation within zip code zone and local factor should be emphasized in the accessibility calculation. Third, due to data limitations, bios will happen when the affordable housing locates near the zip code data boundary and cause under estimated accessibility. Fourth, the labor market in Chinese cities is not as free as US cities. If residents in one AHP (affordable housing project) can reach one major job center with a lot of jobs, it is not necessary to find suitable job there for low-
income people. It will cause over estimation on accessibility without considering access to other job centers.

It is worth to note that the zip code zone boundaries are not exactly consistent with residential district (jiedao) boundaries. Generally speaking, it will be larger than the area of residential district (jiedao). In order to get a smaller unit of location for use in accessibility measurement, zip code zone data is combined with the Beijing land-use map to get employment numbers based on industry sector and reveal major job centers in the city. By overlaying the areas on the land-use map designated as tertiary industry with economic data on the number of jobs, we are able to show the number of jobs in each 1km square area for each land-use area. The result is a map showing the relative important commercial job centers with job densities higher than a certain threshold (Figure 2-3-2). Considering that tertiary industries share in Beijing counts up to overwhelming 65.5% in year 2004 (Beijing Statistical Bureau, 2001), this approach picks up only on commercial job centers rather than industrial job centers.

2.3.3 Mapping the Bus Network
A GIS map of Beijing’s bus system was created from a database of bus stops, available from Beijing Public Transportation website (Beijing Bus, 2012; Fan and Sun, 2011). Starting with only a list of stops and their locations, the stops on each bus line were then combined to form bus routes and finally the bus routes were put together to form a complete network usable for GIS network analysis (Figure 2-3-3). As the assumption of road network speed, this study uses an estimate of 12 km/h for peak hours, and 20km/h at non-peak hours for most locations for urban buses; and
15 km/h for peak hours, and 25 km/h at non-peak hours for suburban buses. We use estimates of 35 km/h in both peak and off-peak hours for the subway and light rail system (Table 2-2-3).
3. Methodology of Measurement

3.1 Measuring Accessibility

Accessibility can be defined as the ability from one place to access urban facilities in another place dependent on factors such as distance and travel cost (Handy and Niemeier 1997). This concept was first brought into the urban planning field in 1959 to measure the potential of interaction (Hansen 1959). In contrast with the initial concept in the transportation field, Hansen emphasizes the relation between accessibility and urban land use pattern. This idea attracted from both scholars and decision makers, and is regarded as an important index to measure the balance between jobs and transportation.

The cumulative opportunity measure is one of basic measures discussed in early literature of this topic (Vickerman, 1974; Wachs and Kumagai, 1973). This method counts the number of potential job opportunities within a pre-determined time or distance.

\[ A_i = \sum_{j=1}^{J} B_j a_j \]

Where

- \( A_i \) Accessibility measured by the potential activity in zone \( j \) to node \( i \);
- \( a_j \) Opportunities in zone \( j \);
- \( B_j \) A binary value, which equals to 1 if zone \( j \) is within the predetermined threshold and 0 if not;

This method is easily applied, whenever nodes and evenly distributed-opportunity data are at hand. However, this method does not account for the attractiveness of each node and the difficulty of reaching them. In this way, much variation is kept out and the results are a little far from reality.

Another traditional measurement to accessibility is the gravity model, which is based on distance decrease rules in geography. It argued that potential gravity among the urban land exists. Driven by this potential gravity, one needs to overcome some friction to gain access from one place to another (Cervero, 1989; Levinson and Kumar, 1995). Then accessibility can be measured by aggregate relation to these places in terms of distance, time, or cost. The weight of each place can be also calculated in this way. The longer distance, more time it takes, or the higher the cost, the lower accessibility there will be. This indicates that people have less opportunity to work in these places (Handy, 1993; Levinson, 1998).

Specifically, the simple expression of gravity model is:

\[ A_i = \sum_j E_j f(C_j) \] (1)

Where:
\( A_i \) is the accessibility score for people living in zone \( i \);

\( E_j \) is the number of employment opportunities in zone \( j \);

\( f(C_{ij}) \) is the impedance function associated with the cost of travel

\( C \) for travel between zone \( i \) and zone \( j \);

For a metropolitan region with \( Z \) zones, \( i,j=1,2,\ldots,N \).

The gravity model successfully explains the job choice among the job centers. However, accessibility in real life highly depends on the operation of the city’s transportation network rather than the spatial distance itself (Handy and Niemeier 1997). Thus, one of the improvements to gravity model is to introduce the real transportation network.

The rules of network analysis partly come from graph theory, focusing on the connectivity among each of the nodes. The simplest network can be depicted as a line between two nodes, \( A \) and \( B \) and they generate two links: \( A - B \) and \( B - A \). If adding more nodes to the network, the links among all the nodes should be calculated base on Law of the Network as

\[
S = N (N - 1)
\]

Where:

\( S \) = network size (number of links)

\( N \) = nodes number

Then, accessibility can be measured with the distance in real road network or bus network. By introducing the network analysis, \( f(C_{ij}) \) in the equation (1) will be improved from considering only geographic distance to real travel distance, time, and/or cost. This research will focus on the time cost between the origins (affordable housing project) to destinations (job centers) based on the bus/road network.

### 3.2 Method Used in This Project

The specific methods used in this research include the following:

**3.2.1 Accumulative approach to accessibility**

Accessibility to job opportunities is measured by the job numbers one can reach from residential location within 30 minutes or 60 minutes, based on affordable housing data, economy data by zip code, and existing transportation network. First, it calculates job density within each zip code zone. Second, it calculates service areas for each of the affordable housing project. Third, it counts how many jobs each of the service areas cover, by adding up the irregular shape of polygons intersected by service area and zip code zones (Figure 3-2-1).
3.2.2 Average commuting time approach to accessibility

This study applies average commuting time along the transportation network as measure of accessibility because travel time has been more and more widely used to analyze individuals’ accessibility to environment since Hagerstrand established the time-geographic framework (Hagerstrand 1970). This framework recognizes that activity participation has both spatial and temporal dimensions (Miller 1999) and from it all space-time (ST) measures are developed. In particular, Mei-Po Kwan’s used network travel time as the relation between two locations when realizing some limits of gravity-type and cumulative-opportunity measures (Kwan 1998). Since the 2000s, with the rapid development of transportation, information, and computational technologies people’s lifestyle has changed as well as tools available for doing this type of analysis. In this way, previous ST measures are further developed by infilling new perspectives and methods. However, travel time is still an important concern (Timmermans, Arentze et al. 2002) as it could be identified in both theoretical study (Kwan and Weber 2003) and empirical ones (Zhao, Lu et al. 2009; Yoon, Deutsch et al. 2010). In addition, given the scant data, using average travel time is more feasible.

Accessibility to commercial jobs is calculated based on data preparation from affordable housing data, land use data, and economic data. First, the origins for low-income people residential location can be identified as the seventy-three government-funded affordable housing development before 2004. Second, the destinations can be identified as job centers using both land use data and zip code economic data (Figure 3-2-2). Third, it makes the assumption that the commuter should travel according to bus network or road network. Then by network analysis in GIS, the OD matrix from all the affordable housing projects to job centers can be created. Based on the OD matrix, it measures the accessibility value by the average commuting time from each affordable housing project to all the potential job centers.
4. Accessibility analysis

4.1 Count Job Opportunity Approach

4.1.1 Accessibility Value by Counting Jobs within Service Area

The first approach of counting data method is widely used in measuring accessibility. In this approach, it generates service areas based on each affordable housing project and the surrounding bus or road network as the starting point. Then it sums up all the job numbers according to the broken down area and job density within zip code zones where each service area covers. The value of accessibility will be measured according to the number of jobs reachable within a certain time.

Here it supposes that a 30 minutes trip to work contains three parts, assuming that the walking speed is 5 km/h and the bus speed is 20 km/h (off-peak hour speed for bus (Figure 4-1-1). First, walk from home to the nearest bus stop from A to B, taking 5 minutes. Second, take on a bus travel from B to C, taking 20 minutes. Third, get off bus and walk to office, taking another 5 minutes. The total commuting time is to add three parts together, which is 5+20+5=30 minutes.
So under this assumption, the accessible area within 30 minutes by bus only covers a service area that can be reached by bus within 20 minutes.

Similarly, it supposes that a 60 minutes typical trip to work contains one more part, which is the 5 minutes transferring and waiting time (Figure 4-1-2). It assumes that the walking speed is 5 km/h and the bus speed is 20 km/h (off-peak hour speed for bus as above. The total commuting time is to add four parts together, which is 5+45+5+5=60 minutes. So under this assumption, the accessible area within 60 minutes by bus only covers a service area that can be reached by bus within 45 minutes.

Take one of the affordable housing projects, Chaoyangxincheng, as example to get accessibility value from the surrounding service area (Figure 4-1-3). When travelling by bus, the affordable housing resident can reach an area of 82.54 km² within 30 minutes (as the red boundary shows in Figure 4-1-3, left). It covers 23 zip code zones, regardless of whether the resident crosses the whole zone or just a small part of it. Then, it breaks down the service area into many small and irregular shaped polygons according to the zip code boundaries cutting (as the highlight part color pink in Figure 4-1-3, right). When we multiply the area with the job density in each of the small polygon, the job number the resident can reach within each polygon will be obtained. By summing
up all the reachable jobs of these small polygons, we will get the total reachable jobs within the
service area (as the color pink area shows in Figure 4-1-3, right).

Figure 4-1-3 Accessibility Value from the Service Area Surrounding Chaoyangxincheng

4.1.2 Accessibility Value by Public Transit
Using the counting job method above, we can repeat the process to calculate all the job numbers
of all the affordable housing project’s service areas. Through this counting job method approach,
the accessibility value will be measured by the job numbers reachable within a certain period of
time. In this part of analysis, we assume that transit time is 30 minutes and 60 minutes.

In order to approximate reality, we will use two speed scenarios: peak hour and off-peak hour.
Travelling by bus, we approximate the speed to be 12 km/h in peak hours and 20 km/h in off-peak
hours for city bus, while the speed 15 km/h in peak hours and 25 km/h in off-peak hours for
suburban bus (with the bus number starts with number ‘9’).

In the 30 minutes scenario by bus, the average size of service areas of the affordable housing
projects are 33.2 km² in peak hours, and 73.3 km² in off-peak hours. When overlapping the
service areas with the zip code boundaries, the accessibility value by counting job method will be
obtained. Generally speaking, it shows that with the increase in distance to the city center, the job
number accessible in both peak and off-peak hour within 30 minutes will decrease (Figure 4-1-4).
The accessible job number in off-peak hour (green line) can more than double of that in peak hour
(red line).

Besides the distance to the city center, it also shows that the local public transit still plays an
important role in accessible job numbers. For example, Baihuanjiayuan which is located outside
the east 3rd ring is not actually far from city center. However, residents from this housing project
can only reach about half of the total job numbers of similar-distanced affordable housing in both
peak and off-peak hours. It might be because only few bus lines pass by this affordable housing
project, while other housing projects have direct lines of transportation to job centers. In this
analysis, it is worth to note that affordable housing projects far on the urban fringe, will usually
have service areas that cover some vacant areas with no data outside of the zip code zones. In this way, the accessibility value will only sum up the jobs inside the zip code zones.

Figure 4-1-4 Job Numbers Accessible by Bus within 30 Minutes during Peak and Off-Peak Hour

Comparing the layout of accessible job number between peak and off-peak hours within 30 minutes by public transit, our study finds that four revealing results. First, there is not much difference between peak and off-peak hours of the accessible job number level, revealing a consistent pattern for public transit users. Second, affordable housing projects located in the southwest and south have the best accessibility, partly because they are mostly within the fourth ring road and near the job reach zones. Third, affordable housing projects located in the east, west, and northeast have a middle level of accessibility, which might be because they are mostly laid along the fifth ring road where the public transit density is not as high. Fourth, affordable housing projects located in the north have the worst accessibility, especially for the cases of Tiantongyuan and Huilongguan (Figure 4-1-5).
In the 60 minutes scenario by bus, the average size of service areas of affordable housing projects are 277.38km² in peak hours, and 572.69km² in off-peak hours. This is much larger than the service area size for a 30 minute transit time. Using the same method outlined above, accessible job numbers for each affordable housing project can be obtained. Generally speaking, the 60 minute transit time also shows a lower job number with the increase of distance to the city center in both peak and off-peak hour (Figure 4-1-6). For some affordable housing projects, especially those located with 10 km from the city center, accessible job numbers is vastly different from peak and off peak hour. For affordable housing projects located even further from the city center, accessible job numbers between peak and off-peak hour is not large, probably because both the peak and off-peak hour service areas cover large areas outside of the zip code zone which can not be calculated.

Similarly, it shows the importance of the local public transit system despite the importance of distance. Like the case mentioned above, Baihuanjiayuan, which is pretty closed to the 3rd ring, has become an accessible job valley when compared with other affordable housing projects that are located equal distance to the city center as seen in the 30 minutes analysis. However, it is worth nothing that the gap in accessible job numbers between peak and off-peak hour is big for some affordable housing such as Junanjiayuan, Kaiyangxiaqu, Wangjingxincheng and Heqingyuan. For these cases, it might be because they are located near exits of high ways or Beijing’s ring roads where traffic jams are more common during peak hour, reducing accessible job numbers. This reveals an inconsistent rank of accessible job numbers during peak and off peak hours for longer commutes like the 60 minutes transit time.
Figure 4-1-6 Job Numbers Accessible by Bus within 60 Minutes during Peak and Off-Peak Hour

Comparing the layout of accessible job numbers between peak and off-peak hours within 60 minutes by public transit, we find three revealing factors. First, the difference between peak and off-peak hours pattern is more obvious than the 30 minutes scenario. Second, in the 60 minutes scenario during peak hours, the accessibility level is clearly divided between the north part and the south part of city. The affordable housing projects located to the south of Changan Street have good accessibility value, while those located to the north have a relatively lower accessibility value. Third, in the 60 minutes scenario during off peak hours, distance to the city center matters much more. Affordable housing projects which are located within or along the third ring road usually have better accessibility. Generally speaking, the accessibility between peak and off peak hour makes a bigger difference in the 60 minutes scenario, probably because commuters spend more time on road during the whole trip (Figure 4-1-7).
4.1.3 Accessibility Value by Car

In this section, this study also utilizes peak hour and off-peak hour scenarios. Travelling by car, we approximate that the speed is 25km/h in peak hours and 40 km/h in off-peak hours (as shows in table 2-2-3 above).

In the 30 minutes scenario by car, the average size of service areas of the affordable housing projects extend about five times larger than travelling by bus, are 156.16 km² in peak hours, and 368.0 km² in off-peak hours. Using the same method as the previous section, accessibility value will be calculated by counting job numbers within each intersection of zip code boundaries and service areas. Our study shows that compared with travelling by bus, accessible job numbers decreases slowly with the increase of distance to the city center in both peak and off-peak hour (Figure 4-1-8). Similar to the bus mode, the job numbers in off-peak hour (green line) can be more than double of that in peak hour (red line) for most of the affordable housing projects.

In the car scenario, our study reveals that the local road network environment matters more than the distance to city center in affecting the accessible job numbers, which is similar to the bus mode where local public transit is more important. This might be because car drivers can easily access larger areas with certain time limits. For example, Junanjiayuan is located much nearer to the city center than Fengyihuayuan, but the complex’s accessibility is actually worse in both peak and off-peak hour. This might because Fengyihuayuan is located nearer to the fourth ring road, which has better connections to the highway. Similarly, it also worth to note that some of affordable housing projects have rather low level of accessibility if they are located near the city’s boundary, for service areas for these affordable housing projects will cover some vacant data area (Figure 4-1-8).
Comparing the layout of accessible job numbers between peak and off-peak hours within 30 minutes by car (Figure 4-1-9), we find four interesting facets. First, generally speaking, travelling during off-peak hours has better accessibility than peak hours. Second, in peak hours, the accessibility level clearly varies according to the location of affordable housing. Specifically, affordable housing projects located along the third ring has the best level of accessibility, while those located outside of the fifth ring road has the worst level of accessibility. Third, in off-peak hours, most of the affordable housing projects have rather good accessibility, except those located far on the urban periphery in the north (Tiantongyuan and Huilongguan), east (projects in Tongzhou Districts) and southwest (Projects in Fangshan District). This study reveals that if it were not for traffic jams during peak hour, residents travelling by car usually have good accessibility level, which shows the advantage of the type of travelling. Fourth, the extreme cases which have the worst accessibility level by car, such us Tiantongyuan and Huilongguan, usually are also the same cases that have the worst accessibility level by bus. This illustrates that accessibility of extremely disadvantaged affordable housing projects can not be improved by changing the mode of transportation. As such, these areas are problematic as they may not be far from the public transit lines, but they are still far from the nearest stop; or they may be close to the highway, but are located near any entrances or exits.
In the 60 minutes scenario by car, the average size of service area of affordable housing projects are even larger, 547.0 km² in peak hours and 1019.8 km² in off-peak hours respectively. By utilizing a similar approach above, this study shows that the accessibility value decreases more slowly than the 30 minutes transit time scenario (Figure 4-1-10). This reveals the advantage of travelling by car other than bus. To some degree, this could mean that a disadvantage in a far location could be offset by changing the transportation mode from bus to car. At the same time, the gap inaccessible job number between peak hour and off-peak hour becomes larger. For most of the cases, the job numbers in off-peak hour (green line) can triple of that in peak hour (red line).
When comparing the amount of accessible jobs between peak and off-peak hours within 60 minutes by car (Figure 4-1-11), our study finds three important facts. First, in contrast with the 30 min scenario by car, the accessibility level does not change much between peak hour than off-peak hours. Second, in peak hours, affordable housing projects located in the north, east and west between the third and fifth ring road have better accessibility level than whose locate in the south, which is contrary to travelling by bus. This is especially the case for the Wangjing area in the northeast, and for areas located along Chang’an Street in both the east and the west. This result tells a different story than travelling by bus. While the accessibility is better for south part of the city for bus taker, it is better for drivers driving to the northern parts of the city. Third, in off-peak hours, there is a similar gap of accessibility between the south and north part of the city, where car drivers in the north seems to have better accessibility levels. It is also worth to note that extreme cases which have the lowest level of accessibility is almost consistent to the 30 minutes scenario by car.

![Figure 4-1-11 Accessible Job Numbers by Car for Affordable Housing in Peak (left) and Off-peak (right) Hours within 60 Minutes](image)

**4.2 Average Commuting Time Approach**

The second approach measures accessibility of jobs by the average commuting time. In this approach, we create a matrix of commuting time (by bus or car) from each of the affordable housing project to each of the job centers by point-to-point network analysis in GIS. Then our study calculates the average commuting time from one particular affordable housing project to all of the available job centers as the accessibility value. Because the unit of measure is in minutes, it is an easier and more direct way for people to understand.

Similarly to the first approach, we divide the traveling mode into two separate parts – by bus and by car. For a bus trip, we approximate that the whole trip contains four parts (Figure 4-2-1). We
approximate that it will take five minutes from home (point A) to the nearest bus stop (Point B), and it will take another five minutes from the bus stop (point C) to work place takes (point D). We also estimate that it will take another five minutes to wait and transfer between the bus stops getting on (point B) and taking off (point C). Finally, the total commuting time is the time cost on the bus network plus the three waiting times at five minutes each, which equal to an additional 15 minutes to each commute.

Similarly, we also estimate that a car trip will comprise of time spent on road and another 5 minutes to find parking (from point B to point C) (Figure 4-2-2). As such, the total commuting time is the time on road network plus five minutes for parking.

To best approximate reality, we will use the travel speed assumption Table 2-2-3 above. For the bus network, we assume that the speed for buses numbered from 1 to 899 is 12 km/h in peak hour and 20 km/h in off-peak hour, while the the speed for suburban bus numbered from 901 to 998 is 15 km/h in peak hour and 25km/h in off-peak hour. For the road network, it assumes that the speed for car is 25 km/h in peak hour and 40 km/h in off-peak hour (Table 4-2-1).

<table>
<thead>
<tr>
<th>Travel Mode</th>
<th>Peak Hour</th>
<th>Off-peak Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus</td>
<td>12 km/h</td>
<td>20 km/h</td>
</tr>
<tr>
<td>Suburban Bus</td>
<td>15 km/h</td>
<td>25 km/h</td>
</tr>
<tr>
<td>--------------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Car</td>
<td>25 km/h</td>
<td>40 km/h</td>
</tr>
</tbody>
</table>

4.2.1 Accessibility by Public Transit

In the scenario of travelling by public transit to tertiary industry jobs, we measure the accessibility by taking the average commuting time from a particular affordable housing project to all the job centers. Specifically in the network analysis in GIS, we have already identified 73 affordable housing projects which were built before 2004. These housing projects are defined as the origin. We have also identified 418 commercial job centers as destinations. By network calculation, an OD Matrix will be created revealing the commute time between each origin and destination. In this way, the average commuting time will represent the accessibility score for each affordable housing project.

According to the calculation, the accessibility score to tertiary industry jobs centers is 80.8 minutes on average in peak hours and 63.8 minutes on average in off peak hours, with a high level of variation among the 73 projects. For example, the project with the best accessibility is Lechengjiaoyuan in Xuanwu District, with an average commute time to tertiary industry job centers of 54.8 minutes in peak hour and 41.2 minutes in off-peak hour. On the other end of the spectrum, there are several projects with very poor job accessibility, such as Songyuan Xiaoqu and Ningxinyuan in Changping Districts with average commute times of 127.1 minutes in peak hour and 104.8 minutes in off-peak hour.

In the figure below, the points with a red hue illustrate good accessibility scores of affordable housing projects, with darker colors reflecting bad accessibility (Figure 4-2-3). In the same map, the blue points represent job locations based on land use and employment data, and the colored dots from green (better accessibility) to red (worse accessibility) represents affordable housing projects. This analysis reveals a job-housing pattern among low-income residents by bus. While most of tertiary industry job opportunities still remain in the city center, affordable housing is built mainly in suburban areas outside of the Fourth Ring Road. And because low-income residents rely heavily on public transit many affordable housing projects have low levels of accessibility. In addition, the least accessible affordable housing projects are those farthest away from the city center, with the worst connections to the bus network. When compared with the counting job approach above, this approach shows a similar accessibility pattern. This is because residents living in the north need more time than those living in the west and the east to reach job locations. This, to some extent, could indicate a relatively insufficient or inefficient provision of public transportation in Beijing’s northern suburbs.
Actually, the average commuting time is slightly different according to on peak, off peak speed mode (Figure 4-2-4). Upon further exploration, our study reveals that the average commute in peak and off peak hour increases more steadily with the increase of distance to the city center (Figure 4-2-4) when compared to the job counting approach. Our analysis shows that affordable housing projects further away from the urban center require more time to access job centers. This can largely be explained by the job centers’ concentration in the urban center. In contrast to the results in job counting approach, the gap between peak and off peak hour is actually narrower. Usually, the accessible measured by average commuting time in off-peak hour (red line) is about 20 minutes more than that value in peak hour (green line).

Besides the distance to city center, our analysis also shows that the difference in average commuting time also because of local public transit. However, distance to the city center plays a more important role here than the job counting approach. In some way, the network analysis approach improves the methodology in that it causes less bias if the affordable housing project is located far on the urban fringe because its primary focus is on the network and their locations.
4.2.2 Accessibility by Car

In the scenario of travelling by car to tertiary industry jobs, our study employs a similar method as the study of public transit. By using the same approach of network analysis in GIS, we use the same 73 affordable housing projects which were built before 2004 as the origins and the 418 commercial job centers as the destination. The only change is that we have switched from bus networks to road networks to accommodate the car as the transportation mode. Based on the OD Matrix created by the road network, we can also calculate the average commuting time as the accessibility score for each affordable housing project.

According to the OD matrix by car, accessibility scores to tertiary industry jobs centers is on average 50.9 minutes for peak hours and 34.6 minutes in off peak hours for all the housing projects. It reveals a travel mode advantage of travelling by bus, in which the average commuting time by car costs more than half of that by bus. And among the 73 affordable housing projects, the average commuting time varies a lot. For example, the project with the best accessibility is also Lechengjiayuan in Xuanwu District (similar to the bus mode), with an average commute time to tertiary industry job centers of 26.8 minutes in peak hour and 16.7 minutes in off-peak hour.

By similar approach, the accessibility layout of these affordable housing projects measured by average commuting time is mapped below (Figure 4-2-5). In this figure, the blue points represent job centers, while the colored dots from green (better accessibility) to red (worse accessibility) represents affordable housing projects. This analysis reveals a job-housing pattern among low-income residents by car where affordable housing projects located within the fourth ring road have better accessibility, compared to those located further out from the city center. Unlike the pattern illustrated in the public transit travel mode, the projects with worst accessibility are not only because they are far from city center, but also because they have weak connection to city highways. Similar to the results by public transit, the projects located in the southwest part of the city have better accessibility. The use of cars as a transportation mode has several effects on accessibility levels. For example, it significantly improves the accessibility for those projects...
located far in the north along Highway G6 and far in the Daxing District along Highway Jinggang’ao. These areas would otherwise have a long commute time by public transit.

When compared with the counting job approach above, our study shows a slightly different accessibility pattern where accessibility is improved for some affordable housing projects located far along the fifth ring due to their access to highways while others located in the south and northwest have lower accessibility due to their distance from highways. These results imply that changing travel mode from public transit to car may improve accessibility where the surrounding road network has good connection with highway.

![Figure 4-2-5 Accessibility Measured by Average Commuting in Peak (left) and Off-peak (right) Hours by Car](image)

By using two different speeds in peak and off peak hours, we are able to show slight differences in the average commuting time by car (Figure 4-2-6). Similar to public transit, our analysis also shows the average commuting time both in peak and off peak hour increases with the increase of distance to the city center. But the slope is much more linear that that of public transit, revealing a the importance of the local road network than the distance to city center. For affordable housing projects that have the worst accessibility, it might cause by misconnection to local road network or uncompleted roads. Also in contrast to the results of the job counting approach, there is not a big gap between peak and off peak hour. Usually, accessibility measured by using a car in off-peak hour (red line) is just 10 or 20 minutes higher than that value in peak hour (green line), which is even more narrow than that of public transit.

The network analysis by car shows that distance is not as important as that of public transit, while local connectivity may play a bigger role. Compared to the counting job approach, network
analysis by car also causes little bias and distortion for the affordable housing project located far on the urban periphery, as long as it has good access to roads nearby.

4.3 Comparison between the Two Method

Our study discusses two methods that measure accessibility: the counting job approach and the average commuting time approach. Generally speaking, it shows a similar accessibility pattern between the two approaches with small differences on the ground.

However, despite which approach we use, affordable housing projects which are located closer to the city center usually have better accessibility. Specifically, if we divided all of the scenarios into four modes: bus in peak hours, bus in off peak hours, car in peak hours and car in off peak hours (Figure 4-3-1) we can show tiny difference between the four modes. By increasing distance to the city center, the number of jobs available within a certain time limit will keep dropping, while the average commuting time to job centers will keep increasing. There might be some local inconsistency between the two methods, but it doesn’t affect the city-wide trend. Similarly, our study will also identified some projects with extremely low level of accessibility in the four modes, such as Tiantongyuan and Huilongguan in the north, Guanzhuang Jiandongyuan and Shuangqiao Daxue in the east and Lithuan, Beiluguan and Xinggongyuan in the southwest. The
Residents living in these projects have poor accessibility to job opportunities.

(a) Travelling by bus in peak hours

(b) Travelling by bus in off-peak hours

(c) Travelling by bus in peak hours
Figure 4-3-1 Accessibility Changes with Distance Increasing in two Approaches

For example, if we examine the difference between the counters of travelling by bus within 60 minutes in peak hours by counting job approach and travelling by bus also in peak hours by average commuting time approach (Figure 4-3-2), it finds that the accessibility layout patterns by two approach are pretty similar. In both maps, accessibility is the highest for projects within the north 2\textsuperscript{nd} ring road and the south 3\textsuperscript{rd} ring road, while it is the lowest for those located along the 5\textsuperscript{th} ring road. Generally for the bus taker in peak hours in the souther part of city has better a level of accessibility.

Figure 4-3-2 Comparison between Methods of Accessibility by bus in peak hours (left: counting job approach; right: average commuting time approach)

When comparing the differences between the two method, the difference between travelling mode – by bus or car is more obvious here. Differences in network development and travel speed
is at the root of the comparatively large disparity between bus and car accessibility levels. As expected, commuting by bus takes more time than by car. However, comparing the relative disparity between bus and car travel times between affordable housing facilities can reveal which areas that are comparatively deprived of public bus connections (Figure 4-3-3). Our study shows that accessibility decreases more smoothly with the increase of distance to city center when travelling by car, compared with a much sharper downward slope when travelling by bus. Thus, the advantage of travelling by car is evident for affordable housing residents.

Figure 4-3-3 Accessibility Gap between Travelling by Bus and Car (left: counting job approach; right: average commuting time approach)

5. Scenario Analysis
In this part, we will further explore several scenarios to simulate future development. It will discuss changes in accessibility under the circumstances of affordable housing location changes, new public transportation network development, job centers relocations and so on. Based on the comparison between counting job approach and average commuting time approach, there is tiny difference in the analysis results. Considering the difficulty in obtaining updated economic data by zip code for future years, it will only explore average commuting time approach in this part.

5.1 New Affordable Housing Built in Year 2005 and 2006
In the first scenario, we explore the changes in accessibility based on new affordable housing projects that were built between 2005 and 2006 by the average commuting time approach. This assumes that tertiary industry job centers and transportation networks have not changed. By comparing the average commuting time to the job centers, the changes in job accessibility for the new affordable housing location can be evaluated. In this part, tertiary industry job centers identified above are taken into consideration, assuming that the job centers have not changed in
In order to simplify this method, we also assume that bus and road networks are the same since 2004 levels. Instead of dividing peak hour speed and off peak hour speed, we will only be approximating an average speed of 15 km/hour for buses, and 30km/hour for cars.

Figure 5-1-1 Affordable housing projects (before 2004 and in 2005 and 2006) and tertiary industry job centers

Figure 5-1-2 Commuting time for affordable housing projects before 2004 and in 2005 and 2006 by bus (left) and car (right)

In this scenario analysis, accessibility results are based on new affordable housing locations. The average commuting time shows that newly built affordable housing projects in year 2005 and 2006 need less time to travel to tertiary industry job centers whether they travel by bus or car (Figure 5-1-2). We can deduce that:
(1) For those traveling by public transit, the average travel time to job centers right shift to longer range. Before 2004, most of the affordable housing residents traveled 61-75 minutes in a one-way commute. For the affordable housing projects built in 2005 and 2006, most of the commuting time has shifted to within 46-60 minutes; while the percentage does not change much within the range of 75-120 minutes. It means that the average commuting time has shrunk for the public transit commuter before 2004 than in year 2005 and 2006 (Figure 5-1-2 left).

(2) For those traveling by car, the average travel time to job centers has not changed much. Before 2004, most affordable housing residents traveled 21-30 minutes in a one-way commute. For affordable housing projects built in 2005 and 2006, the percentage slightly increases, while in other ranges of time it only changes slightly. (Figure 5-1-2right).

(3) Distance might be an importance factor influencing the average commuting time of both modes of transportation, but it is not a necessary factor. For example, for affordable housing projects built before 2004, the commuting time for both bus and car do not always increase with the increase in distance between the projects and the city center. For example, in the cases of Huilongguan, Tiantongbeiyuan and Shuanglongxiaoxu, these projects have longer commuting times by car than other Affordable Housing Projects about the same distance to city center (Fig 5-1-3). Similarly for the affordable housing projects built in 2005 and 2006, the average commuting time travelling by public transit or car does not always increase with the increased distance (Figure 5-1-4).

Figure 5-1-3 Average commuting time by bus and car for AHP with increasing distance (before 2004)
5.2 New Transportation Network in 2011

Beijing’s public transportation developed quickly in the years after 2004, particularly with the growth of the subway system. The number of lines opened jumped from 3 in 2004 to more than 10 by the end of 2011 (Figure 5-2-1). In this scenario, we assume that the locations of affordable housing, tertiary industry job centers, and bus network have not changed. We will also use the average commuting time approach.
Due to the increase in subway and light rail lines, the public transit network is more comprehensive in 2011. The effect on accessibility levels is predictably positive for affordable housing communities. Using the same affordable housing and job center locations that existed in 2004, accessibility for public transit improved on average by 31% during on peak hours, and 18% during off peak hours over 2004 levels to tertiary industry job centers. Because neither the origins nor destinations changed between the 2011 and 2004 analysis. This improvement can be attributed to improvements in public transportation. In fact, the improvements are primarily a result of subway development as the bus system remained essentially the same in our analysis.

Table 5-2-1 Accessibility Rates of Affordable Housing in 2011

<table>
<thead>
<tr>
<th></th>
<th>To Tertiary Industry Job Centers in 2011</th>
<th>To Tertiary Industry Job Centers in 2004</th>
<th>Percent Improvement over 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Travel Time On Peak Times (Min)</strong></td>
<td>56</td>
<td>80.7</td>
<td>31%</td>
</tr>
<tr>
<td><strong>Average Travel Time Off Peak Times (Min)</strong></td>
<td>52</td>
<td>63.8</td>
<td>18%</td>
</tr>
</tbody>
</table>

Mapping the best and worst performing affordable housing units displays the importance of subway lines on improved accessibility levels. Those units with the greatest improvement are noticeably closer to subway lines (Figure 5-2-2).

Figure 5-2-2 Level of Improvement to Commercial Jobs among Affordable Housing from 2004 to 2011 (On Peak)

One significant factor influencing accessibility rates of affordable housing communities is their distance from the city center. Data from 2011 uphold the trend from 2004 that more centrally
located communities experience better levels of accessibility. A chart that plots each affordable housing projects average time to tertiary industry job centers in relation to their distance from Tiananmen shows this trend (Figure 5-2-3).

Figure 5-2-3 Impact of Distance on Travel Time to Tertiary Industry Jobs in 2004 and 2011

Previously, in 2004, accessibility levels by car showed a strong advantage over Beijing’s public transit system which was almost entirely reliant on buses. However, under the assumption that the road network keep still while the subway system developed, that advantage was greatly reduced, and in some cases even disappeared. Among 73 affordable housing units, 25 had better access to tertiary industry jobs on public transit than by car. This is a surprisingly successful improvement in non-car accessibility and is once again related to subway development.

5.3 New Transportation Network in 2020

Following the research from above, we further explore accessibility changes in the scenario of new transportation networks that are to be developed in 2020 by the average commuting time approach. By 2020, more subway lines will be finished which will further improve the public transit system. In this scenario, our analysis assumes that the location of affordable housing, tertiary industry job centers and bus network will not change, evaluating accessibility changes due to only new public transit development (Figure 5-3-1).
With increased development of subway and light rail lines, the public transit network will be better established by 2020. It will improve the average speed of the city’s public transit network, and bring about a positive effect on affordable housing residents who take public transit to work. Similarly, assuming that the affordable housing and job center locations stay the same, accessibility for public transit improved on average by 35% during on peak hour, and 25% during off peak hours over 2004 levels to tertiary industry job centers.

Table 5-2-1  Accessibility Rates of Affordable Housing in 2011

<table>
<thead>
<tr>
<th></th>
<th>To Tertiary Industry job Centers in 2020</th>
<th>To Tertiary Industry job Centers in 2004</th>
<th>Percent Improvement over 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Travel Time On Peak Times (Min)</strong></td>
<td>52.1</td>
<td>80.7</td>
<td>35%</td>
</tr>
<tr>
<td><strong>Average Travel Time Off Peak Times (Min)</strong></td>
<td>47.9</td>
<td>63.8</td>
<td>25%</td>
</tr>
</tbody>
</table>
Similarly, by mapping the rate improvement of the affordable housing projects we show that 53 out of 73 projects will be improved by 2020. Their location a subway stop might be the most important factor to the improvement in their commute (Figure 5-3-2).

Figure 5-3-2 Level of Improvement to Commercial Jobs among Affordable Housing 2004 to 2020 (On Peak)

Previously, we find that the average commuting time usually relates with the increase in distance from the city center. Similarly to the scenario of 2011, distance from the city still counts as one of the most important factors influencing accessibility rates. It shows that the average time to tertiary industry job centers is further improved when compared to 2004, with 2011 levels slightly better, which shows that the development of subway and light rail lines increase the public transit system’s efficiency and reduces the friction on distance when compared to previous years (Figure 5-3-3).

Figure 5-3-3 Impact of Distance on Travel Time to Commercial Jobs 2004, 2011 and 2020 on Public Transportation

In the scenario of 2020, the advantage of travelling by car versus bus keeps shrinking, probably because the subway provides a more efficient means of transportation, especially during peak
hours. Among 73 affordable housing units, 29 had better access to tertiary industry jobs on public transit than by car in 2020. This result has significant implication to the choice of transportation because it means more affordable housing residents will choose to take the subway than drive a car.

### 5.4 Job Centers Relocate in the Suburban Area in 2020

In this part of our scenario analysis, we assume that all the job centers move out to suburban areas, while affordable housing locations and transportation network do not change. We will continue to use the average commuting time approach. It will change the current centralized job pattern into multi-sub centers job pattern, which provides residents with more job choices in the uptown areas.

In the case of Beijing 2020, our study assumes that seven new job centers will emerge in each of the administrative district centers: Tongzhou, Shuiyi, Changping, Mentougou, Fangshan, Daxing and Yizhuang. Instead of current the travel behavior, we also assume that affordable housing residents will commute to the nearest job center. In this part, we will not use the average commuting time as measurement, mainly because we assume residents will not want to take a long commute across the city.

Results show that based upon the nearest job center rule, there is a portion of affordable residents that will be changing their commute from downtown to the outskirts. We also see that a couple of job sub-centers will attract employees from the traditional city job center. These sub-centers are Daxing, Yizhuang and Tongzhou. In addition, there will still be an amount of affordable housing residents who will continue to commute in the downtown area, particularly those located in the northern part of the city like Huilongguan, and Tiantongyuan. Our study also shows that Changping, a supposed new sub-center, is still not so attractive when compared with the traditional city center (Figure 5-4-1).
The commuting time to the nearest job center will decrease compared with the 2004 average commuting time range. For the affordable housing residents who take public transit, most of them spend 15 to 30 minutes on their way to job. It might partly because they choose the nearest job center, and partly because the public transportation system will achieve a certain level of efficiency by 2020. Moreover, affordable housing residents who travel by car, most of them spend less than 15 minutes on the way to job. It is also less than the time they spent in 2004, which is not only because their job location is closer, but also because by traveling to a closer location, they can avoid traffic jams during rush hour (Figure 5-4-2).
6. Conclusion and Policy Implications

This project selects Beijing as case study to explore the job accessibility to commercial job opportunities for low income individuals living in affordable housing projects. Based on the data of Beijing from 2001 to 2004, our study measures the accessibility by two approaches: counting job number approach and average commuting time approach. In the first approach, accessibility is valued by how many job opportunities the residents of affordable housing can reach within certain time, with a set commute time of 30 minutes or one hour. And in the second approach, accessibility is calculated based on the average commuting time for affordable housing projects to all the potential tertiary job centers, based on the OD matrix created by network analysis.

Results shows despite what approach we took, the accessibility for residents travelling by car is much better than those travelling by public transit. This travel mode difference might reflect the job accessibility gap between different income group. From the spatial point of view, accessibility is generally better for affordable housing projects near the city center and decreases with increased distances away from the city center, especially for the public transit users. We also found that Beijing’s local public transit is insufficient for some affordable housing locations where traveling by bus offers less access to job opportunities or require much more time to reach service areas than by car. The results from two different approach are consistent.

By using this approach, we are also able to discuss the changes in accessibility in four scenarios: new affordable housing locations in 2011, new public network in 2011, new public network in 2020 and new job locations in 2020. In the scenario of new affordable housing are built before 2004 and in year 2005 and 2006, our study illustrates that the average commuting time by both public transit and car do not differ by much, suggesting that accessibility is still mainly influenced by the distance to the city center. In the scenario of new public network in 2011 and 2020, we find that public transit efficiency is improved with the development of new subway and light rails lines, and the advantage of car users is reduced. In the scenario of new jobs centers relocating to suburban areas,

Figure 5-4-2 Commuting Time to Nearest Job Center by Public Transit and Car
we find that the commuting time generally decreases because some affordable housing residents change their commuting direction from downtown to the city’s periphery.

The case study of Beijing shows its unique features of job-housing spatial mismatch when compared with the classical model in American cities. In Beijing’s case, affordable housing projects that are located near the city center have better job accessibility, while those located in the far suburban area is weak in job accessibility. This is different from the classical spatial mismatch hypothesis which states that job opportunities will be moving to suburban areas, while the low income group will stay in the city center (Kain, 1968). The job opportunities in Chinese cities like Beijing are still concentrated in Beijing without spreading out to the city’s borders, while the affordable housing for low income group are built further and further in the far suburban area. Considering the lack of public transit around the suburban area, this spatial pattern induces low accessibility for low income groups in Chinese cities. This unique Chinese model for spatial mismatch, reveals the limited accessibility based on income difference. Comparing with Western cities, job accessibility in China might be more associated with income than race (Holzer 1991; Blumenberg and Ong 1998). Moreover, limited job accessibility for low income group make them worse off as they relocate away from job rich areas. This new spatial mismatch in Chinese cities break the “spatial bond” which ties the housing and job together within the same Work Unit (danwei) compound before economy reform. The broken of “spatial bond” also decrease the job accessibility for low income groups.

By exploring job accessibility and its change for low income people, this study will provide implications for future transportation and urban land use. For example, selecting better locations for future affordable housing will make it easier for these groups to access job opportunities; improving local public transit services will also make their commute more convenient. Similar to the advocates of New Urbanism and Smart Growth, improving the accessibility of low income group to jobs will have any benefits for the city. It will not only dissuade private car use, promote urban employment but also improve the social equality for low income group. This project sheds light on modern day Chinese cities which will influence planning professionals and decision makers on their decisions about providing disadvantaged low-income individuals with better job opportunities.
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