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Built Environment Diversities and Activity-Travel Behavior Variations in Beijing, China

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Abstract

The significance of traffic congestion and air pollution in Chinese cities was highlighted during the 2008 Beijing Olympics. Many attribute the problem to the rocket soaring car ownership and the increasing dependence on car for urban Chinese in their daily travel. More fundamental issues, however, have not yet received sufficient attention: apart from increased income, what other factors contribute to the growing demand for car? Apart from increased accessibility to car, what other factors contribute to the increased urban traffic? Based on our recent research on urban transportation in China, we hypothesize that the spatial restructuring of Chinese cities, resulted from Danwei (or work unit), land, and housing reforms, has largely, if not fundamentally, changed the ways that urban Chinese use time and space and consequently their travel behavior. The urban form of Chinese cities especially the major ones used to be characterized by the unique urban enclaves of Danwei (or work unit) compounds. Economic and institutional

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reforms introduced since the 1980s have not only granted great freedom to urban Chinese the choices of jobs and residences but also diversified the built environment. New types of urban forms have emerged and become important consistent components of urban China. This paper investigates the interrelations between urban form remaking, car-dependence and traffic congestion in Beijing, the capital city of China. Specifically, we will characterize the built environment in Beijing and establish associations between built environment and activity-travel behavior in terms of car ownership, the use of time and space, travel frequencies and duration and shares of motorized and non-motorized transport modes. The results show that residents of different types of neighborhood demonstrate significantly different activity-travel behavior in terms of car ownership, time use, travel time and travel distance. These findings support the argument that there are associations between built environment and activity-travel behavior.

Keywords: Built Environment, Activity-travel Behavior, Time use, Structural Equations Model; Beijing.

1. Introduction

The research interests on the connection between built environment and transport could be traced back to 1950s, when Mitchell and Rapkin (1954) published their volume on *Urban Traffic: A Function of Land Use*. Land use measures and urban planning strategies have been considered by both academics and practitioners as effective means to achieve desirable transport objectives including reducing vehicle miles traveled and promoting the ridership of public transport and the use of non-motorized transport modes. Mixed land use, high density and mass transit were largely believed to be effective in containing travel demand and reducing automobile dependence, air pollution and energy consumption (Newman & Kenworthy, 1984, 1989). Nevertheless, some studies seemed to indicate that the effect of land-use policies on transport demand might be marginal (Small, 1980; Sharpe, 1982); others suggested that urban decentralization had helped alleviate traffic congestion at least in the city center and investment in railway transit had actually accelerated suburbanization (Gordon & Richardson, 1989). Several streams of studies on the topic have been developed in the past decades. Substantial research efforts had been devoted into developing integrated land use and transport models particularly in the 1960s and 1970s (Lowry, 1964; Wilson, 1971) and interests in this research field have been lasting for decades till today (see for example, the session on integrated land use and transport models at the latest annual meeting of Transportation Research Board, 2009). Another stream of research focuses on jobs-housing relationship and commuting trips. This includes the debates on 'wasteful' commuting (Hamilton, 1982; White, 1988; Cropper and Gordon, 1991; Small and Song, 1992) and the arguments about jobs-housing balance (Cervero 1989; Giuliano 1991; Levinson & Kumar, 1994; Peng, 1997; Levinson et al., 2005).

Since the 1990s, increased research attentions have been paid to the associations between built environment and travel behavior (e.g., Newman and Kenworthy, 1999; Handy, 1996; Crane, 2000; Cervero, 2002). The term "built environment", or "urban form", greatly broadened the previous research focus of land use or jobs-housing relationship. Ewing and Cervero (2001) provide a summary of empirical findings concerning the importance of built environment in explaining individuals' travel behavior: built environment is found to be a significant predictor of vehicle miles traveled, primary determinant of trip lengths, important explaining factor of mode choices and secondary determinant of trip frequencies (secondary to socio-economic characteristics). High density developments and mixed land-use neighborhoods are found to be associated shorter trips and higher shares of non-motorized transport mode such as walking and cycling (Friedman et al., 1994; Cervero & Duncan, 2003, Khattak & Rodriguez, 2005). A quasi-longitudinal investigation by Handy et al., further suggests that the associations built environment and travel behavior are causalities rather than correlations (Handy et al., 2005).

Nevertheless, some argue that the observed effects of built environments on travel behavior could be in fact due to personal preferences. Specifically, people who enjoy walking would probably choose to live in pedestrian-friendly neighborhoods, and vice versa. So, the built environment might be a result of residential choice, which is highly related to individual travel attitudes, rather than a cause of differentiated travel behavior, as it is often supposed to be. This so-called self-selection issue has been debated in the discussion about the relationship between built environment and travel behavior. Some empirical studies found that attitudes were more significant explanatory factors of travel behavior than land use or urban form variables (Kitamura et al., 1997; Mokhtarian & Bagley, 2002). A new approach employed by Schwanen and Mokhtarian shed more light on this issue. They studied travel behavior of 'matched' (or consonant, i.e. if people currently live in their preferred type of neighborhood) and 'mismatched' (or dissonant, i.e.

if people are not living in their preferred type of neighborhood) residents in both suburban and urban neighborhoods. Clearly, if ‘mismatched’ residents behave like those ‘matched’ residents who live in their dream type of neighborhood, attitudes would prove to have dominant effects on travel behavior. On the other hand, if people actually living in the same type of neighborhood behave alike, it would suggest that built environment factors overweigh personal preferences. In a series of studies, they found that both personal attitudes and residential structures have significant impacts on travel behavior, while the built environment effect might be somewhat stronger (Schwanen and Mokhtarian, 2003, 2005a, 2005b). Similar results are also supported by some recent studies. Cao et al. (2006, 2009) argued that neighborhood characteristics and perceptions were still important factors to explain travel behavior even when attitudinal factors were controlled. They also suggest that both attitudes and the built environment impact non-motorized travel more than auto and transit travel (Cao et al., 2009).

While most of existing studies focus on the connections between built environment and travel behavior, some recent attempts have extended into investigating the impacts of built environment on the use of space and time. Fan finds that dense development, more retail stores and the presence of sidewalks lead to more clustered daily activity locations, less driving time and more walking time, suggesting that land use measures may be effective to induce people towards environmental friendly travel behavior (Fan, 2007). Lee et al. (2009) study the influence of urban form on activity engagements and time-use patterns and find significant relationships between residential urban form and time-use patterns and potential endogeneities between time allocations to different activities (Lee et al. 2009).

Empirical findings reported in the literature are mainly obtained from case studies in the United States, where the built environment is relatively stable. Since the 1980s, the Chinese government has implemented Danwei (or work unit), housing and land reforms (Wang and Chai, 2009). As a result of these reforms, the built environment of Chinese cities has gone through drastic changes in the past decades. The urban form of large Chinese cities, which used to be dominated by Danwei compounds (Wang and Chai, 2009), has been diversified. New types of neighborhoods have emerged and become important basic spatial units. This spatial restructuring has largely, if not fundamentally, changed the ways that urban Chinese use time and space and consequently their travel behavior. Meanwhile, the mobility of urban Chinese in terms of car ownerships and the availability of transport modes have also significantly changed. These changes are manifested in the variations of built environment and travel behavior in urban China today. Thus, Chinese cities offer quasi-longitudinal cases to study the connection between built environment and activity-travel behavior. There are not many studies concerning urban form and travel behavior in China reported in the literature. Wang and Chai (2009) argue that jobs-housing relations in Chinese cities have been largely influenced by the so-called Danwei system. The study compares the commuting behavior of employees living in houses provided by Danwei and those living in houses bought or rented from the market. They find that Danwei employees commute shorter and are more likely to use non-motorized transport mode than commodity housing residents. Pan *et al* (2009) study the influence of urban form on travel behavior in four neighborhoods of Shanghai. They find that residents of pedestrian/cyclist-friendly neighborhood travel shorter distance than those of other types of neighborhoods.

This paper investigates the interrelations between built environments, car ownerships and activity-travel patterns in Beijing, the capital city of China. We will differentiate the basic residential neighborhoods that constitute the built environment of Beijing and establish associations between built environment and activity-travel behavior in terms of car ownership, travel frequencies and duration of different out-of-home activities. Structural equations model is used to establish causal links between these variables. The rest of the paper is organized as follows. Section 2 will discuss the transformation and variations of the built environment of Chinese cities. Section 3 introduces the case, data and variables. Section 4 presents findings of modeling analysis. The last section discusses findings and concludes the paper.

2. Built Environment Transformation in Urban China

Before the introduction of economic and urban reforms in the 1980s, the built environment of major Chinese cities was largely made up of self-contained Danwei (or work unit) compounds (Wang and Murie, 2000; Gaubatz, 1999; Wang & Chai, 2009). Danwei, a common name for state or collective-owned institutions or enterprises in socialist China, had been the basic social, economic and spatial unit in urban China (Bray, 2005). The land use patterns of most large cities were dominated by self-contained work units of different sizes and different types (e.g., public institutions, stated-owned enterprises, etc.) (Wang and Murie, 2000); the spatial structure of cities during that period was formed “with the assumption that most urban residents would rarely have any need to travel beyond the walls of their work-and-living units" (Gaubatz, 1999). So, Danwei was not only the work unit, but also the living neighborhood, the dominated type of neighborhoods that one could identify in large Chinese cities during that period.

The Danwei compounds-dominated urban structure has been greatly changed in the past 30 years. Though the traditional Danwei neighborhoods remain important constituent elements of the built environment, as a result of three decades' economic reforms (specifically, Danwei, land and housing reforms), new types of neighborhoods or living communities have emerged and become equally important constituent elements of the built environment of Chinese cities today. In the 1980s, the increased housing demand could not be accommodated within the traditional Danwei compounds and Danwei had to build houses in other places. This had led to the development of new neighborhoods called Danwei *Xiaoqu*, which may be considered as a new form of Danwei communities or what we refer to as reformed Danwei communities. Residents of Xiaoqu might come from different Danweis. Danwei was encouraged to purchase or construct houses for their employees, which stimulated the development of reformed Danwei communities. Danweis, in particular, large Danweis, might be allocated land by the government to construct such communities for their employees. A major difference between the traditional Danwei and reformed Danwei communities is that the reformed Danwei communities are mainly for residential purpose and they do not necessarily co-locate or are close to working places.

Land and housing reforms lay down the foundation for the establishment of the housing market. Urban land reform paved the ways for land-use rights to be transferred through auction and the market force was introduced for land allocation; on the other hand, housing reform eventually removed the responsibilities of Danwei for housing provision in 1998. Housing, used to be a welfare entitlement, became a commodity that needs to be purchased from the housing market. Since then the demand for commodity housing has substantially increased. Inevitably commodity housing prospered. Commodity housing development usually takes the form of small districts or housing estates, which form the commodity housing neighborhoods. In terms of location and architecture design, commodity houses are quite different from the traditional Danwei houses. They are usually built in suburb where large pieces of land are available. Some may be built on land cleared from urban renewal projects, which may be in places near city centers. Unlike the traditional Danwei housing that consisted mainly of three-to-four-storey rectangular blocks with basic facilities, the commodity housing is generally composed of medium-rise to high-rise apartment buildings with attractive appearances and luxury interior designs. In about ten years, commodity housing neighborhoods or communities became a prevailing form of residential developments in Chinese cities.

In parallel with the development of commodity housing communities, social welfare housings are introduced to provide subsidized housing for those who cannot afford the market price housings. Since the 1980s, urban governments had begun to allocate land for housing the citizens or peasants who lost their dwellings in the processes of urban renewal or rural urbanization. These settlement communities (the so-called '*an-ju xiao-qu'* or '*jie-kun xiao-qu'*) gradually evolved into the so-called affordable housings ('*jing-ji- shi-yong-fang'*) and the so-called 'two-limitation' housings ('*liang-xian' fang*, meaning price ceiling and size ceiling), which are the major types of social welfare housings today. With a much lower price than and quality inferior to that of commodity houses, social welfare housings are targeted on the less privileged with low income and cannot afford commodity housings. Table 1 summarizes the typical neighborhoods or communities which may be identified in major Chinese cities today.

(*Insert Table 1 about here*)

In the city centre of Chinese cities one usually finds Traditional Residential Areas, such as *Hutong* in Beijing or *Lilong* in Shanghai. Mostly built before 1949, those private housings were confiscated by the socialist government and distributed to Danwei or individuals. The majority of residents worked nearby and conducted maintenance or entertainment activities in downtown area. Some old blocks had been demolished or renewed. Remaining old districts, marked by low and crowded houses, narrow paths and poor living conditions, have become residential places for migrants and floating population. Original inhabitants, many of whom retired or unemployed, also have generally low income and mobility. Nevertheless, some of the residents in these areas work in suburban enterprises, and hence have to commute from city center to outskirts. It should be noted that some similar residential areas were left over in suburbs during the process of urban sprawl and rural urbanization, namely the ‘village in city’, residents of which are mainly migrant workers. Such cases are mostly found in cities in southern China, such as Guangzhou and Shenzhen (Huang, 2006).

Traditional Danwei communities, mainly built in the pre-reform era, usually occupy inner suburb locations signifying the urban expansion in recent decades. The Traditional Danwei Compound retains many of its original characteristics, including the proximity of work and residence. Compound residents, many obtained the whole or partial house property rights at rather low prices, have gained most benefits from the Danwei welfare system. These people usually have high income and can afford private cars, although they have generally simple commuting patterns. Residents of Reformed Danwei Communities, on the other hand, have extremely diversified travel patterns. Like traditional compounds, these reformed compounds usually located in old urban districts close to the city centre, characterized by mixed-use, compact construction and traffic congestion. Inhabitants comprise a mixture of people of different socio-economic backgrounds, working at different places and ranging in various socio-economic ranks. While some compounds were reconstructed into decent neighborhoods, others might deteriorate into slum like communities for accommodating floating population.

Newly built communities after the reform, like Commodity Housing Communities and Social Welfare Housing Communities, mainly located in suburban areas (Feng, 2004). While new communities continued to adopt the walled guarded space form, isolated internal circulation and integrated necessary living facilities, the most important difference is that housing is separated from working place. The suburbanized residence depends much more on motorized transport modes, which are also reflected in the automobile-oriented neighborhood design. This has given rise to long-distance trips and complicated travel patterns of these suburban residents.

As a typical spatial form of residential districts in urban China, *walls* of new communities have gained different meanings in the new context – not any more as a boundary between Danwei members and 'outsiders', but rather a demarcation of social ranks. Commodity housing owners, living in Commodity Housing Communities, usually have high income, decent occupations and high social status. Since social welfare housing mainly aims at low to medium income citizens, the location, design and surroundings of welfare communities are less preferable. However, some more underprivileged people (mainly the migrant workers) do not even have the access to social welfare housing. They could only find temporary accommodations in deteriorating neighborhoods. Differentiation of built environments leads to redistribution of social classes, and hence may reveal peculiar spatial patterns of activity-travel behavior and life style.

Before the reform, social space in urban China was mainly classified by work-units and social ranks are manifested by the hierarchies within the Danwei system (Wang & Murie, 2000). Work-units had their own criteria in dwellings distribution, by which employees were ranked according to their working years, family structures, political status, academic qualifications, etc. The urban reform, however, turned the socio-political classification into monetary differentiation (Wu, 2002). Socio-economic class, especially income level and residential registration (*hukou*), is playing an increasingly important role in distinction of social areas and spatial patterns (Gu *et al.*, 2005; Li & Huang, 2006; Feng *et al.*, 2007). New segregation is formed between the rich and the poor, 'cadre' and workers, urban residents and rural migrants, who might live in close proximity but separated communities. It is thus important to take into consideration of the socio-economic divisions in the study of activity-travel behavior of residents in various types of neighborhoods.

3. Data and Descriptive Analysis

3.1 Case and data

Beijing, the capital city of China, is selected for the case study for its leading roles in China's urban development, the representative of its socio-spatial structure and the diversities of its neighborhood types. All the major types of neighborhoods or communities identified in the previous section can be found in Beijing.

Data were collected by face-to-face interviews conducted in October, 2007. Two neighborhoods for each type and in total 10 neighborhoods, which vary in location, size and types of residents, were selected for study. Table 2 describes the sampled neighborhoods. As the Table shows, the sampled neighborhoods match the major characteristics of the five neighborhood types presented in Table 1. Figure 1 illustrates the location of the sampled neighborhoods. As it shows, JDK and QHBY, the two Traditional Residential Areas, are located in the city centre. The four Danwei-based neighborhoods (YDY, SLH, TRY, and HPL) are situated close to the city center. The four newly built neighborhoods (DDJY, FZY, WJHY and HLG), i.e., the commodity housing and social welfare housing neighborhoods, are located in the outer suburbs.

(Insert Table 2 about here)

In each neighborhood we drew a random sample of 60 households and were able to successfully interviewed 45 to 60 households. In total, we collected data from 520 households involving 1119 individuals. In general, two members of each household were asked to participate in the survey, but for large families three members might be interviewed and for families with a single member, only one member was interviewed. Children under 16 were excluded as they were considered as dependants in decision making for mobility and travel. In addition to households and individuals' socio-demographic characteristics such as family size, household income, age, occupation, etc., respondents were asked to provide information on car ownership and distance, travel time as well as transport mode to workplace and the most frequently visited shop and entertainment place. A two-day activity-travel diary was also collected. Respondents were asked to report activity type, timing, activity destination, trips involved, etc.

(Insert Figure 1 about here)

Table 3 presents the socio-economic characteristics of the sample stratified by the types of neighborhoods. As shown in the table, the socio-economic profiles of respondents from the five different types of neighborhoods are quite different. Residents of traditional residential area and traditional Danwei compound have similar age structure with more than 50% respondents aged 40 to 59, whilst those of the newly built neighborhoods especially commodity housing communities are much younger, more than 50% of them are in the age category of 19-39. The age structure of the reformed Danwei communities falls in between the two extremes. In terms of education attainment, respondents of commodity housing and social welfare housing communities have much higher education level than those of other types of neighborhoods especially traditional residential area as well as reformed Danwei communities. Over 85 percent of respondents from commodity housing communities have attained a level of tertiary education, while that from traditional residential area is only 44%. With more than 30% of households having a monthly household income over 10000 RMB, commodity housing communities also have the largest proportion of high income households. Traditional Danwei compounds have the largest percentage of middle income households. On the other hand, over 50% of households from the traditional residential area earn less than 3000 RMB per month, belonging to the lowest income group. For employment status, less than 50% of respondents from the traditional residential area have a full-time job. This is the lowest among the five types of neighborhoods.

(Insert table 3 about here)

3.2 Descriptive analysis

To generate intuitive findings regarding the association between built environment and activity-travel behavior, we conduct some descriptive analyses. We compare the auto ownership, mode share, time use of residents of different types of neighborhoods. Results are presented in Tables 4 and 5.

To facilitate the analysis on activity patterns and time use, the 16 types of activities are aggregated into three major categories:

- Subsistence activities, which are work, work-related, and school activities;
- Maintenance activities, including housework, chores and errands, daily shopping and dinning, family and personal care, etc.
- Recreation activities, including sports, tours, entertainment and social activities.

Table 4 compares car ownership as well as the distances, travel times and transport modes for trips to workplace, the most frequently visited shop and entrainment place between the five types of neighborhoods. As the table shows, car ownership varies substantially between different neighborhoods. As expected, commodity housing communities have the highest car ownership: more than 60% of households own private cars. On the other hand, the traditional residential areas and traditional Danwei compounds have the lowest car ownerships: the percentages of households with private cars are respectively 13.0% and 23.91%. This big contrast is partly the result of income disparities between residents of the different neighborhoods and partly that of the differences in location and land-use patterns between the neighborhood types. As acknowledged earlier, traditional residential areas and traditional Danwei compounds are more likely located in city center and jobs-housing opportunities are better balanced than commodity housing and social welfare housing communities. Perhaps to someone's surprise, the car ownership of social welfare housing communities is also quite high: about 46% of households have private cars. One possible explanation is that social welfare housing is usually located in the urban fringe where public transport services are not well provided and to some extent it becomes necessary to have private cars for trip making. Another reason is that social welfare housing recipients are not the poorest groups of people in urban China. They may not be rich enough to buy commodity housing, but they may afford a private car.

(Insert Table 4 about here)

The average distances to workplace vary substantially between different types of neighborhoods. As expected, traditional Danwei communities have the shortest distance to workplace, whilst the social welfare housing communities have the longest average commuting trips. What surprises is that residents of traditional residential areas have the second longest distance to workplace. This is likely caused by job decentralization to the suburb and residents of traditional residential areas may need to commute reversely from city center to the suburb. Despite of the large variations in trip distances, differences in travel time are less noteworthy. The average commuting time is around 30 minutes for all five types of neighborhoods except for traditional Danwei communities. This could be explained by the different levels of congestion that may be experienced at different places of the city and the differences in transport modes. Somehow verifies an earlier argument about its disadvantaged location, social welfare housing communities have the highest share of motorized transport mode for commuting trips.

Table 5 presents the time use patterns of respondents from different neighborhoods on a normal workday. We differentiate the time used for in-home and out-of-home activities as well as the total time spent for travel during the day. As the table reveals, time use patterns substantially vary between neighborhood types. Residents of traditional Danwei compounds spend the least amount of time for travel but most for out-of-home activities. Residents of commodity housing communities appear to prefer staying at home; they have the most time used for in-home activities and the least for out-of-home activities. Interestingly, although social welfare housing communities and traditional residential areas seem rather opposite in their locations with the former located in the fringe and the latter in the city centre – their residents have similarly the longest travel time and modest time allocated for in-home and out-of-home activities. This reminds us that location may not sufficiently explain the differences of activity-travel behavior in urban China.

(Insert Table 5 about here)

To sum up, these preliminary findings provide some interesting starting points for further analysis. Despite the Danwei and housing reforms, traditional Danwei compounds are found to be still effective in containing travel demand and car dependence. Commodity housing communities and social welfare housing communities, in some ways similar to suburban neighborhoods in U.S. cities, can be generally characterized as automobile oriented communities, which generate demands for long distance travel. To one's surprise, traditional neighborhoods in the city centre are also found to be associated with lone distance trips. All these observations would be examined and further explored in the following section.

4. Multivariate Analysis

4.1 Model structure and variables

While the results of descriptive analyses have shown meaningful variations in car ownership and travel behavior between the different types of neighborhoods in Beijing, suggesting that there are likely associations between built environment and travel behavior, the nature and direction of possible causal relationships remain unknown. Moreover, the neighborhoods differ not only in their origins, but also in location, spatial form, access to public transport, composition of residents, etc. So, what are and how the real factors causing the variations in mobility and travel behavior between neighborhoods: spatial variables, transport accessibilities, or the socio-economics of residents? In other to answer these questions, a structure equations model is developed. Figure 2 depicts the model structure. Before hypothesizing the causal relationships between the variables, we first introduce the exogenous and endogenous variables, which are listed in Table 6 and Table 7 respectively. Exogenous variables include six personal socio-demographics and three households' variables. Definitions of the exogenous variables are presented in Table 6. Variables on built environment, mobility as well as activity-travel behavior are included as endogenous variables. Existing empirical studies usually define built environment by dividing neighborhoods into traditional and suburban (Cao et al., 2006) or simply use built environment variables (Pan et al., 2009). In this study, we use both neighborhood types and spatial variables to characterize the built environment. As shown in Table 7, there are four built environment variables including neighborhood type, distance to the city center, distance to the nearest subway station and living space per capita. Since Beijing is nearly a central symmetric city in shape, the “city centre” here is defined as the intersection of Beijing’s two axes (north-south and east-west axes), which is approximately the front gate of the Forbidden City. It may be arguable to treat Beijing as a monocentric city, but the physical distance to the city centre is an appropriate variable to differentiate the different neighborhoods in location. Distance to the nearest subway station is an indicator of neighborhoods’ accessibility to mass transit. Geometric centroids of the neighborhoods are used in distance measurement. Other variables in the table are self-explanatory.

(Insert Table 6 about here)

(Insert Table 7 about here)

- Built environment, car ownership and activity-travel behavior:

We assume that built environment influences both private car ownership and activity-travel behavior; it impacts directly and indirectly on activity-travel behavior and the indirect impacts are channeled via car ownership. Since housing decisions usually have priorities over private car ownership, the causal relationship of built environment on car ownership is hence supposed to be unidirectional.

While the possible influence of built environment on travel behavior has been widely discussed, that on activity participation and time use has received relatively less attentions in the literature (fan, 2007). Some suggests that built environment is less relevant in explaining variations in time allocation and activity patterns than travel behavior such as travel time, distance, mode choice and trip frequencies (Schwanen, 2003). However, we argue that the pursuit of and time allocation to out-of-home activities are both motivated and constrained by the availabilities of opportunities largely determined by the built environment. Besides, travel behavior is derived from he pursuit of activities. Thus, the possible causal relationships from built environment to activity and time allocation and then to travel behavior is one of the major linkages to be verified in the structural equations model.

- Socio-demographics and the built environment:

One of the major counter arguments against the effects of built environment on travel behavior is residential self-selection, which purports that people with particular travel preferences tend to live in the types of neighborhoods favoring his/her travel preferences.

Though we contest that residential and travel attitudes tend to influence more the choice of transport mode than time allocation and activity participation (Kitamura et al., 1997; Cao et al., 2009), it is justifiable to include this link in the structural equations model to more convincingly establish the possible causal effects of built environment on activity-travel behavior.

However, in the context of urban China, the freedom of choosing where to live has been more determined by institutional factors (e.g., housing policies, types of work-unit, etc) than by personal preferences. As we discussed earlier, before the 1990s, housing were mostly allocated by work-units. After the land and housing reforms, institutional factors, such as housing policies, work-unit factors and *hukou* status, still play important roles in individuals' housing choices (Huang & Clark, 2002; Huang, 2004). The development of housing market has increased the freedom of housing choices. Nevertheless, what types of neighborhoods where individuals may live are more determined by who they are not what they want. For instance, Danwei-based communities are mostly for employees of government and public institutions; Social Welfare Housings are theoretically only provided to citizens with limited income; and Commodity Housings "select" residents by their affordability.

For this reason, we believe that in urban China, individuals' socio-demographic characteristics, not their preferences, determine their built environment.

- Socio-demographics, mobility and activity-travel behavior:

It is well documented in the literature that individuals' socio-demographics are important explanatory factors of mobility and activity-travel behavior (Lu and Pas, 1999). Some even suggest that socio-demographic variables are much more important factors than built environment variables (e.g., Cervero & Duncan, 2003). Thus, in order to better understand the impacts of built environment on car ownership and activity-travel behavior, it is necessary to control socio-demographic variables.

As the causal relations between activities and travel behavior are well examined in the literature (Lu and Pas, 1999), here we focus only on the essential links between these two behaviors. Since we investigate the activity-travel behavior on a normal weekday, most subsistence activities may be compulsory. Paths from obliged subsistence activities to other activities, between maintenance and recreation activities and from these activities to travel time and trip frequency were considered.

(Insert Figure 2 about here)

4.2 Modeling results

Excluding the cases with missing values on key variables, a total of 1044 samples were used for estimating the structural equations model. Tables 9 to12 list the modeling results in details. Goodness-of-fit indicators suggest that the model is highly significant and well fitted. As the tables indicate, most of the causal relations hypothesized in the previous section are verified by the model. In the rest of this section, we shall explain the modeling results.

- Built environment, car ownership and activity-travel behavior

Modeling results presented in Table 8 indicate that built environment have both direct and indirect effects on car ownership and activity-travel behavior. Neighborhood type is proved to have significant impacts on car ownership. Specifically, living in

Traditional Residential Area or Traditional Danwei Compound less likely own private cars, whilst those in Commodity Housing Community more likely to have cars than those from other neighborhoods. Since socio-demographic factors such as income level and family structure have been controlled, this can be considered as the genuine effects of built environment ob car ownership. Understandably, the auto-oriented design of Commodity Housing Communities offers every convenience for private car owners, and its suburban location also implies the need for private car to move around. As for Traditional Danwei Compounds, because of their location and convenience, there is hardly much need for private cars. In addition, these compounds were mostly built in the early years when private car was not considered accessible to most people, so parking space was not allocated, underground garages were not available. The significant negative impact on car ownership of Traditional Residential Areas, however, probably should be attributed to the inconvenience of the built environment rather than the lack of need, because earlier descriptive analysis shows quite long travel distance of their residents.

Neighborhood type also influences activity-travel patterns directly or indirectly. Living in Traditional Residential Area has significant negative direct impacts and positive indirect impacts on time for both maintenance and recreation activities. On the other hand, living in Social Welfare Housing Community has significant positive direct impacts but negative indirect impacts on time for all types of out-of-home activities. These indirect relationships could be ascribed to mediating variables including car ownership, built environment variables and other activities. Commodity Housing Community impacts negatively on out-of-home subsistence activities. Generally speaking, the impacts of neighborhood types on activity patterns are less significant than those on travel behaviors, which somehow verifies similar findings reported in the literature.

The significant positive impacts on trip frequency and negative impacts on total travel time of Traditional Danwei Compound residence meet our expectations. Social Welfare Housing Community has negative indirect impact on trip frequency but positive total impact on daily travel time. In other words, Traditional Danwei Compound residents tend to have more daily trips but spend less travel time, whilst residents of Social Welfare Housing Community have few daily trips but spend more time for travel. This is partly because of the jobs-housing proximity of the former and the fact that the latter is usually located in the suburbs. As residents of Social Welfare Housing Community generally travel towards the city centre, it's more convenient to pursue as many out-of-home activities as possible in the same trip, thus their travel distance and time are usually longer; on the other hand, Traditional Danwei Compound residents are more likely to work near their home and thus can easily make more trips. In addition, Traditional Residential Area has significant positive impact on daily travel time but no positive impact on daily trips, which again associate traditional neighborhoods in city centre with longer travel. These findings mostly agree with the previous assumptions and results of the descriptive analysis.

Other built environment variables are found to affect activity-travel behavior significantly as well. As expected, distance to city center and accessibility to transit significantly impacts on trip frequency and activity patterns. As the distance to city centre increases, residents tend to have less time on out-of-home subsistence and maintenance activities, fewer trips but more time spent on recreation activities. The proximity to mass transit railway station is found to significantly reduce car ownership and naturally induces more trips and time for out-of-home subsistence activities. Larger living space could provide more chances for in-home activities, and hence presents negative impacts on time for out-of-home maintenance and recreation activities.

Interestingly to note is that the model does not reveal significant impacts of auto ownership on activity-travel behavior

(Insert Table 8 about here)

- Socio-demographics and built environment

Table 9 reveals some important relations between socio-demographics and built environment. As a result of the differences in the history of community development, residents of different neighborhoods have different age structures. It appears that residents of the Traditional Danwei Compounds are significantly older and those of the Commodity Housing Communities are significantly younger. It's worthy to note that the possession of Beijing *hukou* and the fact of being employed seems more likely living closer to the city center and in traditional communities, especially Traditional Danwei Compounds. People without Beijing *hukou*, most of whom flooded into Beijing to make a living after the economic reform, tend to live in Commodity Housing Communities. Meanwhile, individuals with higher income, education and larger families are more likely living in suburban and newly built neighborhoods with larger living space. Particularly, income level has the largest positive coefficient on Traditional Danwei Compound, indicating considerable connection between Danwei Compound and high income residents. Household variables might work better in this part of the model, because residential choice is more of a household matter. These results in general accord with our earlier description of resident composition of different neighborhoods.

(Insert Table 9 about here)

- Socio-demographics and car ownership

As shown in Table 10, most of socio-demographic variables have significant impacts on car ownership. As expected, both education and income level have positive effects on car ownership. Owning private cars is not only an indication of financial affordability, but also a sign of social status. Hence car ownership seems higher for people with higher education and more decent professions. Interestingly, the possession of Beijing *hukou* negatively influences auto ownership. It's partly due to the negative indirect effects via built environment, given the relations between *hukou* and neighborhood types shown in Table 9. While floating population has become a synonym for the poor and underprivileged in urban China, another group also without Beijing *hukou* yet ranks among the upper class in the city. They usually have middle to high income and education levels. Since they have only been in Beijing in the recent decades, there are fewer chances for them to live in traditional neighborhoods or work in traditional work-units. Moreover, they could seldom enjoy social welfare housings as they are not "de jure" citizens. Consequently, it's easy to understand why they tend to live in Commodity Housing Communities and are more likely to have private cars.

Household variables also strongly influence car ownership. Understandably, larger families are more likely to own private cars. Numbers of working members and the presence of kids under 12 also have positive impacts on car ownership. Actually, the number of working members directly determines household income level, whilst the presence of kids might need more maintenance trips. On the whole, income still proves to be the most important influential factor on auto ownership.

(Insert Table 10 about here)

- Socio-demographics, activities and travel behavior

The causal relationships of socio-demographics on activities and travel behavior are listed in Table 10 and Table 11. Generally speaking, age, employment status, income level and the number of kids have more significant influences upon activity-travel patterns. Gender is found to have positive impacts on subsistence activities and negative impacts on maintenance activities, which coincide with the common sense of the division of labour between the two genders (working husbands and housewives). With the increase of age, individual tends to have less time on out-of-home subsistence and maintenance activities, more time on recreation activities, more trips and less total travel time. *Hukou* status mainly impacts on time for subsistence activities. Education level has positive impacts on total travel time. Understandably, employment status has significant positive effects on time for subsistence activities and on daily total travel time, but negative effects on time for other activities. Income level positively affects time for out-of-home subsistence and maintenance activities, and negatively influences recreation activities, total travel time and daily trips. As for the family structure, larger family size may lead to more travel time, and number of kids negatively impacts on time for all types of activities. As for impacts of activities on travel behavior, as shown in Table 11, the modeling results in general confirm earlier findings reported in the literature. For example, more time for out-of-home activities motivate more trips and longer travel time; duration of subsistence activities negatively impacts on time for other activities.

(Insert Table 11, about here)

It is also interesting to see the correlations between neighborhood types and spatial variables in Table 12, which shows that different neighborhood types vary significantly in the distance to city center, accessibility to nearest subway stations and average living space. This result confirms our earlier classification of neighborhood types and helps improve our understanding of the built environment diversities in Beijing.

(Insert Table 12 about here)

5. Discussions and Conclusion

Urban China has been undergoing a process of spatial restructuring from Danwei-based built environment to a new urban landscape rich in socio-spatial diversities. The spatial restructuring has changed the distribution of jobs, housing, shopping and other opportunities. As various new types of neighborhoods have emerged and daily life in urban China has become diversified, it is possible to establish connections between built environment and activity-travel patterns in Chinese cities.

This paper shows that residents of different neighborhoods demonstrate substantial differences in car ownership, time use patterns and travel behavior. Although the Danwei system had changed since the reform policies were introduced, Traditional Danwei Compound is still found to significantly reduce residents' travel time, distance and automobile reliance. On the other hand, the newly developed built environments, such as Commodity Housing Community and Social Welfare Housing Community, are proved to induce more travel time, longer trips, more private cars and less time on out-of-home activities. In addition, accessibility to public transit presents significant containing effects on private automobiles. It is also found that large living space would probably reduce time for out-of-home activities. The study shows that built environment factors, including neighborhood types and other spatial variables, have significant genuine effects on car ownership and activity-travel behavior. However, built environment effects on travel behavior in terms of daily travel time and trip frequency are found stronger than those on time allocation for out-of-home activities. Relations between socio-demographics and built environment as well as activity-travel behavior are also examined in the analysis.

Similar to research findings in U.S. cities, newly built, auto-oriented, suburban neighborhoods in Beijing are also associated with more automobile use and longer trips. On the other hand, however, residents of the traditional neighborhoods in the city centre, though have lower car ownership, seem not to have shorter trips either. Hence we may wonder, whether the traditional "pedestrian/cyclist-friendly" style encourage the use of non-motorized transports modes, or people living in these neighborhoods just can not afford cars. Do the traditional neighborhoods contain automobile dependence or individuals' mobility? Another notable finding in this study is that, Traditional Danwei Compound residents still have the shortest travel budgets and thus have more time to pursue more out-of-home activities. This finding further verifies the findings of an earlier study on the association between the jobs-housing relationship and travel behavior (Wang and Chai, 2009). Nevertheless, Reformed Danwei Community, which quite resembles Traditional Danwei Compound in both location and design, does not have similar effects on travel behavior.

This study has some limitations. Firstly, we didn’t compare activity patterns and travel behavior on the workday with that on weekend, so the effects of non-work trips might be underestimated. Secondly, the discussion of auto mobility and car reliance could have been combined with modal split of trips for different purposes. Nevertheless, it provides a meaningful perspective for future study as well as urban planning and traffic management. The built environment, residential distribution and individual life style in Chinese cities are still changing along with the processes of urbanization, suburbanization and market development. Further researches are expected to trace these changes and extend current knowledge on the relationships between built environment and activity-travel behavior.

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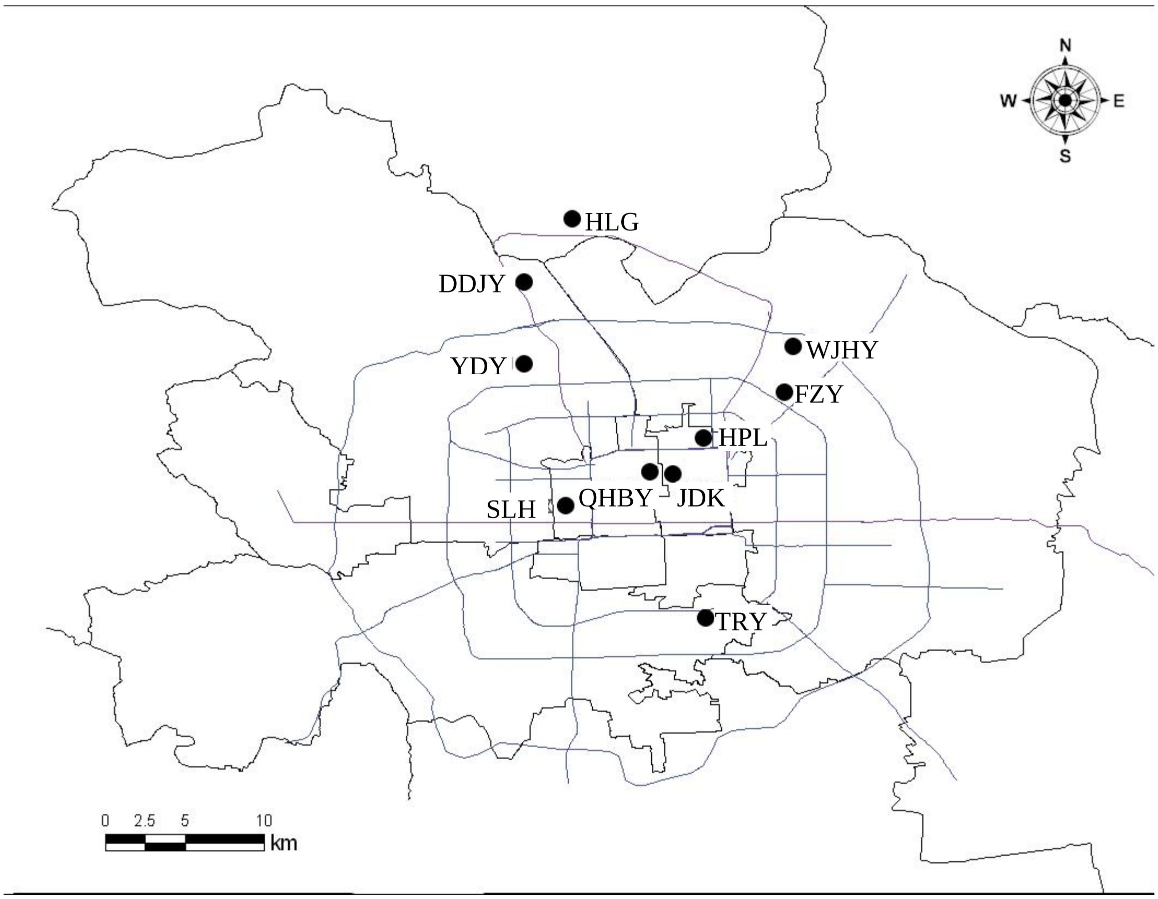

Figure 1 Location of sampled neighborhoods

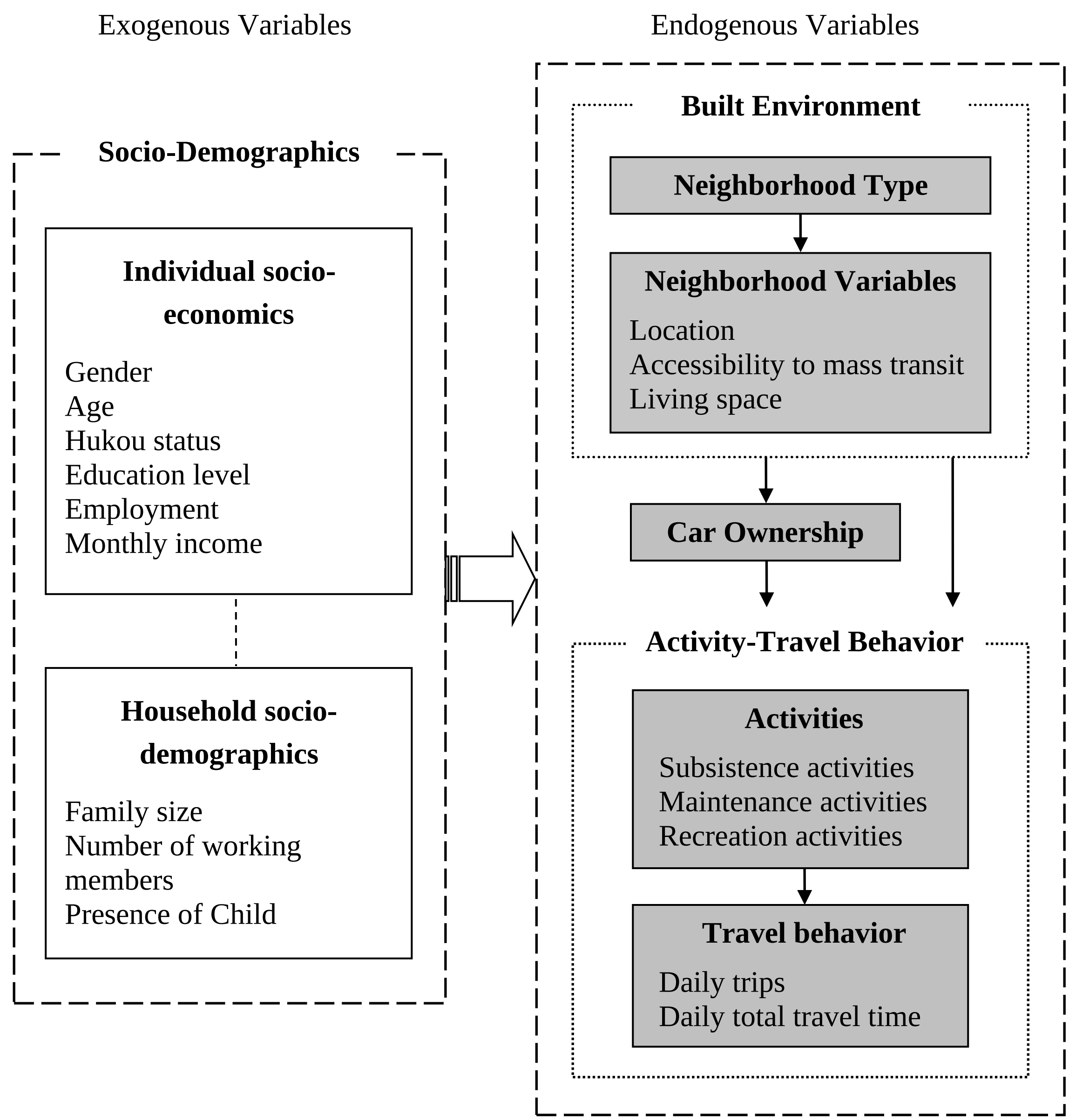

Figure 2 Model structure

Table 1 Five typical residential types in urban China

Neighborhood Type	Age of Construction	Builder	Location in the City	Composition of Residents
Traditional Residential Area (TRA)	Before 1949	Self-built	Old city centre / rural urbanization areas*	Original inhabitants & migrants
Traditional Danwei Compound (TDC)	1950s - 1970s	Danwei & the state	Surrounding the old city centre	Danwei employees
Reformed Danwei Community (RDC)	1950s - 1970s Renewal in 1980s - 1990s	Danwei	Surrounding the old city centre	Mixed
Commodity Housing Community (CHC)	1980s till now	Real estate developers	Suburban & renewal areas**	Mid-to-high income group
Social Welfare Housing Community (SWC)	1980s till now	The state, Danwei & real estate developers	Suburban area	Low-to-mid income group

* *This research mainly focuses on Traditional Residential Areas in old city centre.*

** *This research mainly focuses on Commodity Housing Communities in suburban areas.*

Table 2 Sampled neighborhoods

Neighborhood Type	Name (abbreviation) (Sample size)	Age	Composition of Residents
Traditional Residential Area (TRA）	Jiao-Dao-Kou (JDK) Qian-Hai-Bei-Yan (QHBY) （216）	Before 1950s	Floating, aged or low income population
Traditional Danwei Compound（TDC)	Yan-Dong-Yuan (YDY) San-Li-He (SLH) （196）	1950s Renewal in 1990s	Employees of universities and civil servants and their families
Reformed Danwei Community (RDC)	Tong-Ren-Yuan (TRY) He-Ping-Li (HPL) （230）	1950s - 1970s Renewal in 1980s - 1990s	Employees and retirees from various stated-owned enterprises
Commodity Housing Community (CHC)	Dang-Dai-Cheng-Shi-Jia-Yuan (DDJY) Fang-Zhou-Yuan (FZY) （206）	Late 1990s - early 2000s	White-collar or private entrepreneurs with high income
Social Welfare Housing Community (SWC)	Wang-Jing-Hua-Yuan (WJHY) Hui-Long-Guan (HLG) （259）	Late 1990s - early 2000s	Residents with middle-to-low income

Table 3 Sample profiles

Frequencies (%)		TRA	TDC	RDC	CHC	SWC
Gender	Male	50.00	46.40	48.48	50.96	50.38
	Female	50.00	53.60	51.52	49.04	49.62
Age	16-18	4.13	4.59	3.04	0.48	2.68
	19-39	33.03	33.16	33.04	68.75	50.57
	40-59	58.26	56.63	48.26	19.71	32.18
	>60	4.59	5.61	15.65	11.06	14.56
Education	Primary	16.51	8.67	16.88	6.25	11.11
	Secondary	39.45	27.55	32.47	8.65	18.39
	Tertiary	44.04	63.78	50.65	85.10	70.50
Employment	Full time	49.54	70.92	58.44	67.31	60.69
	Part time	13.30	7.65	4.33	3.37	4.58
	Student	6.88	5.61	4.76	0.96	3.05
	Unemployed	30.28	15.82	32.47	28.37	31.68
Monthly Household Income (RMB)	0 - 3000	55.56	15.22	26.17	4.04	18.10
	3000 - 10000	43.43	79.35	65.42	64.65	66.38
	> 10000	1.01	5.43	8.41	31.31	15.52
Total samples (Households)		99	92	107	99	116
Total samples (Individuals)		216	196	230	206	259

Table 4 Car ownership and distance, travel time as well as transport mode to workplace and the most frequently visited shop and entertainment place

		TRA	TDC	RDC	CHC	SWC
Car ownership	Percentage of households with a private car	13.00	23.91	32.41	61.39	46.22
Trip to workplace	Average distance (km)	9.16	3.68	7.92	8.91	11.87
	Average travel time (min)	30.02	21.71	26.45	30.19	36.95
	Transport mode#	42.57	20.00	61.45	67.70	73.15
Trip to most frequently visited shop	Average distance (km)	4.31	1.98	3.34	4.64	3.67
	Average travel time (min)	17.16	15.90	17.75	20.12	15.71
	Transport mode#	18.45	20.65	35.85	62.89	41.30
Trip to the most frequently visited entertainment place	Average distance (km)	1.91	1.84	4.29	6.04	2.76
	Average travel time (min)	20.64	15.32	21.25	18.85	10.83
	Transport mode#	17.07	19.42	33.91	64.93	38.82

#: transport mode is measured by share of motorized transport modes including car, bus and train, etc.

Table 5 Time use on a normal workday (minutes): in-home, out-of-home and travel

Neighborhood		In-home		Out-of-home		Travel	
	N	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**
TRA	198	868.33	228.09	477.23	212.94	94.44	64.82
TDC	184	872.99	198.30	498.93	185.52	68.08	48.35
RDC	222	889.74	214.95	467.59	199.34	82.68	51.62
CHC	197	937.92	244.56	411.37	226.21	90.72	58.49
SWC	243	873.44	238.13	469.37	214.26	97.19	62.41

Table 6 Exogenous variables

Variable Name	Description
gender	Female=0, Male=1
age	16-18=1, 19-29=2, 30-39=3, 40-49=4, 50-59=5, 60-69=6, 70 or above=7
hukou	1 for Beijing citizen, otherwise 0
edu	Education attainment: 1 for tertiary level or above, otherwise 0
employ	Employment status: 1 for employee or student, otherwise 0
income	1 if monthly income > 2000 RMB, otherwise 0
famsize	Number of household members
worker	Number of household members in the workforce
Kid	Number of 0-12 years old children in the household

Table 7 Endogenous variables

Category	Variable Name	Description
Neighborhood Type	Tra	1 for TRA residents, otherwise 0
	Tdc	1 for TDC residents, otherwise 0
	Rdc	1 for RDC residents, otherwise 0
	Chc	1 for CHC residents, otherwise 0
	Swc	1 for SWC residents, otherwise 0
Neighborhood Variables	cdis*	Distance to the city centre (km)
	sdis*	Distance to the nearest subway station (km)
	Perarea	Living space per capita (sq meters)
Mobility	Car	1 for private car owners, otherwise 0
Activities	Sub	Duration of out-of-home subsistence activities on a day (minutes)
	Mtn	Duration of out-of-home maintenance activities on a day (minutes)
	Rec	Duration of out-of-home recreation activities on a day (minutes)
Travel Behavior	Trip	Number of daily trips
	Time	Daily total travel time (minutes)

*: Distance measurement from Google Earth positioning system.

Table 8 Total, direct and indirect effects between built environment, car ownership and activity-travel behavior

		Neighborhood type					Neighborhood variables			Car Ownership
		TRA	TDC	RDC	CHC	SWC	Location	Accessibility	Living space	
Car Ownership	Total	-0.1382***	-0.1178***	0.0214	0.1469***	0.0581	-0.0010	0.0862**	-	-
	Direct	-0.1409**	-0.1270***	0.0590	0.1543***	0.0359	-0.0010	0.0862**	-	-
	Indirect	0.0028	0.0092	-0.0376*	-0.0075	0.0221	-	-	-	-
Subsistence Activities	Total	0.0394	0.0134	0.0048	-0.0673**	0.0159	-0.0966*	-0.0851***	-0.0182	-
	Direct	-0.0186	0.0145	-0.0569	-0.0430	0.1016**	-0.0966*	-0.0851***	-0.0182	-
	Indirect	0.0581	-0.0011	0.0617***	-0.0244	-0.0857**	-	-	-	-
Maintenance Activities	Total	0.0133	-0.0210	0.0640	-0.0571	0.0118	-0.1386**	-0.0086	-0.2542***	-0.0164
	Direct	-0.2215**	-0.0551	-0.0088	0.0785	0.2308***	-0.1973**	-0.0247	-0.2392**	-0.0153
	Indirect	0.2348***	0.0341	0.0728*	-0.1356***	-0.2190***	0.0588	0.0162	-0.0150	-0.0011
Recreation Activities	Total	-0.0256	0.0135	0.0200	-0.0409	-0.0184	0.0624	-0.0065	-0.0349	-0.0020
	Direct	-0.1753**	-0.0075	0.0121	-0.0323	0.1387**	-0.0867	-0.0637	-0.2098**	-0.0126
	Indirect	0.1497**	0.0210	0.0079	-0.0085	-0.1571**	0.1491***	0.0572**	0.1749***	0.0106
Daily trips	Total	-0.0053	0.0729**	0.0564	-0.0529	-0.0438	-0.1292**	-0.1674***	0.0184	-0.0052
	Direct	-0.0242	0.0839**	-0.0592	-0.0328	0.0603	-0.1289**	-0.1641***	0.0555	-0.0028
	Indirect	0.0189	-0.0110	0.1156***	-0.0200	-0.1041**	-0.0003	-0.0033	-0.0370	-0.0023
Daily total travel time	Total	0.1187**	-0.0992***	0.0297	0.0453	0.1170***	0.0513	0.0035	-0.1114	-0.0243
	Direct	0.0957	-0.1048***	0.0431	0.0741	0.0993	0.0685	0.0152	-0.0776	-0.0223
	Indirect	0.0230	0.0056	-0.0134	-0.0288	0.0177	-0.0172	-0.0117	-0.0338**	-0.0020

*: significant at 0.10 level; **: significant at 0.05 level; ***: significant at 0.01 level. All activities are out-of-home.

χ^2=21.77 (df = 27)，P-Value for Test of Close Fit (RMSEA < 0.05) = 1.00

Table 9 Effects of socio-demographics on choice of residential place

		age	hukou	edu	employ	imcome	famsize	worker	kid
TRA		-0.0177	0.0773**	-0.0665*	0.0708*	-0.2116***	-0.0605*	-0.1169***	-0.0314
TDC		0.1183***	0.1524***	-0.0631*	0.1439***	0.1534***	-0.1248***	-0.0109	0.0610*
RDC		0.0573	0.0883***	-0.0710*	-0.0264	-0.0100	0.1188***	0.1012***	-0.2170***
CHC		-0.1200***	-0.3148***	0.1070***	-0.0998**	0.0774**	-0.0504	0.0028	0.2185***
SWC		-0.0311	-0.0097	0.0889**	-0.0791*	0.0147	0.0996**	0.0268	-0.0143
Location: cdis	Total	-0.0638*	-0.1603***	0.1101***	-0.0759*	0.0718*	0.0522	0.0023	0.0749**
	Direct	-	-	-0.0261	0.0359**	-0.0551***	-0.0025	-0.0482***	-0.0403**
	Indirect	-0.0638*	-0.1603***	0.1362***	-0.1118***	0.1269***	0.0546*	0.0505*	0.1152***
Accessibility: sdis	Total	-0.0113	0.0031	0.0287	-0.0378	0.1022***	-0.0014	-0.1133***	0.2144***
	Direct	-	-	-0.0085	-0.0539*	0.0898***	0.0350	-0.0715**	0.1355***
	Indirect	-0.0113	0.0031	0.0373*	0.0161	0.0124	-0.0365*	-0.0418**	0.0788***
Living space: perarea	Total	-0.0466	-0.1679***	0.1841***	-0.1557***	0.1778***	0.0038	0.1314***	0.0604*
	Direct	-	-	0.0701***	-0.0399***	0.0183	-0.0613***	0.0443***	-0.0243
	Indirect	-0.0466	-0.1679***	0.1140***	-0.1158***	0.1595***	0.0651**	0.0871***	0.0847***

*: significant at 0.10 level; **: significant at 0.05 level; ***: significant at 0.01 level. Effects of socio-demographics on neighborhood types are all direct.

Table 10 Total, direct and indirect effects of socio-demographics on car ownership and activity-travel behavior

		gender	age	hukou	edu	employ	income	famsize	worker	Kid
Car Ownership	Total	-	-0.0152	-0.0964***	0.0714*	-0.0014	0.1776***	0.0980***	0.1022***	0.0824**
	Direct	-	0.0145	-0.0229	0.0361	0.0498	0.1466***	0.0710**	0.0868**	0.0468
	Indirect	-	-0.0297**	-0.0735***	0.0353***	-0.0512***	0.0310**	0.0270**	0.0155	0.0355**
Subsistence Activities	Total	0.0857***	-0.1455***	0.0872***	-0.0329	0.5240***	0.0765**	0.0111	0.0239	-0.0387
	Direct	0.0857***	-0.1543***	0.0607**	-0.0253	0.5121***	0.0905***	0.0112	0.0180	-0.0151
	Indirect	-	0.0087	0.0266**	-0.0076	0.0119	-0.0140	-0.0001	0.0059	-0.0236**
Maintenance Activities	Total	-0.0607*	-0.0519	-0.0518	-0.0116	-0.2130***	0.0609	-0.0028	0.0325	-0.0429
	Direct	-0.0408	-0.1164**	-0.0419	-0.0093	0.0540	0.1162**	-0.0156	0.0337	0.0061
	Indirect	-0.0200	0.0645**	-0.0099	-0.0022	-0.2670***	-0.0553*	0.0127	-0.0012	-0.0490*
Recreation Activities	Total	0.0023	0.0428	-0.0147	0.0169	-0.2524***	-0.0401	-0.0182	0.0059	-0.0756**
	Direct	0.0163	-0.0996**	-0.0393	0.0198	-0.0847*	0.0635	-0.0351	0.0381	-0.0868**
	Indirect	-0.0140	0.1424***	0.0247	-0.0029	-0.1677***	-0.1036***	0.0169	-0.0321	0.0112
Daily trips	Total	-0.0449	0.2402***	0.0171	-0.0324	-0.0496	-0.0741*	-0.0471	-0.0133	0.0464
	Direct	-0.0393	0.2195***	-0.0005	-0.0286	0.0165	-0.0715*	-0.0273	-0.0413	0.1014***
	Indirect	-0.0057	0.0207	0.0176	-0.0038	-0.0661**	-0.0026	-0.0197	0.0280**	-0.0550***
Daily total travel time	Total	0.0299	-0.0384	-0.0089	0.1282***	0.1349***	-0.0434	0.0798**	-0.0479	-0.0202
	Direct	0.0282	0.0004	0.0150	0.1246***	0.1562***	-0.0119	0.0615	-0.0376	-0.0009
	Indirect	0.0017	-0.0388***	-0.0239	0.0036	-0.0213	-0.0315**	0.0183	-0.0103	-0.0193

*: significant at 0.10 level; **: significant at 0.05 level; ***: significant at 0.01 level.

Table 11 Effects between activities and travel behavior

	Subsistence activities	Maintenance activities	Recreation activities
Maintenance activities	-0.2479***	-	0.5578***
Recreation activities	-0.6201***	-0.6438	-
Daily trips	0.0059	0.1108***	0.2511***
Daily total travel time	0.0952**	0.1103***	0.1161***

*: significant at 0.10 level; **: significant at 0.05 level; ***: significant at 0.01 level. All activities are out-of-home. All effects are direct. Indirect causal links between activity-travel behaviors are simplified in this model.

Table 12 Effects of neighborhood type on spatial variables

		TRA	TDC	RDC	GC	SWC
Location:	cdis	-0.4994***	-0.0685***	-0.2496***	0.2652***	0.5910***
Accessibility:	sdis	0.0262	0.1056***	-0.4389***	-0.0835**	0.2636***
Living space: perarea		-0.6638***	-0.0719***	-0.0127	0.3216***	0.3377***

*: significant at 0.10 level; **: significant at 0.05 level; ***: significant at 0.01 level. All effects are direct.