Chin. Geogra. Sci. 2013 Vol. 23 No. 4 pp. 492–505
doi: 10.1007/s11769-013-0616-7

Springer Science Press
www.springerlink.com/content/1002-0063

Residents′ Activity-travel Behavior Variation by Communities in Beijing, China

ZHAO Ying, CHAI Yanwei

(*Department of Urban and Economic Geography*, *College of Urban and Environmental Sciences*, *Peking University*, *Beijing* 100871, *China*)

Abstract: China′s transition from a planned economy to a market economy has resulted in many changes in its urban structure and society and provided an opportunity for a quasi-longitudinal case study on the relationship between the built environment and activity-travel behavior. This paper draws upon data from an activity diary survey conducted in Beijing in 2007. The survey sample comprised 652 residents living in *Danwei* (work unit), commodity housing, and affordable housing neighborhoods. On the basis of the three-dimensional geo-visualization analysis of the space-time path and statistical multivariate regression models of daily travel and leisure time, it was found that both residential spatial factors and socio-demographics influence residents′ daily behaviors. The findings show that *Danwei* residents have less daily travel time than those who live in commodity housing, but people living in affordable housing endure the longest travel time. Daily leisure time is associated more with individual attributes. We argue that although China′s transition is currently gradual, the *Danwei* system may continue to play significant roles in daily life, and it might provide a valuable model for neighborhood spatial planning.

Keywords: built environment; activity-travel behavior; *Danwei* (work unit); housing reform; Beijing

Citation: Zhao Ying, Chai Yanwei, 2013. Residents′ activity-travel behavior variation by communities in Beijing, China. *Chinese Geographical Science*, 23(4): 492–505. doi: 10.1007/s11769-013-0616-7

1 Introduction

Over the last three decades, China has transited from a planned economy to a market economy, which has resulted in many changes in society (Ma, 2002). Housing reform in urban China has been a crucial part of this institutional transition, and it has introduced market mechanisms into a previously welfare-oriented system (Wang and Murie, 2000). China′s starting point, in terms of housing reform, is very different from that seen in western countries. For example, the *Danwei* (work unit) was the traditional form of residential space for decades, but it was not easy to dismantle the *Danwei* system′s influence immediately after the housing transition (Wang and Chai, 2009). Meanwhile, commodity housing and affordable housing neighborhoods, supported by positive policy from the central government, appeared in the housing system and now account for a considerable proportion of the housing market (State Council, 1994; 1998).

The promotion of housing reform in China tremendously expanded urbanized areas in cities and further affected activity-travel behavior of urban residents. For example, the urbanized area of Beijing increased from 488.3 km^2 in 1998 to 1310.9 km^2 in 2008 (National Bureau of Statistics of China, 1999; 2009). The individual ownership of automobiles more than doubled during the 2004–2009 period, reaching 3 × 10^6 by 2009 (Beijing Statistical Bureau, 2010). Because of the historic nature of the downtown and the *Danwei* zones that occupy the

Received date: 2012-11-01; accepted date: 2013-01-31
Foundation item: Under the auspices of National Natural Science Foundation of China (No. 40671058, 41071102), National 'Twelfth Five-Year' Plan for Science and Technology Support (No. 2012BAJ 05B04)
Corresponding author: CHAI Yanwei. E-mail: chyw@pku.edu.cn

city centers, commodity and affordable housing are usually built beyond the city centers (Wang and Murie, 2000), which changes the original landscape and produces a particular spatial pattern. On the other hand, new residential areas that do not follow *Danwei*'s job-housing principle are built and are criticized for being long-travel-oriented, automobile-oriented, and for worsening traffic conditions (Pan *et al*., 2009). Although some studies have investigated the relationship between the built environment and travel behavior (Schwanen and Mokhtarian, 2005; Cao *et al*., 2007; Wang *et al*., 2011), most studies are based on a western theory background; they focus only on travel and ignore the importance of the activity-travel interaction and daily patterns.

By focusing on individual daily patterns, this paper investigates changes in residents' activity-travel behaviors in different neighborhoods. We hypothesize that residents' behaviors in daily life are affected not only by individual socio-economic factors but also by spatial and institutional factors that are unique to China and are represented by neighborhood type. The paper's contributions are twofold. First, the research is based on the Chinese context to make up for the deficiency of research focusing on the interaction between built environments and behavior in the developing world. China's fast-paced economic growth and socialist system together provide a valuable and relatively unique case to be studied. Second, the paper attempts to define individual behavior as an integrated pattern consisting of activity and travel, following the viewpoint that travel is derived from activity demand in an activity-based approach. In particular, we apply three-dimensional geo-visualization to observe general behavior, and test travel time as a fixed constraint and leisure time as a flexible counterpart to determine individual behavior patterns.

2 Study Background

2.1 Spatial restructuring in China: housing and institutional change

China's housing transition was completed in stages. From 1949 to 1978, the housing system was dominated by public rental housing for the welfare-oriented housing system (Huang, 2004). The *Danwei* was the fundamental social-spatial unit of urban China (Bray, 2005). It was designed to provide most of the basic material necessities and other welfare needs to its members, including housing and daily life facilities such as dining halls, bathrooms, and shops. The *Danwei* also included facilities for education (e.g., kindergarten), recreation (e.g., sport fields), and medical care facilities (e.g., clinics) (Chai, 1996). The *Danwei* compound actually became a self-contained community where people worked and lived, often without having to leave the area.

Economic reform took place in 1978 and the government began to focus on economic development. In the housing sphere, a national reform program began in 1988, which aimed to increase housing consumption by creating a housing market and realizing housing privatization (Li and Huang, 2006). In 1998, welfare allocation of housing finally came to an end and a transition to increased home ownership began. Some people bought housing from *Danwei*, and some bought commodity housing from the market. Consequently, as urban residents were no longer accommodated within *Danwei* and residents could freely choose residential places, their activity space extended beyond *Danwei* (Huang, 2003).

A special type of housing with government-controlled prices targeting mid- or low-income groups, called affordable housing, had also been promoted because of the high prices of commodity housing, especially in big cities like Beijing and Shanghai (State Council, 1998). Affordable housing is usually for sale at prices lower than the market price. But affordable housing is usually located in suburbs where infrastructures are not well developed, in order to reduce construction costs. For all these reasons, new urban spatial structures have emerged with respect to different types of neighborhoods.

There are only a few studies that explore the urban housing process and its relationship with behavior patterns in Chinese cities. The contextual discussion of Chinese housing reform (Wang and Murie, 2000) and urban spatial transformation coordinated with traffic composition (Gaubatz, 1999) provided valuable insight into distinctive patterns by viewing socialist ideals in China at the country level. One important case study by Pan *et al*. (2009) examined the effects of urban spatial transformation on travel in Shanghai. It demonstrated that residents in traditional neighborhoods travel shorter distances and provided evidence on how to slow down motorized modes by building pedestrian/cyclist-friendly urban forms. Along with the case study in Beijing, another study by Wang and Chai (2009) investigated the impacts of the reform and the influence of *Danwei* on job-housing relationships and commuting behavior, and found that *Danwei* housing commuters have shorter commuting trips and higher usage of non-motorized transport mode than those in commodity housing. Another study characterized the built environment into different types of neighborhoods and discussed the interaction between urban space and activity-travel behavior (Wang *et al*., 2011). The result illustrated the significant differences in behavior indicators among residents of different neighborhood types.

2.2 Activity-travel pattern studies based on time geography

Hagerstrand′s (1970) time-geographic framework has been widely used to analyze constraints on residents′ activity-travel behavior in an urban space. It recognizes that activity participation has both spatial and temporal dimensions, which means that activities occur at specific locations for limited time periods. The basic conceptual tool in this framework is the space-time path tracing a movement in space and time at the disaggregated level, which is a powerful representation of activity-travel patterns (Miller, 2005). Because time can not be turned back and one person can not appear in more than one place at the same moment, the path in the form of a single line represents one person in geographic space. The slope of the space-time path shows travel capability from one location to another. The extent might show how much urban space one can reach, and the number of stops might present the number of facilities one can utilize.

A time-geography approach has been developed to explore individual activity engagement under spatial constraints, considering temporal impacts. The first notable experiment is Program Evaluating the Set of Alternative Sample Path (Lenntorp, 1978), which provided a calculation of an individual′s reach to access how to utilize public transportation. The last decade has witnessed a resurgence in time-geography approaches because of the availability of individual-level data and improvements in geo-computational capabilities of Geographical Information System (GIS) (Kwan, 2000; Shaw and Yu, 2009). Kwan and Lee (2004) have used three-dimensional geo-visualization to analyze six days of GPS-recorded travel data and found that female drivers largely use highways and major arterials in more or less the same time. Ahmed and Miller (2007) have applied space-time mapping techniques to explore, visualize, and analyze urban space distortions introduced by the transportation system. Some studies have also focused on simulation models to assess the effects of planning measures on the choice of opportunities and activities, and these results have helped to assess whether urban policies can improve quality of life (Dijst *et al*., 2002; Van Eck *et al*., 2005).

The analysis of activity-travel patterns based on a space-time path is also helpful to monitor the geographical distribution and mobility for different population subgroups. Kwan (1999) investigated gender differences in her comparison of space-time paths and the interaction between fixed and flexible constraints. The results showed that women encounter higher levels of fixed constraints and tend to share more domestic responsibility. Kwan and Lee (2004) also studied three-dimensional space-time paths of African Americans and Asian Americans and indicated that Asian Americans are more spatially scattered than African Americans. Janelle and Goodchild (1988) extended the spatial behavior research and coordinated it with a temporal dimension as they explored variations among subpopulations. Chen *et al*. (2011) develop an ArcGIS extension to facilitate exploratory analysis between subgroups with varied social-demographics. In general, three-dimensional geo-visualization is a powerful approach to examine activity-travel patterns in space and time simultaneously at the disaggregated level, and it has potential to be fruitfully applied in geographic studies.

2.3 Built environment and activity-travel behavior

A large number of geographical studies have discussed the impacts that the built environment has on activity-travel patterns. On the basis of travel distance and automobile dependence analysis, earlier studies have shown that high density, high accessibility, and mixed land use developments influence residents to drive less and walk more (Cervero, 1996; Handy, 1996; Ewing and Cervero, 2001). However, studies in which travel time as a better measure than distance is the dependent variable are relatively few. Recent studies have contributed to the study of travel time by identifying trip purpose and transport mode. Schwanen *et al*. (2002) found that travel time for car drivers tends to increase with the degree of urbanization of the residential environment. Fan (2007) examined activity and travel time allocation influenced by urban form and demonstrated the association between compact developments and the use of more walking and less driving travel.

Some researchers argue that residents' behaviors are impacted more by personal preference than by the built environment. This is called 'self-selection'. Some studies have illustrated that personal attitudes to residential environment, rather than physical land use characteristics, are the true determinants of travel behavior (Schwanen and Mokhtarian, 2005; Cao *et al*., 2006; 2009). Meanwhile, socio-demographics are relatively important factors for studying activity-travel behavior. Travel time and leisure time are likely high for men and might increase with age (Kwan 1999; Schwanen *et al*., 2002). For employment status, there might be a positive association between commuting time and work duration, and a passive relationship between leisure time and work duration (Schwanen and Dijst, 2003). Income and car ownership are related, and their influences are confusing because of the balance between increased opportunities and transport efficiency (Schwanen *et al*., 2002).

Particular attention has been paid to non-work travel time because of the time budget hypothesis: if an individual spends less time on work-related activity and travel, he or she might spend more time on non-work behavior. Although the causal relationship between the spatio-temporal environment and activity-travel was shown to be weak from evidence of the Netherlands (Schwanen and Dijst, 2003), some studies have identified that residential context primarily affects the propensity of shopping activities by car, and a high degree of urbanization encourages daily travel time for leisure activities (Schwanen *et al*., 2002). Fan and Khattak (2009) found that residents with high accessibility to parks and shops are more likely to participate in recreational and shopping activities. Also, recent studies show that built environment characteristics such as increased net residential densities and enhanced street connectivity are associated with more physical activities, which might help create healthier and more livable neighborhoods (Handy *et al*., 2002; Bodea *et al*., 2009; Ding and Gebel, 2012).

In summary, studies on the impact of the built environment on residents' activity-travel behavior suggest the important contribution made by this paper. First, most studies are based on cities in the United States and Europe, but China's cities have different backgrounds (such as socialist developments) and drastic changes over recent history. Second, time is an important dimension to measure activity-travel behavior. Many studies treat daily behaviors as separate episodes defined by purpose or mode, but these studies need an advanced perspective to examine behavior at the individual level as a time-consequent process with a time-budget consideration. The data and methods in China allow us to conduct research from the individual integration perspective.

3 Research Design

3.1 Framework

Figure 1 provides a theoretical framework for the activ-

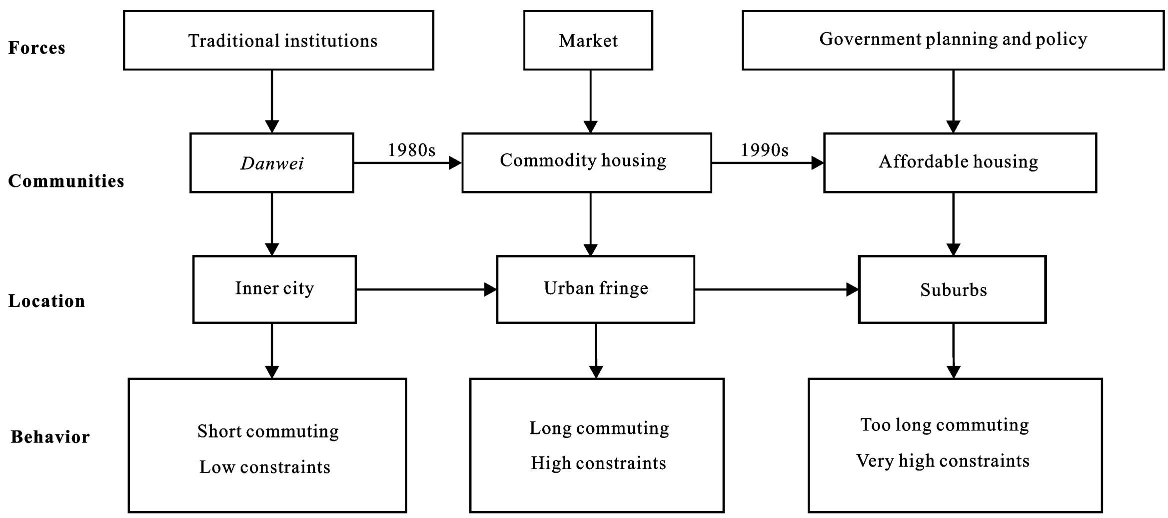


Fig. 1 Research framework for residents' behavior in Beijing

ity-travel patterns of residents in the transitional context in Beijing. Different neighborhoods, with distinct locations relative to an urban center, represent different forces in transitional urban China. From *Danwei* to commodity housing and then to affordable housing, the locations generally become farther away from the urban center and into the suburbs. The primary reason is because the urban center is dominated by *Danwei* or historical housing, so that urban spaces are formed as circles of different housing estates (Wang and Murie, 2000). Residents′ behaviors might be affected by residential areas and their job-housing relationship. *Danwei* encourages a job-housing balance so that resident travel may have more freedom and cover more space. Residents in commodity and affordable housing might endure higher space-time constraints because they need not follow the principle of finding jobs close to home. This change of the residential environment results in the change of residents′ activity-travel patterns leading to increased commuting distance, travel time, and use of private cars, which lowers quality of life and forms unsustainable development.

3.2 Data and study area

Beijing, the political and cultural center of China, was selected for this case study because it is a representative city with rapid urban development and includes all of the major types of neighborhoods. The data used in this study came from a 48-hour activity diary survey conducted on Sundays and Mondays in October and November of 2007. Coordinated with the data from the National Census and other statistics on urban development in Beijing, such as location and age of neighborhoods, we selected two neighborhoods to represent each of three categories across the entire city (Fig. 2). Because of the general spatial pattern of Chinese cities, it was not easy to select neighborhoods that were in close proximity. Although this sample may not capture the overall diversity of China, it covered four districts. Xicheng is an old district where State-owned ministries or institutions are located; Haidian is a high-educated district with lots of universities; Chaoyang is a foreign-affair district with high-grade housing; Changping is a suburban district builting lots of affordable housing. We list the characteristics of six neighborhoods (Table 1) and use the variations of neighborhood types as quasi-longitudinal cases. As shown in Fig. 2, Yandongyuan and Sanlihe, the *Danwei* neighborhoods affiliated separately to Peking University and National Development and Reform Commission are located in city area. The

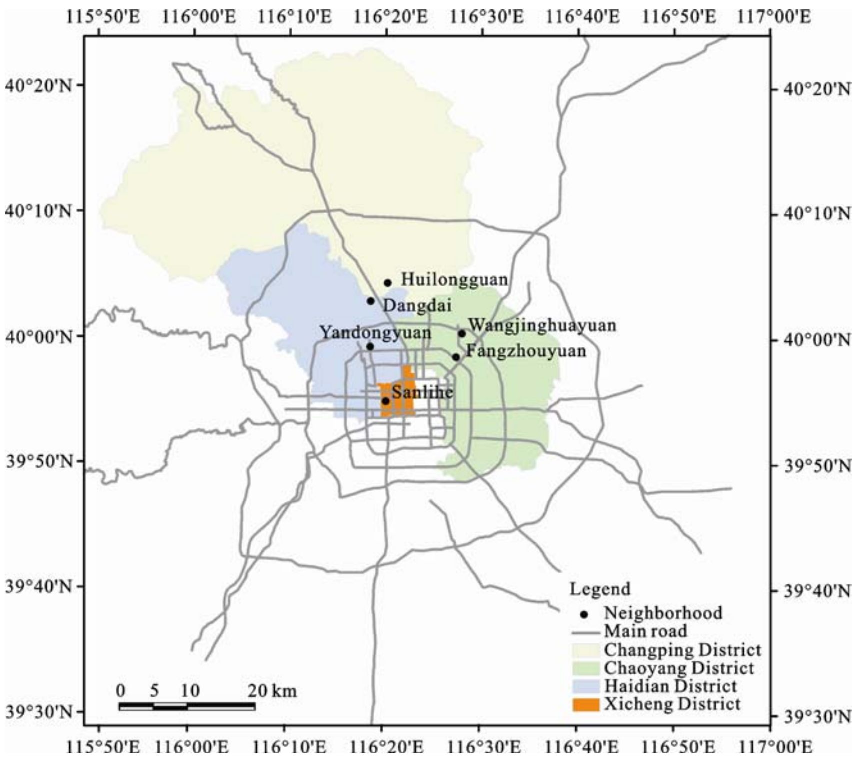


Fig. 2 Geographical locations of surveyed neighborhoods in Beijing

Table 1 Characteristics of surveyed neighborhood in Beijing

Community type	Neighborhood name	District	Age	Traits of neighborhood	Sample size	Nearest subway (km)	Low-class-road length in 1 km radius (km)	Retail employee in 1 km radius (10^3 person)	Commercial density class*	Distance to urban center** (km)
Danwei	Yandongyuan	Haidian	Early 1980s	Residential neighborhood of Peking University	100	0.586	0.038	5.175	4	12
	Sanlihe	Xicheng	Mid 1990s	Residential neighborhood of National Development and Reform Commission	90	0.856	0.193	28.257	3	4.8
Commodity Housing	Dangdai	Haidian	Early 2000s	Younger generation and highly educated	90	0.979	0.054	4.097	1	16.3
	Fangzhouyuan	Chaoyang	Late 1990s	Highly educated and high-income	114	2.266	0.057	4.734	2	9.8
Affordable Housing	Wangjinghuayuan	Chaoyang	Early 2000s	Social welfare housing for mid or low income	127	2.309	0.074	1.423	2	12.8
	Huilongguan	Changping	Late 1990s	Social welfare housing for employees in local affiliates in Beijing	131	0.934	0	0.005	2	19.3

Notes: Density class: 1, <10 facilities/km^2; 2, 10–100 facilities /km^2; 3, 100–200 facilities /km^2; 4, >200 facilities /km^2; ** Distance estimated in Google Map two commodity housing neighborhoods (Dangdai and Fanzhouyuan) are situated close to the city centre. The newly built affordable housing neighborhoods (Wangjinghuayuan and Huilongguan) are located in the suburbs. Their locations generally reflect the urban structure in Beijing, meanwhile associated with the feature of each district discussed above.

With support from neighborhood associations, we randomly surveyed 60 households in each neighborhood. All household members over 16 years old were asked to complete the questionnaire, which contained items about individual working attributes, 48-hour activity-travel records for one Sunday and one Monday, and individual socio-demographics. Because some respondents provided incomplete information, the rate of valid responses was 86.7%.This study focuses on the behavior pattern on workday, so that the usable sample finally consists of 652 individuals with complete activity and travel reports on a Monday.

According to socio-demographics reported by all valid responses, including gender, age, education, employment status, and monthly income, Table 2 lists the sample profile by neighborhood types. The gender of respondents was balanced. For the age distribution, the majority of respondents were between 30 and 60 years old. For income level, *Danwei* residents were mostly composed of low-income residents, whereas people living in commodity housing had relatively higher incomes.

4 Descriptive Analysis

4.1 Space-time paths comparison

We describe and compare the space-time patterns of three groups from different neighborhoods using three-dimensional visualization techniques. The three-dimensional technique represents urban space in two dimensions (X-axis and Y-axis) and the time of day (Z-axis).

Table 2 Sample profile of different neighborhoods in Beijing

		Danwei		Commodity		Affordable		Total	
		Freq.	Per.	Freq.	Per.	Freq.	Per.	Freq.	Per.
Gender	Male	101	53.2	99	48.5	130	50.4	330	50.6
	Female	89	46.8	105	51.5	128	49.6	322	49.4
Age	16–29	22	11.6	45	22.1	58	22.5	125	19.2
	30–39	48	25.3	97	47.5	78	30.2	223	34.2
	40–49	62	32.6	21	10.3	33	12.8	116	17.8
	50–59	47	24.7	20	9.8	49	19.0	116	17.8
	>60	11	5.8	21	10.3	40	15.5	72	11.0
Education	Elementary or middle school	16	8.4	13	6.4	28	10.9	57	8.7
	High school	54	28.4	18	8.8	47	18.2	119	18.3
	Junior college degree	35	18.4	44	21.6	75	29.1	154	23.6
	Bachelor degree	57	30.0	86	42.2	64	24.8	207	31.7
	Master degree and above	28	14.7	43	21.1	44	17.1	115	17.6
Employment	Full-time job	135	71.1	138	67.6	155	60.1	428	65.6
	Part-time job	15	7.9	7	3.4	12	4.7	34	5.2
	Student	10	5.3	2	1.0	8	3.1	20	3.1
	Unemployed	11	5.8	23	11.3	22	8.5	56	8.6
	Retired	19	10.0	34	16.7	61	23.6	114	17.5
Monthly income (yuan (RMB))	0–500	18	9.5	17	8.3	21	8.1	56	8.6
	500–1000	13	6.8	5	2.5	14	5.4	32	4.9
	1000–2000	37	19.5	34	16.7	81	31.4	152	23.3
	2000 –4000	82	43.2	66	32.4	91	35.3	239	36.7
	4000 –6000	32	16.8	41	20.1	35	13.6	108	16.6
	>6000	8	4.2	41	20.1	16	6.2	65	10.0

Notes: Freq. means frequency; Per. means percentage.

This means that the purpose of visualization is to assign a Z value using a temporal attribute and to create an outline along the Z-axis. The method of space-time path generation and representation is referenced from two previous studies (Zhao *et al*., 2009; Chen *et al*., 2011). The shapes of the space-time paths refer to different constraints, which might be known with these data. The time-budget constraint provides theoretical foundation to limited time available to a person. That means if a person spends a large amount of time on fixed activities (e.g., work) or travel (e.g., commuting), he or she would have to adjust their flexible behavior on when and where they travel (e.g., leisure far away from home). Considering a relatively uniform eight-hour working time, travel time refers more as a fixed constraint associated with the individual's home-work relationship, travel capability, and urban spatial influence.

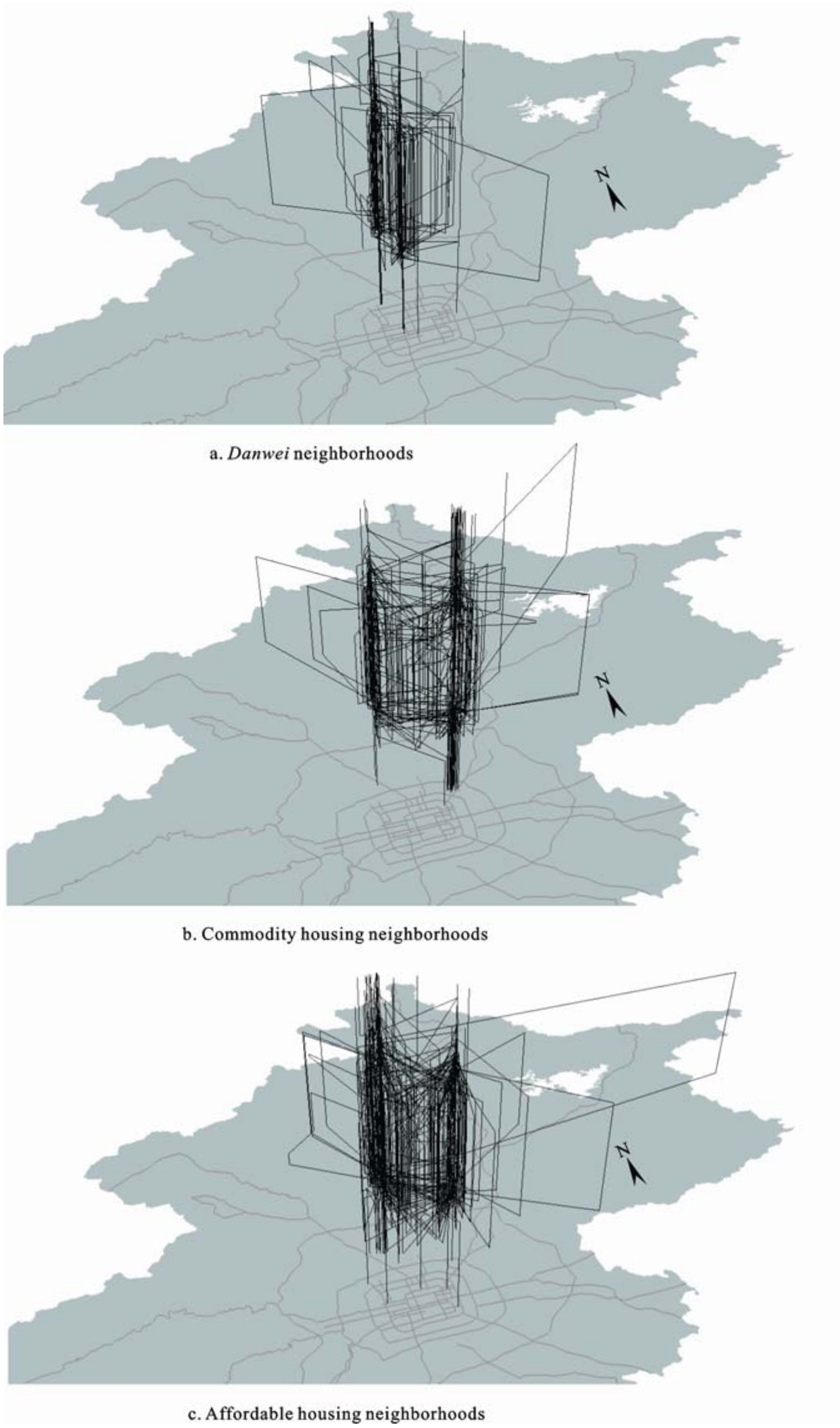
Residents from different neighborhoods show behavior variations in space and time. *Danwei* residents have shorter commuting times (Fig. 3a), which are indicated by the short slope travel segments connecting their homes to their workplaces. As they have a less fixed travel time, they tend to perform plenty of short stops back home at lunch time or engage in other non-work activities after work. Their space-time paths appear to be more fragmented and remain close around their home location. For people in commodity housing neighborhoods, the time-budget constraint, including work and commuting imposed on non-work activities, is evident (Fig. 3b). Long commuting and work times are revealed by long travel distances between home and workplaces and long activity durations at the workplace, as indicated by length of the slope segments and the vertical episodes. In spite of a relatively large number of constraints, people undertake several non-work activities, including some short stops near the workplace at lunch time, shopping, or business stops after work. As for people in affordable housing neighborhoods (Fig. 3c), the space-time paths have many similarities with the paths of commodity housing, except that they tend to have more fixed constraints because of their extremely long commuting times. The separation of home and workplace results in an increased amount of time spent on commuting, which allows for fewer flexible activities or travel compared to other two groups. The shapes of space-time paths seem to be the most extensively occupied by the long length of slope segments in the morning and evening rush hours.

The space-time path analyses give the general impression on behavior variations among different neighborhoods. It is helpful to identify space-time constraints coordinate for residents in daily life. Because of the stable level of work duration, we pay more attention to travel times, especially commuting times, and how they vary between the three neighborhood types. The short commuting times of *Danwei* residents might be because of the path dependence of the original building concepts of *Danwei*—the close home-work distance. The long commuting times of commodity and affordable housing residents are associated with a home-work separation that developed after the housing reform, demonstrating that people tend to choose housing freely and endure long-distance commuting to obtain housing. The varied patterns of the space-time paths seem to reflect the contradiction of job-housing balance in modern cities.

4.2 Community difference on activity-travel pattern

Figure 4 shows the average travel time and leisure time in the three neighborhood types at the individual level. The average travel time increases by 20 minutes from the *Danwei* to the commodity housing residents, and increases by 5 minutes for the affordable housing residents. This finding supports the discussions mentioned above on job-housing relationships in the three neighborhood types and the consequent results of the diversified travel demand. For daily leisure time at the individual level, we hypothesize that if people encounter less fixed constraints (like a small amount of time for commuting), they may spend more time on flexible activities for leisure purposes. Figure 4, however, illustrates that leisure time increases from *Danwei* to commodity housing, and even more so to affordable housing. One possible reason may be associated with leisure activities in Beijing, as respondents reported mostly low-cost entertainment like watching TV or walking near their homes as their main leisure activities. Another reason might be that self-selection plays a crucial role if the space-time constraints are loosened. Most residents in *Danwei* are the old-generation who get used to work-based lifestyle, but a considerable proportion of residents in affordable housing are the young-generation who prefer recreational lifestyle.

To clearly identify explicit differences in behavior



a. *Danwei* neighborhoods

b. Commodity housing neighborhoods

c. Affordable housing neighborhoods

Fig. 3 Three-dimensional space-time paths of residents in different neighborhoods in Beijing

patterns, we summarize travel time and distance at the trip level (Table 3). According to travel time and distance analysis by neighborhood type, it is obvious that trips conducted by *Danwei* residents are the shortest among the three groups. Residents in commodity housing neighborhoods have the longest travel distance, and residents from affordable housing have the longest travel time. This interesting result may be associated with individual travel capacity, meaning that commodity residents could afford higher speed or higher efficiency transport modes to make up for their relatively high travel demands. Consequently, the travel time and dis-

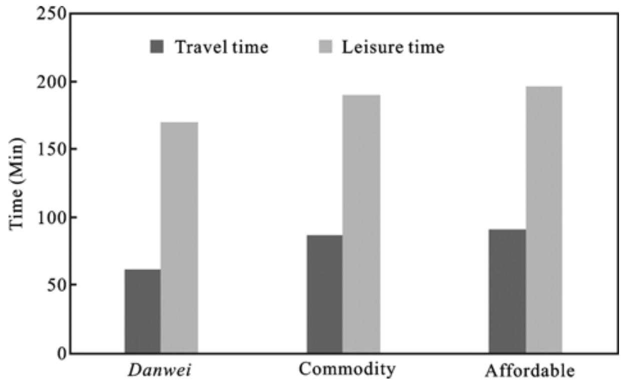


Fig. 4 Community difference of travel time and leisure time at individual level in Beijing

Table 3 Travel time and distance by community types and travel modes in Beijing

	Travel time (Min)		Travel distance (km)	
	Mean	SD	Mean	SD
Community type				
Danwei	18.78	19.669	1.360	2.835
Commodity	30.19	26.388	3.613	6.382
Affordable	31.15	29.488	3.497	6.654
Travel mode				
Public transportation	55.90	29.499	6.313	7.618
Car	40.35	25.304	5.897	8.336
Bike or walk	13.30	11.134	0.837	1.851
Total	26.91	26.341	2.849	5.713

tance analysis classified by travel modes further reveals the efficiency of each transport mode. Trips taken by public transportation system usually last for longer periods of time and longer travel distances. However, car trips take much shorter amounts of time to travel similar distances, compared to public transportation. That means if people could afford car-use, they might travel longer distance in shorter periods of time. For slower modes of transportation, such as biking and walking, trips have characteristics of shorter time periods and distances, because of their limited travel speeds.

5 Multivariate Analysis

Based on geo-visualization and descriptive analyses, we see a general picture of the built environment and behavior variations. In this section, we report on the investigation of the joint effects of residential space, socio-demographics, and personal travel capacity on time allocation. The focus is to apply multivariate models on daily travel times and leisure times, while considering the influence of both neighborhood type and personal attributes.

5.1 Model on travel time

The first model estimates the decision of daily travel time during a workday. The F-test indicators suggest that the model is highly significant (0.000) and well-fitted. Table 4 indicates that the causal relations between residential space and daily travel time are verified by the model. Age, employment status, and mode of commuting have significant impacts on travel time.

The neighborhood type is an integrated indicator with considerations of space attributes and institutional effects. The result shows that *Danwei* significantly reduces daily travel time, and corresponds to existing studies on traditional-style neighborhood design. Residents in commodity housing tend to travel for longer time periods than those in *Danwei* (coefficient of 0.082). Additionally, residents in affordable housing endure more space-time constraints (coefficient of 0.101). These findings reflect two important points. First, traditional neighborhoods with higher densities, smaller blocks, and a better job-housing balance encourage less travel time. Second, the three types of housing represent different stages of housing reform in China, and the results demonstrate a trend of increased travel through the process of the urban transition.

As for socio-economic variables, it is not expected that gender has an impact on travel time. One reason is that the dependent variable is daily travel duration mixed with varied purposes, so that we could not identity gender preference on either work or non-work travel. Another reason might relate to a unique effect of decades of socialist development in China that highlights equality between men and women. Age has a positive effect on daily travel time (with a confidence level over 90%). Older people tend to travel longer time because they have enough spare time, and their high percentage of time spending? walking or cycling also increases travel time. The employment situation also plays an important role in travel duration. Full-time employees have the longest travel time duration, a little longer than residents who are employed part-time. Daily travel times on workdays mostly depend on commuting times and distances. Part-time employees usually perform work and non-work activities close to home, so that full-time employees have longer travel times. Students have the second longest travel time among all the groups, which may be caused by unfair educational resource allocation. Better educational facilities are usually located in urban central area, where might be difficult to access for residents in the commodity and affordable housing.

Only commuting mode choice has a significant impact on the daily travel time with respect to personal travel capability. People who travel to work utilizing public transports have the longest travel times, whereas car-drivers dominate the second longest travel time. As discussed previously, use of a car as private transportation has higher efficiency, and traveling by car takes shorter time periods compared to public transportation.

5.2 Model on leisure time

The second model investigates daily leisure time. We assume that leisure time is the indicator to represent allocation of travel time for flexible activities compared with travel time as a fixed counterpart. The model is well-fitted with F significance at 0.000. The right side of Table 4 indicates our findings that socio-demographic variables, rather than residential context, determine whether a person spends a large amount of time on leisure activities.

Residential space has no significant effects on leisure time. Although *Danwei* residents have shorter travel times, which provide more time to conduct leisure activities, they unexpectedly spend less time on leisure purposes. People in commodity and affordable housing have similar patterns. This demonstrates the allocation of leisure time for flexible activities mostly depends on self-selection rather than spatial influence.

The likelihood of spending a large amount of time for leisure purpose is higher for men, older people, workers with less working time, and low-income groups. The influence of gender is strong, with men much more than

Table 4 Multivariate regression model for travel time and leisure time

		Travel time			Leisure time		
		Coef.	*t*-value	*P*-value	Coef.	*t*-value	*P*-value
Neighborhood type (*Danwei* as reference category)	Commodity	0.082	1.688	0.092	0.022	0.454	0.650
	Affordable	0.101	2.064	0.039	0.007	0.147	0.883
Gender	Male	–0.022	–0.571	0.568	0.101	2.715	0.007
Age (>60 as reference category)	16–29	–0.25	–3.286	0.001	–0.097	–1.305	0.192
	30–39	–0.238	–2.71	0.007	–0.338	–3.935	0.000
	40–49	–0.161	–2.226	0.026	–0.179	–2.538	0.011
	50–59	–0.137	–2.314	0.021	–0.176	–3.052	0.002
Employment (Retire as reference category)	Full-time job	0.199	2.665	0.008	–0.4	–5.474	0.000
	Part-time job	0.085	1.786	0.075	–0.139	–2.986	0.003
	Student	0.131	2.463	0.014	–0.286	–5.505	0.000
	Unemployed	0.070	1.228	0.220	–0.085	–1.531	0.126
Monthly income yuan(RMB) (0–500 as reference category)	500–1000	–0.056	–1.103	0.270	–0.133	–2.677	0.008
	1000–2000	0.027	0.323	0.746	–0.207	–2.568	0.010
	2000–4000	0.027	0.287	0.774	–0.224	–2.475	0.014
	4000–6000	0.097	1.259	0.208	–0.188	–2.509	0.012
	>6000	0.027	0.407	0.684	–0.206	–3.228	0.001
Driving license	Pass	0.064	1.450	0.148	0.018	0.412	0.681
Household car-ownership	Own	0.058	1.613	0.107	–0.023	–0.672	0.502
Commuting mode (walk/bike as reference category)	Public transport	0.395	8.801	0.000	–0.011	–0.261	0.794
	Car	0.217	4.556	0.000	–0.005	–0.103	0.918
Constant			3.625	0.000		11.906	0.000

Notes: Coef. means standard coefficient in multivariate regression model; *t* value means the result of *t*-test of individual parameters (usually if $|t| > 2$, the variable influence is significant); *P*-value determines the likelihood of a value in a sample, given that the Null Hypothesis is true (If $P < 0.05$, the significance level >95%)

women spending time on leisure travel. This is in line with existing findings that men tend to engage more often in leisure or recreational activities, women more often engage in household activities in their spare time, and that men hold dominant roles in Chinese families. Elders and less-working-time groups are associated with larger amounts of spare time to encourage the engagement of leisure activities. As income levels increase, people tend to endure more fixed space-time constraints, like long working-times and commuting, so that they are less likely to engage in leisure activities. Additionally, the considerable percentage of low-income residents in *Danwei* with high travel accessibility (Table 2) might provide more opportunities to participate in leisure. With respect to personal travel capacities, we originally assumed that good travel capacity, such as owning a car or commuting by car, might ensure enough time for leisure. The model, however, indicates that the causal relationship between travel capacity and leisure engagement is not significant.

6 Conclusions and Discussion

Economic reform in urban China introduced market mechanisms into a centrally planned housing system (Huang, 2003). Compared to the pre-reform period, when most residents had to live in houses provided by *Danwei*, residents now have more freedom to choose where to reside and they do not have to live close to their workplace (Wang and Chai, 2009). Using activity diary data collected in Beijing, we applied two main methods to analyze activity-travel patterns. First, we used three-dimensional geo-visualization of space-time path to examine behavioral patterns by comparing space-time paths among different neighborhoods. Then, we sought to detect the influence of socio-demographics on activity-travel patterns based on multivariate regression models. For daily travel time, the results show that *Danwei* residents have relatively less daily travel time than those in commodity housing, but people living in affordable housing endure the highest space-time constraints. Elders with long work durations who go to work by public transportation tend to travel for longer periods of time. For daily leisure times, elder men with short work durations and high incomes are likely to spend long time on leisure, but the influence of residential environment is relatively weak.

In summary, this study offers some insightful results. On one hand, although the *Danwei* system has been accused of shortcomings, this study suggests that it at least contributes positively to the sustainability of transportation. Cervero and some other researchers (Cervero, 1996; Van Eck *et al*., 2005) believed that a self-contained living community leads to reduced travel time and improved living conditions. But, urban restructuring in China causes physical space changes, such as urban sprawl and suburbanization, which force residents to travel for long time periods and endure high space-time constraints. This paper gives evidence on the value of the *Danwei* space and reminds urban planners to pay attention to and make good use of existing *Danwei* space, because it is in accordance with the basic principle of building sustainable neighborhoods: residents work near their residential places and decrease travel demands. *Danwei* might be a possible way in China to realize the goal of compact city in Europe or new urbanism in US (Chai, 2012).

On the other hand, this study provides a new perspective for studying human behavior, by integrating spatial and temporal dimensions. We use the space-time path to observe differences of general behavior patterns by varied communities. Geo-visualization might be a powerful method to represent multi-dimensional objects, but alone it may not be sufficient because of technical and human cognitive limitations (Andrienko and Andrienko, 2007). To examine the effective mechanism, therefore, we apply multivariate models on daily travel time as a fixed constraint and daily leisure time as a flexible counterpart. Geo-visualization as a method is currently a 'work in progress' and needs further development, for example, studies should be conducted to calculate key parameters (number, time, mode), to cluster typical modes, and to mine abnormal behavior.

The research also has possible implications and lessons for policymakers. The evidence to transform from the *Danwei* format to commodity neighborhoods shows the beginnings of a lifestyle transition from low-carbon to high-carbon usage, which has implications for urban planners when building neighborhoods that are environmentally friendly and encourage a high quality of life. More widely, the traditional elements like *Danwei* system might have positive effects on urban development for socialist or post-socialist countries. Planners might try to keep the advantages of *Danwei*'s spatial arrangement to provide enough workplaces around residential areas and necessary facilities in daily life in order to reduce travel time and car-use, which is a good approach to realize sustainable development.

Finally, our analysis suggests that residents in affordable housing neighborhoods may endure the highest spatial constraints, meaning that low-income living in these neighborhoods may allow residents to cope with the double burden of long-distance commute and unaffordable car-use. These characteristics force residents to spend more time on travel and less time on leisure, which results in a lower quality of life. This suggests that when governments promote the building of affordable housing and public housing, they should not only satisfy the quantity demand, but also pursue improvement of quality of life. If the affordable housing has to be built in a suburb, planners might facilitate public transportation systems and work opportunities around their new neighborhoods.

Acknowledgements

Space-time path analysis was supported Chen Jie in Institute of Geographic Sciences and Natural Resources Research, Shih-lung Shaw in the University of Tennessee and Hongbo Yu in Oklahoma State University. Thanks to Martin Dijst in Utrecht University, Daniel Brooker in Peking University and Cao Xinyu in University of Minnesota Twin Cities to give comments and suggestions. Zhang Yan and Ma Xiujun in Peking University are acknowledged for their contribution to the primary idea.

References

Ahmed N, Miller H J, 2007. Time-space transformations of geographic space for exploring, analyzing and visualizing transportation systems. *Journal of Transport Geography*, 15(1): 2–17. doi: 10.1016/j.jtrangeo.2005.11.004

Andrienko N, Andrienko G, 2007. Designing visual analytics methods for massive collections of movement data. *Cartographica*, 42(2): 117–138. doi: 10.3138/carto.42.2.117

Beijing Statistical Bureau, 2010. *Beijing Statistical Yearbook 2010*. Beijing: China Statistics Press. (in Chinese)

Bodea T D, Garrow L A, Meyer M D *et al*., 2009. Socio-demographic and built environment influences on the odds of being overweight or obese: The Atlanta experience. *Transportation Research Part A*, 43(4): 430–444. doi: 10.1016/j.tra.2008.11.009

Bray D, 2005. *Social Space and Governance in Urban China: The Danwei System from Origins to Reform*. Stanford, California: Stanford University Press.

Cao X, Handy S L, Mokhtarian P L, 2006. The influences of the built environment and residential self-selection on pedestrian behaviour: Evidence from Austin, TX. *Transportation*, 33(1): 1–20. doi: 10.1007/s11116-005-7027-2

Cao X, Mokhtarian P L, Handy S L, 2007. Do changes in neighborhood characteristics lead to changes in travel behavior? A structural equations modeling approach. *Transportation*, 34(5): 535–556. doi: 10.1007/s11116-007-9132-x

Cao X, Mokhtarian P, Handy S, 2009. The relationship between the built environment and nonwork travel: A case study of Northern California. *Transportation Research Part A*, 43(5): 548–559. doi:10.1016/j.tra.2009.02.001

Cervero R, 1996. Traditional neighborhoods and commuting in the San Francisco Bay Area. *Transportation*, 23(4): 373–394. doi: 10.1007/BF00223062

Chai Yanwei, 1996. Danwei-centered activity space in Chinese cities: A case study of Lanzhou. *Geographical Research*, 15(10): 30–38. (in Chinese)

Chai Y. 2012. New Danweism: A new conceptual framework for the future development in Urban China. In: *International Conference on Spatial and Social Transformation in Urban China*. Hong Kong, Dec. 13–14.

Chen J, Shaw S-L, Yu H *et al*., 2011. Exploratory data analysis of activity diary data: A space-time GIS approach. *Journal of Transport Geography*, 19(3): 394–404. doi: 10.1016/j.jtrangeo.2010.11.002

Dijst M, de Jong T, and van Eck R J, 2002. Opportunities for transport mode change: An exploration of a disaggregated approach. *Environment and Planning B*, 29(3): 413–430. doi: 10.1068/b12811

Ding D, Gebel K, 2012. Built environment, physical activity, and obesity: What have we learned from reviewing the literature? *Health & Place*, 18(1): 100–105. doi: 10.1016/j.healthplace.2011.08.021

Ewing R, Cervero R, 2001. Travel and the built environment: A synthesis. *Journal of the Transportation Research Board*, 34: 89–105. doi: 10.3141/1780-10

Fan Y, 2007. *The Built Environment*, *Activity Space, and Time Allocation*: *An Activity-based Framework for Modelling the Land Use and Travel Connection*. University of North Carolina at Chapel Hill, PhD Thesis.

Fan Y, Khattak A, 2009. Does urban form matter in solo and joint activity engagement? *Landscape and Urban Planning*, 92(3-4): 199–209. doi: 10.1016/j.landurbplan.2009.05.006

Gaubatz P, 1999. China's urban transformation: Patterns and processes of morphological change in Beijing, Shanghai and Guangzhou. *Urban Studies*, 36(9): 1451–1521. doi: 10.1080/0042098992890

Hagerstrand T, 1970. What about people in regional science? *Papers of the Regional Science Association*, 24: 7–21. doi: 10.1007/BF01936872

Handy S, 1996. Methodologies for exploring the link between urban form and travel behavior. *Transportation Research D*, 1(2): 151–165. doi: 10.1016/S1361-9209(96)00010-7

Handy S, Boarnet M G, Ewing R *et al*., 2002. How the built environment affects physical activity: Views from urban planning. *American Journal of Preventive Medicine*, 23(2S): 64–73. doi: 10.1016/S0749-3797(02)00475-0

Huang Y, 2003. Renters′ housing behavior in transitional urban China. *Housing Studies*, 18(1): 103–126. doi: 10.1080/02673 03032000076867

Huang Y, 2004. The road to homeownership: A longitudinal analysis of tenure transition in urban China (1949–1994). *International Journal of Urban and Regional Research*, 28(4): 774–795. doi: 10.1111/j.0309-1317.2004.00551.x

Janelle D G, Goodchild M F, 1988. Space-time diaries and travel characteristics for different levels of respondent aggregation. *Environment and Planning A*, 20(7): 891–906. doi: 10.1068/ a200891

Kwan M P, 1999. Gender, the home-work link, and space-time patterns of nonemployment activities. *Economic Geography*, 75(4): 370–394. doi: 10.2307/144477

Kwan M P, 2000. Interactive geovisualization of activity-travel patterns using three-dimensional geographical information systems: a methodological exploration with a large data set. *Transportation Research Part C*, 8(1-6): 185–203. doi: 10.1016/S0968-090X(00)00017-6

Kwan M P, Lee J, 2004. Geovisualization of human activity patterns using 3-D GIS: A time-geographic approach. In: Goodchild M F *et al*. (eds). *Spatially Integrated Social Science*. New York: Oxford University Press.

Lenntorp B, 1978. A time-geography simulation model of individual activity programmes. In: Carlstein T *et al*. (eds). *Timing Space and Spacing Time. Vol 2*: *Human Activity and Time Geography*. London: Enward Arnold, 162–180.

Li S, Huang Y, 2006. Urban housing in China: Market transition, housing mobility and neighborhood Change. *Housing Studies*, 21(5): 613–623. doi: 10.1080/02673030600807043

Ma L J C, 2002. Urban transformation in China, 1949–2000: A review and research agenda. *Environment and Planning A*, 34(9): 1545–1569. doi: 10.1068/a34192

Miller H J, 2005. A measurement theory for time geography. *Geographical Analysis*, 37(1): 17–45. doi: 10.1111/j.1538-4632.2005.00575.x

National Bureau of Statistics of China. 1999. *China Statistical Yearbook 1999*. Beijing: China Statistics Press. (in Chinese)

National Bureau of Statistics of China. 2009. *China Statistical Yearbook 2009*. Beijing: China Statistics Press. (in Chinese)

Pan H, Shen Q, Zhang M, 2009. Influence of urban form on travel behavior in four neighborhoods of Shanghai. *Urban Studies*, 46(2): 275–294. doi: 10.1177/0042098008099355

Schwanen T, Dijst M, 2003. Time windows in workers′ activity patterns: Empirical evidence from the Netherlands. *Transportation*, 30: 261–283. doi: 10.1023/A:1023905020890

Schwanen T, Dijst M, Dieleman F M, 2002. A microlevel analysis of residential context and travel time. *Environment and Planning A*, 34(3): 1487–1507. doi: 10.1068/a34159

Schwanen T, Mokhtarian P L, 2005. What affects commute mode choice: Neighborhood physical structure or preferences toward neighborhoods? *Journal of Transport Geography*, 13(1): 83–99. doi: 10.1016/j.jtrangeo.2004.11.001

Shaw S L, Yu H, 2009. A GIS-based time-geographic approach of studying individual activities and interactions in a hybrid physical-virtual space. *Journal of Transport Geography*, 17(2): 141–149. doi: 10.1016/j.jtrangeo.2008.11.012

State Council, 1994. State Council′s decision on deepening the reform of urban housing system. State Council Documentation, No. 43. (in Chinese)

State Council, 1998. A notification from the State Council on further deepening the reform of urban housing system and accelerating housing construction. State Council Documentation, No. 23. (in Chinese)

Van Eck R J, Burghouwt G, Dijst M, 2005. Lifestyles, spatial configurations and quality of life in daily travel: An explorative simulation study. *Journal of Transport Geography*, 13(2): 123–134. doi: 10.1016/j.jtrangeo.2004.04.013

Wang D, Chai Y, 2009. The jobs-housing relationship and commuting in Beijing, China: The legacy of *Danwei*. *Journal of Transport Geography*, 17(1): 30–38. doi: 10.1016/j.jtrangeo. 2008.04.005

Wang D, Chai Y, Li F, 2011. Built environment diversities and activity-travel behavior variations in Beijing, China. *Journal of Transport Geography*, 19(6): 1173–1186. doi: 10.1016/j. jtrangeo.2011.03.008

Wang Y P, Murie A, 2000. Social and spatial implications of housing reform in China. *International Journal of Urban and Regional Research*, 24(2): 397–417. doi: 10.1111/1468-2427. 00254

Zhao Ying, Chai Yanwei, Chen Jie *et al*., 2009. GIS-based analyzing method for spatial-temporal behavior data. *Geography and Geo-Information Science*, 25(5): 1–5. (in Chinese)