Modality, Activity Participation and Well-being

Evidence from Commuters in Beijing

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Evidence from Commuters in Beijing

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(met een samenvatting in het Nederlands)

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1. Introduction

1.1 Transport and daily life: Environmental and social sustainability

Reducing traffic congestion, air pollution and emissions of greenhouse gases have become challenges for transport planners in cities around the world (e.g., Banister, 2008; Buehler and Pucher, 2011; Chai, 2013; Gössling et al., 2016). Encouraging more environmentally sustainable travel patterns is not only a goal of many planning and transport policy endeavors but also a widely discussed topic in transport research (Banister, 2011; Boschmann and Brady, 2013; Fujii and Taniguchi, 2006; Gärling and Schuitema, 2007). Especially in the Western context, high car ownership levels (e.g., Carrasco and Cid-Aguayo, 2012; Delmelle et al., 2013; Farber and Li, 2013; Rubin and Bertolini, 2016) limit the use of other travel modes, such as walking, cycling and public transport (Kent, 2014; Sheller and Urry, 2000) and result in various problems, such as more traffic volume, energy consumption, vehicle emissions and further global ecological harm (Barr and Prillwitz, 2014; Haynes et al., 2005). While car ownership rates in advanced economies are approaching saturation, motorization continues unabated in developing countries, fuelled by economic growth and rising incomes (Cervero, 2013). With the rapid growth in the ownership and use of motor vehicles, metropolitan areas in China are currently also experiencing extreme transport problems, such as traffic congestion and air pollution, similar to their Western counterparts. For example, it is estimated that the economic costs directly and indirectly caused by traffic congestion in Beijing are approximately 70 billion RMB (approximately 8.9 billion Euros) per year (China Economic Net, 2014), and automobile emissions are responsible for approximately 22.6% to 32.2% of Beijing's air pollution (measured from December 2010 to January 2012; Cheng et al., 2013).

In recent decades, daily mobility and mode choice in Chinese cities have developed in the presence of fundamental transformations in the built environment and soaring car ownership (Shen, 1997; Wang and Zhou, 2017; Zhao et al., 2010). In Beijing, the built environment expanded 3.5 times from 1981 to 2004 (Zhao et al., 2010) with rather similar population densities in different parts of the city (Yang et al., 2012; Yao and Wang, 2014). The sprawling pattern of housing development and large investments in vehicle-based infrastructure resulted in a non-pedestrian/cyclist-friendly urban form after the 1990s and created a poor local job-housing balance, thus further increasing the demand for longer travel (Pan et al., 2009; Yang et al., 2007; Zhao, 2011). Consequently, the share of non-motorized daily transport modes, especially cycling, dramatically decreased and car trips increased (Yang et al., 2017; Zhao, 2014). The residential and transport choices of the urban residents in China are simultaneously constrained, however, due to institutional factors, such as the existence of the government's housing schemes and car management policies. From the housing perspective, institutional transformations have changed the *Danwei* (or work unit) compound[1]-dominated urban structure into a structure in

1 *Danwei* compounds used to be the basic social, economic and spatial unit in urban China (Bray, 2005; Wang et al., 2011), which provides housing, work and also facilities such as retail, education, recreation, and medical facilities to its residents. See Chen and Han (2014) for a detailed description of the urban housing market in post-reform China.

which commodity-, resettlement-[2] and social welfare housing were introduced, resulting in a more complicated housing market (Wang and Chai, 2009; Wang. et al., 2011). Households living in privatized *Danwei* housing and resettlement housing do not have a free choice in where to live (Zhang et al., 2017). Residents in social housing are primarily located in suburban areas, far away from places of employment and usually lacking facilities (Feng and Zhou, 2004). With respect to transport, although car ownership in major Chinese cities is currently below 50%, which is considerably lower than that in Western cities (Wang and Zhou, 2017), the environmental and traffic congestion problems caused by car use are no less severe (Cheng et al., 2013; Mehndiratta et al., 2012). Therefore, many Chinese cities adopt radical policies (e.g., license plate lottery, license plate auction, road space rationing) to reduce car use (Guo et al., 2015; Yang et al., 2017; Zhao et al., 2017). These policies slow the growth of car ownership in the longer term by limiting individuals' private car availability and lead to car owners' daily use of alternative modes through financial penalties.

As an alternative to car dependent travel behaviour, the use by travellers of multiple transport modes in a specified period (typically one week) has received much attention in Western Europe (Frändberg and Vilhelmson, 2014; Kuhnimhof et al., 2006; Nobis, 2007) and the U.S. (Block-Schachter, 2009; Buehler and Hamre, 2014) and has been termed "multimodality" (Kuhnimhof et al. 2006, Nobis 2007). The use of a single mode in a specific period is termed "monomodality". Individuals' modality styles are likely to be associated with individuals' personal attributes, vehicle accessibility and environmental attributes (Scheiner et al., 2016; Vij et al., 2011; Vij et al., 2013). For example, multimodality is often seen as an "urban behaviour" (Block-Schachter, 2009; Kuhnimhof et al., 2012). However, studies of modality styles have focused on US and European cities, where car ownership levels have mostly stabilized, and mobility cultures have been established (Cervero, 2013; UN DESA, 2010). However, it is not clear how modality styles are distributed and will further develop in highly dynamic cities in a developing economy, such as China's.

Moreover, studying the causality relationships between these contextual attributes (e.g., built environment, institutional backgrounds) and modality styles is interesting, considering the significant differences of Chinese cities with North American and European cities. In this dramatically changing but also constrained context, we can expect that the interactions between car ownership, individuals' availability of travel modes and their modality styles are likely to be shaped differently, and understanding these relationships is crucial when developing a sustainable transport system. Furthermore, the sustainability of transport systems must be discussed not only from an environmental perspective but also from a social perspective. The social aspect refers to themes such as fulfilment of basic needs, health, well-being, social justice, social cohesion, social capital and participation (Colantonio, 2009; Cuthill, 2010; Dempsey et al., 2009; Liu, 2016). However, social sustainability needs to be contextualized because the social-cultural, institutional and geographical contexts can lead to differences in the interpretation of social sustainability goals and, more importantly, how these goals are likely to be

2 Due to the urban renewal process in many Chinese cities, property users in redeveloped areas will be relocated and provided with resettlement housing. However, they usually have little control in choosing the location of the resettlement housing (Zhang et al., 2017).

achieved in these contexts (Liu, 2016). For example, certain unique Chinese institutional barriers or facilitators (e.g., car accessibility), individual barrier or facilitators (e.g., three-generation household structure) and external impacts (e.g., high density urban landscape) may provide a different angle to understanding the social benefits/costs of different transport modes.

Social implications of travel are in particular relevant for commuters in Chinese cities such as Beijing due to changes in commuting patterns in the past decades. A recent review has summarized that the dominant trend in commuting patterns in Chinese cities has changed from pre-1978 intra-*Danwei* commuting to reverse commuting from the city center to the inner suburbs in the years from 1978 to 1998 and to long distance suburb-to-city commuting since 1998 (Ta et al., 2017). These t rends have typically emerged in Beijing, the capital city of China (e.g., Zhao et al., 2011; Meng, 2011; Wang and Chai, 2009). Currently, Beijing is one of the most motorized cities in China, experiencing severe traffic congestion problems, despite a series of implemented car management policies (Guo et al., 2015; J. Yang et al., 2014; Zhang et al., 2017). Specifically, commuting trips account for 66.3% of all of the trips in Beijing (Beijing Transport Research Center, 2016), and workers are the largest group (54.6%) among the urban population (Beijing Statistical Bureau, 2016). Additionally, Beijing is the only Chinese city with the longest commute in terms of both time and distance (Engelfriet and Koomen, 2017), indicating that commuters may suffer more from transport-related problems, such as traffic congestion and long commute durations. Particularly when considering time constraints imposed by inflexible work schedules and long commute, investigating how commuters' modality styles affect their daily lives in terms of activity participation, social interaction, and their satisfaction with travel can contribute to the understanding of social sustainability of transport in the Chinese context.

With respect to activity participation, social interaction and travel time, previous studies have primarily investigated the influence of access to transport resources, passenger vehicles in particular, and they are mainly based on one-day observation data. Generally, these studies find a positive impact of car availability on activity participation (Srinivasan and Bhat, 2006), social interaction (Frei and Axhausen, 2009; Rubin, 2015) and travel time savings for non-work activities (Farber et al., 2011). However, auto-mobility has also been associated with more "asocial and sedentary lifestyles" with fewer out-of-home amusement activities and shorter durations (Farber and Páez, 2009) or longer travel time for non-work activities (Schwanen and Dijst, 2002). In a similar vein, the effects of a multimodal travel pattern on activity participation, social interaction and travel time require more research, especially in a Chinese context. For instance, the role of the car as a "mobility enabler" may not apply in the Chinese context, given the higher reliance on public transport. It is likely that the unique urban landscape and socio-economic and cultural background in Chinese cities will not only provide different conditions for the presence of modality styles but also its social impacts on activity participation/interactions, and travel may differ from those in Western contexts. For example, the extended household structure and collectivist orientation among individuals in China (Dijst, 2014; Zhao et al., 2016) have implications for travel mode choices (Feng et al., 2014). These characteristics may also offer commuters more time for activity participation out of base (with extra helpers in the household) and encourage more interactions with family members but less with other companions.

In addition to the participation in travel/activities, individuals' experience of their daily travel and activities requires further investigation in the context of Chinese cities. Apart from personal, spatial and episodic attributes (Abou-Zeid and Ben-Akiva, 2011; Bergstad et al., 2011; De Vos et al., 2014; Olsson et al., 2013; Páez and Whalen, 2010; Schwanen and Wang, 2014), trip and activity satisfaction are also related to the transport context. For example, trip satisfaction has been found to be positively associated with factors, such as travel mode, comfort, safety and design aspects (Ettema et al., 2013; Friman and Gärling, 2001; Novaco and Gonzalez, 2009; Stradling et al., 2007). In the context of rapidly growing and congested cities in China, key questions are how density, congestion and pollution influence satisfaction with travel by car and public transport and how travellers evaluate alternative travel modes such as cycling or walking. For activity satisfaction, it is expected that a better and more extensive set of available transport options makes it easier for travellers to reach more satisfactory destinations (Buliung et al., 2008; Schwanen et al., 2008) and that satisfaction with travel carries over to activities (De Vos, 2017; Friman et al., 2017). In a more general sense, subjective flexibility in travel options reflects individuals' perceived freedom in decision-making and may affect satisfaction through the size of choice sets (Botti and Iyengar, 2006; Van Hees, 2004) and the pre-assessment expectations (MORI, 2002; Schwartz, 2004). Additionally, these attributes are found to differ from the observations in Western countries due to the social, cultural and family norms in China (Shen et al., 2015). For example, in contrast to Western societies (Schwanen et al., 2008), younger people face more time-constraints than the elderly, and the space-time constraints are less for women due to help from extended household structures and inexpensive labour (Feng, 2013). However, the impacts of flexibility indicators have rarely been investigated directly in previous well-being studies or within the Chinese context. Associating these contextual factors with the flexibility attributes of trip/activity episodes (i.e., modal flexibility for trips, space-time flexibility for activities) may contribute to a better explanation of the episodic well-being of travellers of different modality styles.

1.2 Research objectives and questions

Against the background of transport-related problems (e.g., air pollution and traffic congestion) and the increasing motorization in Chinese cities, it is crucial to determine how built environment attributes and access to transport resources (i.e., private car in the household) affect urban residents' use of multiple travel modes, especially the use of more sustainable travel modes. Our aim is to understand the shares and determinants of individuals' modality styles in Beijing (multi/mono- modality and habitual travel modes) and to explore how their modality styles affect activity participation, social interaction, travel time and well-being (Figure 1.1). Given the dominance of commuters in the total travel population in Beijing and given the accumulation of negative externalities during the peak hour, we aim to answer these questions for daily commuters. To achieve this objective, we developed a set of research questions, as addressed in subsequent chapters. We begin by presenting an overview of our sample commuters' modality styles observed at the weekly level, how these factors are shaped and how they will affect the commuters' weekly activity participation (Chapter 2). Next, we continue to explore their influences on individuals' daily life practices from the perspective of their social interactions and travel time for multi-purpose commute trips (Chapter 3 and Chapter 4). Furthermore, how commuters experience the trips and activities will be measured from the cognitive perspective, namely, trip satisfaction and activity satisfaction. Their relation to individuals' modality attributes and episodic level attributes (e.g., flexibility) will be investigated, respectively, in Chapter 5 and Chapter 6.

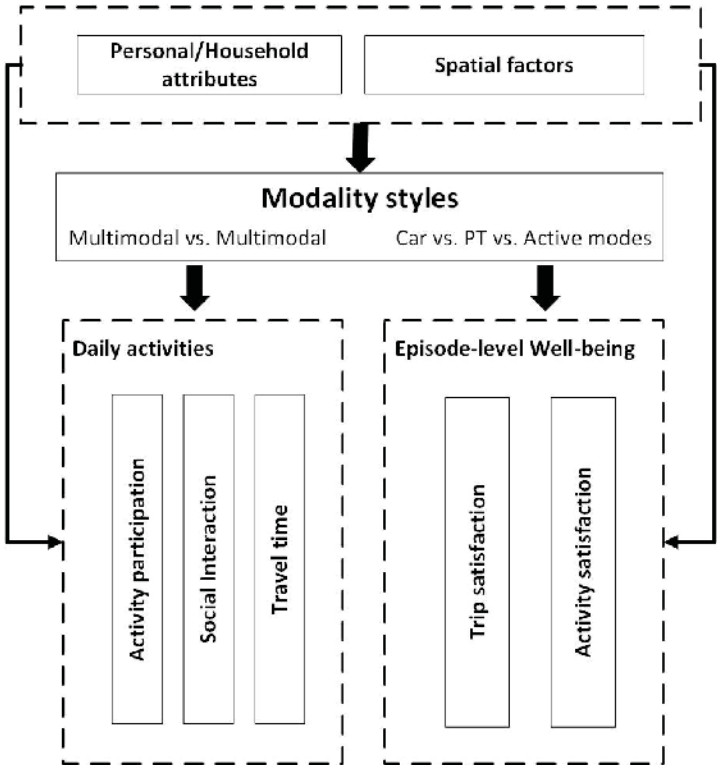

Figure 1.1 Conceptual model

1. *What are the shares and determinants of commuters' modality styles, and what is the impact of these modality styles on commuters' non-work activity participation?*

Multimodality is promoted as a strategy to encourage the use of sustainable travel modes to reduce car use in Western studies. Predictors of multimodality have been explored, including socio-demographics and built environment attributes. To date, limited insight exists into the distribution of different modality styles in a developing economy context similar to in Beijing, which is characterized by low car ownership levels and high public transport and walking/cycling dependency. Furthermore, while the car is found to benefit individuals by facilitating their non-work activity participation in diverse categories of daily life, the effect of multimodality on activity participation has not been examined to date in Chinese megacities and is therefore also a key issue in our analysis. Chapter 2 will first describe presence of modality styles among our sampled commuters in Beijing, explore how multimodality interacts with car ownership and car use, and further simultaneously estimate the impacts of car ownership, car use and modality styles on the respondents' non-work activity participation in a one-week period.

2. *What is the impact of commuters' modality styles on their social interactions with different companions?*

Face-to-face interactions with social contacts are important for an individual's well-being. Previous studies mostly found that car use can facilitate social interactions in workers' daily activities, but car use is discouraged in Beijing in order to reduce congestion and environmental damage. While previous empirical studies are primarily performed in developed countries with high car ownership and car dependence, the relationship between transport and social interaction may play out differently in land use and transport systems in urban China. Against this background, Chapter 3 will explore how transport options influence social interaction in a family oriented and collectivist culture with relatively low car ownership levels. In particular, the influence of individuals' modality styles is examined for commute and non-commute days, which differ strongly in terms of time constraints.

3. *What is the impact of socio-demographics, spatial attributes and alternative mode use on the trade-off between extra travel time and non-work activity duration in multipurpose commute trips?*

Trip chaining behaviour may provide greater efficiency and convenience in individuals' daily lives, but the substantial increase in non-work stops while commuting may result in severe problems for the urban transport system. Trip chaining in the context of commuting might imply detours and extra travel time. Previous studies have found that the trade-off between extra travel time and activity time in multi-purpose trips is affected by journey type, trip purpose, traveller socio-demographics and built environment opportunities. However, travel mode choices were assumed to be the same for direct trips and trip chains in previous studies. In Chapter 4, we assume that commute trip chains may in fact be the results of more complex behavioural adjustments, such as switching travel modes. Based on the multiday observations, we can examine whether commuters' travel modes for multipurpose commuter trips are more motorized than their direct commute counterparts. In the examination of determinants on the extra travel time in multi-purpose commute trips, not only socio-demographics, spatial attributes and the chosen travel mode will be included but also whether there is a switch to a motorized alternative mode.

4. *What differences exist between travel modes in commuting satisfaction and how can this be explained by modal flexibility and modality styles?*

Numerous previous studies have explored the relationship between travellers' travel modes and their trip satisfaction. Various characteristics of the chosen travel modes have been found to influence trip experiences. However, apart from the chosen modes, travellers' variability in mode use and their ability to vary have not been investigated in the trip satisfaction literature. While multimodal travellers' experience with various modes is an indicator of available choices, modal flexibility (i.e., travellers' perceived ability to vary transport modes) indicates whether the mode is chosen out of preference or due to a lack of other options. These two factors can contribute to a better understanding of trip satisfaction and are very relevant in a multimodal but constrained setting, such as Beijing. Chapter 5 will first present commuting trip satisfaction by various modes in Beijing and focus particularly on the influence of commuters' multimodal behaviour on multiple workdays and their modal flexibility for each commuting trip.

5. *What is the impact of activity flexibility and commuters' modality styles on momentary subjective well-being with non-work activity episodes?*

Well-being measured at the episodic level reflects momentary changes and the effect of immediate environmental circumstances. To date, the literature has explored the effects on activity satisfaction of both individual and activity attributes. However, with most studies focusing on the function or purpose of the activities (indicated by activity types), there is a lack of understanding of another attribute: activity flexibility. By reflecting the space-time constraints imposed on and opportunities offered to individuals, investigating activity flexibility contributes to a better explanation of activity scheduling, activity execution and consequently, activity satisfaction levels. Furthermore, with the ability to employ multiple travel modes and to reach more opportunities in urban spaces, multimodal travellers may benefit from higher activity flexibility and consequently higher activity satisfaction. Chapter 6 aims to explore the momentary subjective well-being with non-work activity episodes and further explores how they are associated with the temporal and spatial flexibility of activities, as well as individuals' modality styles.

1.3 Study area: Shangdi-Qinghe Area in Beijing

As the capital of China, Beijing is a public transport-dominated city. From the perspective of public transport service provision, Beijing had 18 metro lines covering 554 km at the end of 2015 (Beijing Transport Institute, 2016). According to the city's master plan, over 100 km of new subway lines have been planned to be built before 2020, and the public transport system is still heavily subsidized (Zhao, 2014). Additionally, the Beijing municipal government has promoted sustainable transport as an effective way of reducing car use and has built a citywide bike-sharing system with the participation of other private companies (Li and Zhao, 2017). Of the total number of trips in 2015, trips by public transit accounted for 50.0% of all the trips (trips on foot excluded) by the residents in 2015, whereas trips by private car accounted for 31.9%. According to the National Household Travel Survey (NHTS) in 2009, the average annual person trips per household by car in the U.S. reached 2892 trips and only 66 trips by public transport (Santos et al., 2011). In the Netherlands, almost half of the total number of trips in 2014 were made by car and an equal share by bike or on foot; trips by public transport and other means of transport are less than 10% (CBS, 2016).

However, Beijing is also one of the most motorized cities in China. Urban residents in Beijing have become increasingly dependent on automobiles. Although still lower than its Western counterparts, private car ownership increased sharply from 1.8 million to 4 million between 2005 and 2011 in Beijing. Because of a license plate-lottery policy implemented since 2011, the growth of the number of private cars slowed down and reached 4.5 million in 2015 (Beijing Transport Research Center, 2016). According to this license plate-lottery policy, residents must take part in a monthly draw to obtain the license plate and there is no additional cost involved. Moreover, the chance to get a license plate in Beijing decreased to 0.132% in the lottery held in October 2016 (Network News, 2016). Furthermore, to reduce car use in the urban area, a strict traffic restriction policy has been implemented since 2008 in Beijing that forbids cars to enter the 5th ring road from 7 am to 8 pm on one specific workday according to the last digit on their car plates. Controlling car use and encouraging the use of sustainable travel modes are set as the primary goals in transport policy-making in Beijing (Beijing Transport Research Center, 2013).

The study area for this research is located northwest of Beijing's 5th ring road, namely, Shangdi-Qinghe area (Figure 1.2). This area serves as a residential centre with 240,000 residents as well as a job sub-centre with more than 5,000 companies and 160,000 jobs. As one of the largest sub-centres in Beijing, this area covers a 16 square-kilometre area with mixed land use that includes residential, commercial, industrial and retail functions. Due to rapid urban development and suburbanization since the early 1990s, this area has experienced explosive growth. During the 1950s–1980s, it was a traditional industrial area with *Danwei* compounds characterized by mixed land use and short job–housing distance (Wang and Chai, 2009). Since the late 1980s, affordable social welfare housing has been built, and residents from the city center moved there with financial support from the government, thus leading to a serious job–housing spatial mismatch. Since the mid-1990s, the development of the market economy has led to a flourishing real estate market and high-technology industry. Some former industrial areas were renewed and gated communities were built to attract high-income residents (Tana et al., 2015). The rapid development in the past decades has left this area with diverse community types. The area is served by an express way and a light railway (subway line 13) that connect it with another residential new town to the north (i.e., the Huilongguan area), an employment centre to the south (i.e., Zhongguancun Science Park), and the central city of Beijing, resulting in huge traffic flows during rush hours. Further, given the lack of parking spaces for car users, as well as bicycle lanes for cyclists in the area, there could be illegal parking along the street and cyclists moving between the automobiles. Consequently, even more severe traffic congestion is likely to accompany the traffic disorder on the roads (Figure 1.3).

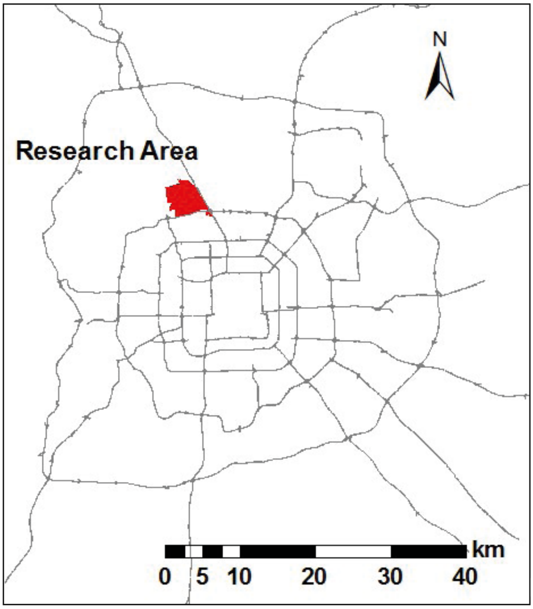

Figure 1.2 Research field location

Figure 1.3 Traffic congestion in morning/evening peak-hours in Shangdi-Qinghe area (Photo by Wenrui Ma)

1.4 Data and methodology

The data analysed in the study were collected in the Shangdi-Qinghe area from October to December in 2012. The survey collected the socio-demographic characteristics of the respondents, entries in activity diaries filled out by the respondents for one week, and GPS data from GPS loggers carried by the respondents for that same week. A survey website was used for collecting the activity-travel diaries and socio-demographic information. For each participant, the daily travel trajectories from the tracking device were visualized on the website, and the participant was required to fill in the activity-travel diaries on the website according to the visualized trajectories at the end of every day during the survey. Additionally, based on the information presented on the website, the investigators provided help with the survey, such as checking on the devices' condition and the daily completion of the diaries and communicating with participants to ensure the successful completion of the survey.

In the general information questionnaire, the respondents were asked about their personal attributes, including gender, age, monthly income, employment status, education level, profession, registration (local Beijing or not), home and workplace location. Household information were also collected including the household structure (i.e., extended household, number of children under 16), and the number of household private cars. Furthermore, housing information, community information and routine activities were asked in the survey. In the activity-travel diaries, the respondents were asked to continuously report each trip and activity episode during the week. For each episode, start/end time, duration, companions, activity type/travel mode, and the satisfaction with the episodes were also asked. Furthermore, a series of questions that assess the levels of perceived space–time flexibility of an activity was asked, and a question of the modal flexibility was asked for a trip.

Survey participants were recruited from the residents and employees in the Shangdi-Qinghe area. For each community or company, the sample size is determined according to the number of the total residents or employees (0.5 -1%) and then the participants are randomly selected with the help of the residential committee or the human resource department in the companies. Due to the survey methods, each participant needed to be over 14 years old and able to use the Internet by himself/herself or with the help of his/her family. A total of 791 participants were recruited from 23 communities and 19 companies to participate in the survey, and 709 of them completed the online dairies resulting in an 89.6% completion rate. This rate is notably high for this kind of survey and is largely due to the investigators' support. For the analysis in this thesis, only commuters with full 7-day activity diaries are included. The socio-demographic and commute/work attributes of these 410 commuters are presented in Table 1.1. Furthermore, specific research questions and sub-datasets with different components (e.g., activity episodes, trip episodes and individuals) will be used.

Table 1.1 Personal attributes of the sampled commuters

Socio-economic attributes		**No.**	**Pct. (%)**
Gender	Female	225	54.9%
	Male	185	45.1%
Age	Age < 30	184	44.9%
	Age 30 – 49	205	50.0%
	Age >= 50	21	5.1%
Marriage	unmarried (single, divorced, widowed)	113	27.6%
	Married	297	72.4%
Personal Income	Low income (<4000 RMB /Month)	212	51.7%
	Middle income (4000 -10,000 RMB/Month)	169	41.2%
	High income (>=10,000 RMB/Month)	29	7.1%
Education	Below college	41	10.0%
	College and university	305	74.4%
	Above college	64	15.6%
Household structure	Other household structure	356	86.8%
	Extended household (i.e., three or more generations living together)	54	13.2%
Household car ownership	No car	188	45.9%
	At least one car	192	46.8%
	Missing values	30	7.3%
Work and commute related factors		**No.**	**Pct. (%)**
Employment status	Part-time employed	14	3.4%
	Full-time employed	396	96.6%
		Avg.	**Std.**
Work Duration	Weekly work duration (min)	2338.90	632.00
H-W distance	Straight-line distance between home and work place(km)	7.73	6.58
Commute duration	Average duration for direct commute tours	84.42	43.32

As Table 1.1 shows, there are more female commuters involved in the survey, the average age is 33.41 and the majority is married (72.4%). The household car ownership among our sample commuters is lower than the average situation in Beijing (63 cars for every 100 households in 2014). On average, the job-housing distance is 7.73 km, on average they spent 84.42 minutes on a commuting tour and approximately 37 hours on working. Although our dataset is not representative of the whole population in Beijing, investigating their modality styles and their daily lives in a relatively long-time period (one week) can still contribute to the understanding of social sustainability aspects of transport in Chinese cities.

1.5 Thesis outline

This thesis consists of seven chapters. Chapter 2 to 6 are based on papers that have been published or submitted to peer-reviewed journals. As a consequence, there are some overlaps in theoretical frameworks and data description. The structure of this thesis is as follows.

Chapter 2 provides a brief overview of the modality styles distributed among our sample commuters and the determinants. Furthermore, how individuals' modality styles interact with car ownership, car use, and the impacts on non-work activity participation in the week are estimated. Chapter 3 investigates the influence of modality styles on individuals' social interaction with different companions, in commute days and non-commute days respectively. Chapter 4 examines the extra travel time attributed non-work stops in multi-purpose commute trips, and how extra time are affected by personal/household attributes, spatial factors and travel modes. Particularly, we examine whether the use of more motorized travel modes can help saving travel time. Chapter 5 focuses on the satisfaction with direct commute trips by various modes, and especially how commuters' experience with alternative modes (multimodality) and self-reported modal flexibility can affect commuting satisfaction. Chapter 6 examines the satisfaction with non-work activity episodes, and further investigates how they are affected by the space-time flexibility of activities and also individuals' modality styles. We end the thesis with a conclusion, where we return to the research questions and elaborate on the theoretical and policy implications of this research.

1

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2. Multimodality and non-work activity participation: a case study of Beijing

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2

ABSTRACT

Multimodality is promoted as a strategy to encourage the use of sustainable travel modes and reduce car use. While a car is found to facilitate individuals' participation in activities, it is unclear how the use of multiple travel modes can influence urban residents' daily life practices. Furthermore, multimodality is mainly investigated in developed countries with high car ownership and mobility issues related to car dependence. The profiles of modality groups may differ in a context of relatively low car ownership but expansive public transport systems, as in Beijing. Based on the dataset of "Daily Activity and Travel Survey of Beijing, 2012", we present the distribution of different modality groups among our sampled commuters and measure their out-of-base activity participation at the weekly level. A structural equation model is used to estimate the interactions between car ownership, car use and multimodality and how these interactions affect commuters' activity participation. Our research shows that car ownership encourages more car use, while car users are less likely to be multimodal. However, taking into account all direct and indirect effects, car ownership is found to lead to a diverse mix of transport travel modes that are not car dependent in practice. Additionally, car ownership itself does not affect individuals' non-work activity participation but only matters via car use and multimodality. Specifically, car users mainly benefit from saving travel time for non-work activities but do not show higher non-work activity participation. In contrast, with the use of multiple travel modes, multimodal travellers are more likely to engage in various non-work activities but also spend more time travelling.

Keywords: Car ownership; car use; multimodality; non-work activity; Beijing

2.1 Introduction

To combat the negative externalities associated with car use, multimodality – the use of multiple transport modes in a specified period – is seen as a strategy for encouraging the use of public transport and active modes and reducing car dependence (Kuhnimhof et al., 2006; Nobis, 2007). Using longitudinal datasets, Buehler and Hamre (2014a) found significant shifts towards more multimodal behaviour among motorists between 2001 and 2009 in the U.S., and Kuhnimhof et al. (2012) identified an increasing share of younger drivers using alternative travel modes in the past decade in Germany. By inducing occasional switching from car use to more environmentally benign modes of transport, multimodality has been found to be associated with a reduction in car use and car dependency (Block-Schachter, 2009; Diana, 2010).

While multimodality is associated with lower levels of car use, the car is found to benefit individuals by facilitating their non-work activity participation in diverse categories of daily life practices, such as social/discretionary/leisure activities (Farber and Páez, 2009; Lin and Wang, 2014), meeting family members (Rubin, 2015; Rubin and Bertolini, 2016), and personal affairs such as shopping and sports (Susilo and Dijst, 2010). For commuters with time constraints imposed by work and commute durations, the use of cars offers the possibility of including non-work activity locations in their daily activity prisms (Bhat, 1997; Islam and Habib, 2012; Rubin, 2015). As multimodality is associated with less car use, this raises questions about the effect of multimodality on individuals' daily life practices and the extent to which multimodal travel pattern can accommodate participation in desired social and recreational activities.

To date, studies of multimodality have been predominantly conducted in Western contexts, characterized by high levels of car ownership. For contexts with low-density land-use and automobile-dominated transport systems in North America, multimodality usually implies combining car use as the dominant travel mode with limited use of other modes (Buehler and Hamre, 2015; Ralph, 2016). In European contexts, which often feature more compact urban forms, diverse groups combine multiple modes, such as substantial cycling by multimodal groups in Denmark (Olafsson et al., 2016), the Netherlands (Kroesen, 2014) and Germany (Kuhnimhof et al., 2010). Asian megacities, on the other hand, are characterized by high urban densities and a strong dependency on public transport and lower levels of car ownership. For instance, in Beijing, public transport dominates, accounting for 44.0% of all trips (trips on foot excluded) by its residents in 2012 (Beijing Transport Research Center, 2013), while there were 63 private cars for each 100 households at the end of 2012. It is likely that the expansive public transport system and high-density urban landscape in Beijing provide different conditions for multimodality, implying that different forms and extents of multimodality may be present, with effects on activity participation that differ from those in Western contexts.

Based on a dataset collected in Beijing in 2012, this paper contributes to the current literature in two ways: first, we explore multimodality and its determinants and effects in a developing economy context characterized by a high reliance on public transport and less car ownership; second, in addition to studying the effect of multimodality on car use, we investigate its influence on non-work activity participation as an indicator of social inclusion.

The remainder of this paper is organized as follows. The next section reviews the literature on modality and activity participation and presents the conceptual model. Section 2.3 presents the research design for this analysis, including data collection, measurements of key concepts and methodology. The model estimation results are discussed in Section 2.4. The conclusion and discussion are presented in the final section.

2.2 Literature review

2.2.1 Modality, car ownership and car use

Multimodality is generally defined as the use of at least two travel modes (as main modes for different trips) in a specified period (Block-Schachter, 2009; Nobis, 2007), while monomodality is the exclusive use of one transport mode in that period. Modality reflects the individual's modal mix and one's familiarity with different modes (Diana and Mokhtarian, 2009). Furthermore, modality is defined in some studies in terms of behavioural predispositions, which suggest that they reflect higher-level orientations or lifestyles, which are hypothesized to influence all dimensions of an individual's travel and activity behaviour (Vij et al., 2011; Vij et al., 2013).

Predictors of multimodality have been explored including social demographic attributes such as gender, age, income, the presence of child, being full-time employed (Buehler and Hamre, 2015; Kuhnimhof et al., 2006; Nobis, 2007; Scheiner et al., 2016), and policy-related attributes such as quality of the public transport system, and travel demand management measures (e.g. Block-Schachter 2009; Brons et al. 2009; Kuhnimhof et al. 2006). Furthermore, multimodality is found to vary by "the overall mobility culture of a particular city" (Klinger, 2017), and regarded to be very much "an urban behaviour" in many studies, as the percentage of multimodal people increases with city size (Block-Schachter, 2009; Kuhnimhof et al. 2006).

Car ownership is usually regarded as an exogenous variable when explaining multimodality. Various studies found a "monopolizing effect" of car ownership, as it can lead to monomodal car use (Buehler and Hamre, 2015; Chatterjee et al., 2016; Kuhnimhof et al., 2012). However, car ownership may also lead to multimodal travel behaviour (Buehler and Hamre, 2014; Ralph, 2016), as it provides an additional option, which makes it easier to combine modes. The relationship between car ownership and multimodality is, however, mediated by car use and its impact may vary between contexts. For instance, while car ownership often leads to monomodality in US settings, it may be more associated with multimodality in settings where other travel modes provide a better alternative (Olafsson, 2016; Kuhnimhof, 2010; Kroesen, 2014).

From the above, it follows that car ownership, car use and multimodality may be interrelated in complex interactions. In this paper, we aim to understand the pathways through which car ownership and car use influence multimodality and eventually activity participation, thereby taking these complex potential interactions into account.

2.2.2 Non-work activity participation and mobility styles

As activity participation is an indicator of quality of life (Farber et al., 2011), many studies focus on activity participation associated with transport-disadvantaged, or segregated, groups. These studies highlight the role of transport in fulfilling and/or limiting activity participation across vulnerable groups (Hodgson and Turner 2003). For example, Farber and Páez's (2009) study in Portland found that reliance on automobiles significantly reduced the frequency and range of social activities among respondents. However, the impacts of reliance on transport modes are found to differ across geographical and population segments. For example, based on a national dataset in the U.S., Merlin (2015) found, for households without vehicles, that high residential and employment densities appear to support greater non-work activity. For households with full access to vehicles, their non-work activity participation appears to be supported by "higher than average" residential and employment densities and mid-range urban and metropolitan area sizes. Golob et al. (1995) explored how the use of specific travel modes affects the relationships between out-of-home activity duration and travel time. They included one segmentation variable in their model, representing a four-way classification of "mode dependency" (exclusively car, car + walking or cycling only, car + public transport, exclusively modes other than car). Their analysis revealed "mode dependency" differences in sociodemographic effects. For example, no gender difference is found between car dependent and public transport dependent groups. However, women in groups combining car and other modes undertake more maintenance activities and travel than men (Golob et al., 1995).

Several studies have explicitly linked multimodality to activity participation. For example, in Ralph's (2016) latent profile analysis, four types of young people are identified from the United States National Household Travel Survey (NHTS): Drivers, Long-distance Trekkers, Multimodals, and Car-less. Compared to those who essentially use the car for all their trips, the group of multimodal car users who use alternative modes for half of their trips and the car-less group are regarded as "limited" and "very limited" in mobility. It was found, however, that members of the multimodal group with "limited" mobility did not appear to limit their activity participation", while those in the "car-less" group were likely to be "stuck in places". These conclusions are based on the observed trip-making of different modality groups but do not address activity participation explicitly. The effect of multimodality on activity participation has not yet been examined and is therefore also a key issue in this paper.

With respect to the direct relationship between activity duration and travel time for non-work activities, some studies show that travel time increases with activity duration (Kitamura, 2002; Kitamura et al., 1998; Levinson and Kumar 1995), whereas other studies find a trade-off between travel and activity time, given the limited time budget of each individual (Dijst and Vidakovic, 2000; Chen and Mokhtarian, 2006; Susilo and Dijst, 2010). The ratio of travel and activity time has been found to be influenced by the transport system but also by personal and household attributes, daily constraints such as work and commute duration, and the built environment (e.g., Schwanen and Dijst 2002; Susilo and Dijst 2009; Zhang 2005). The effects can, however, vary across contexts. For example, while shopping travel time decreases as accessibility to vehicles increases in Canadian cities (Farber et al., 2011), in Dutch cities that discourage car use, drivers take relatively long shopping travel time (Schwanen and Dijst 2002).

2.2.3 Conceptual model

Our research aim is to explore how car ownership and car use influence modality style and investigate their eventual effects on individuals' non-work activity participation. In this respect, we assume that car ownership may have a direct effect on activity participation but also an indirect effect via car use and multimodality. Similarly, car use also has both a direct and an indirect effect on activity participation. As the review above suggests, car ownership, car use and multimodality are all likely to be affected by factors such as personal/household characteristics and spatial factors, which are therefore used as control variables. Finally, car ownership, car use and multimodality may influence activity participation in more or less effective ways, expressed in travel time needed to participate. To investigate these effects of car use and multimodality, non-work travel time is also included as a variable in the model.

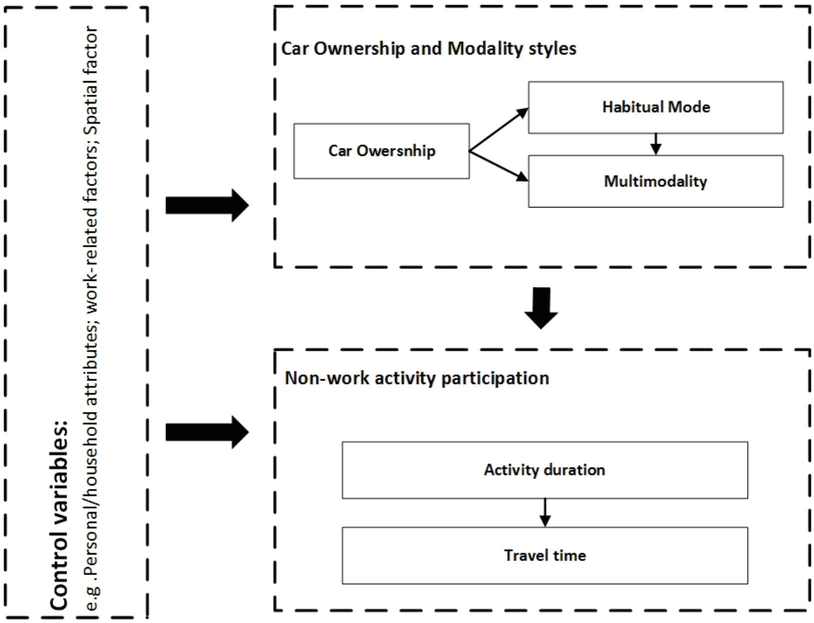

Figure 2.1 Conceptual model

2.3 Research Design

2.3.1 Dataset

Data were obtained from the "Daily Activity and Travel Survey of Beijing, 2012," conducted from October to December 2012 in the Shangdi-Qinghe area of Beijing. This survey includes socio-demographic characteristics of commuters, an activity diary filled out for one week and data from GPS loggers carried by respondents. As the study defines modality style at the weekly level and requires non-work activity participation data for a whole week, only commuters with complete travel and activity diaries for a whole week and full socio-demographic information recorded are included in the study. The dataset for the present analysis includes 380 commuters. Their personal/household attributes and the spatial characteristics of their homes and workplaces are presented in Table 2.1.

Table 2.1 Socio-demographic and spatial factors in the model

Socio-economic attributes		**No.**	**Pct. (%)**
Gender	0 = female	212	55.79
	1 = male	168	44.21
Age	0 = age <30	171	45.00
	1 = age > =30	209	55.00
Personal income	0 = low income (< RMB 2000/Month)	195	51.32
	1 = middle and high income	185	48.68
Household structure	0 = other household structure	325	85.53
	1 = extended household	55	14.47
Work-related factors		**Avg.**	**Std.**
Work duration	Weekly work duration (min)	2241.73	653.99
H-W distance	Straight-line distance between home and work place(km)	7.80	6.62
Spatial factors		**Avg.**	**Std.**
Home density level	Density of facilities within 1 km around home	244.37	135.21
Home mix level	Facility diversity within 1 km around home	0.36	0.06
Workplace density level	Density of facilities within 1 km around workplace	308.56	195.39
Workplace mix level	Facility diversity within 1 km around workplace	0.33	0.06

Our sample is not representative of the Beijing population as a whole. The survey was conducted in the Shangdi-Qinghe area of Beijing, which is located northeast of Beijing's 5th ring road. This suburban area is a residential centre with 240,000 residents that also functions as a job sub-centre with more than 5,000 companies and 160,000 jobs. Respondents were selected from communities and companies in this area. The sampled commuters are generally young (with approximately 45% under the age of 30), with approximately 50% of respondents having monthly incomes under RMB 2,000. Almost 15% of the sample live in extended households, with three generations living together. Furthermore, for the commuters in our dataset, the average work duration in one week is almost 38 hours, and the average straight-line distance between the workplace and home is 7.8 km. For spatial factors, points of interest (POIs) data (Long and Liu 2013) in Beijing were used to assess the density and the facility mix level in a 1 km radius around the two bases (home and workplace). POI density is calculated as the number of POIs within a 1-kilometer buffer. The mix level is calculated using the entropy measure shown in the following equation (Frank et al. 2004, Long and Liu 2013):

$$M = -\sum_{i=1}^{n} p_i \times log\ (p_i)$$

In the equation, p_i is the proportion of the POIs of type I; n denotes the number of POI types under consideration. POI types (n=4) here include commercial, public service, public recreation, and transport facilities.

2.3.2 Endogenous variables: modality and activity participation indicators

(1) Household car ownership

Of all 380 commuters, only 16 have 2 cars in the household, 176 have 1 car, and the other 188 reported no private car in the household. Hence, 50.5% of the sample has access to a household car, which is slightly lower than average in Beijing (63%) and markedly lower than average in Western countries. For instance, the car ownership level was 206 vehicles per 100 households in the entire U.S. in 2013 (Davis et al. 2013).

Because most car-owning households have only one car, respondents must mostly share the car with family members. On the other hand, there are 71 commuters with household cars but without driving licenses, implying that they cannot use the car independently.

As only a very few households have more than 1 car, commuters are divided into two groups as a dichotomous variable: with a household car (50.5%) and without a household car (49.5%).

(2) Modality style indicators

Modality styles are determined by observing individuals' uses of different transport modes during a whole week. Based on the observations, modality styles are indicated by two dichotomous variables: habitual mode and mono-/multimodality.

Three types of transport modes are identified in our analysis: car, public transport (bus and subway), and active travel modes (bike and walking). For each commuter, the most frequently used travel mode is defined as the habitual travel mode. A dummy variable is used to indicate whether the car is the habitual travel mode. For 27% of the sample, the car is the habitual travel mode. This is lower than the share living in a household with a car (50.53%), which suggests that many individuals with access to a car do not depend on it in daily practice.

Multimodality is defined as the mixing of modes across trips (rather than within trips, which can be termed intermodality). Predominantly using a single mode for multiple trips is defined as monomodality. The threshold value used to identify monomodality differs across studies. Nobis (2007) defined individuals who use a single mode for over 70% of all trips as monomodal, while the threshold for Vij et al. (2011) is 90%, and the cut-off value for Buehler and Hamre (2014b) is less than 7 trips by other modes in a week. Three thresholds were tested to define monomodality: using a single mode for 100% of trips in a week, more than 90% of trips in a week or more than 70% of trips in the week. With a 100% threshold, 28.68% of the individuals are categorized as monomodal. When the threshold of 70% is applied, the monomodal group increases to more than 70% of the sample. After comparison, the threshold of 90% was adopted, which indicates that monomodal travellers show a high tendency to rely on a single mode in daily practice but on average use alternative modes for less than one tour in one week. Under this threshold, 60.26% of respondents are defined as multimodal travellers in daily life, while the other 39.74% are more likely to depend on one mode type (Table 2.2).

(3) Out-of-base non-work activity participation

Out-of-base activity participation is indicated by the total duration of non-work activity participation during one week. Three types of non-work activity are defined: 1) personal/household affairs, including shopping, seeing a doctor, taking care of family members and engagement in household-related affairs; 2) social/recreational activities, including social activities and leisure/recreational activities, as reported by commuters; and 3) other non-work activities. In total, there are 1,856 activity episodes, including 878 personal/household activity episodes, 776 social and recreational activity episodes and 202 other activities (Table 2.2). Thirty-three respondents did not report any out-of-base non-work activities during the week. Furthermore, 92 individuals reported no personal/household affairs, 110 reported no social/recreational activities, and 259 reported no other activities during the week. On average, respondents spent approximately 3 hours on personal/household affairs, 3.5 hours on social/recreational activities and only 30 minutes on other activities in the week.

Travel time for non-work activities is calculated from two components: travel time for non-work tours and the travel time for non-work activities in multi-purpose commute tours. For multipurpose commute tours, travel time for non-work activities is calculated by deducting the direct commute duration from the total travel time for the tour. With multiday activity diaries collected, a commuter’s direct commute tour duration is calculated by averaging all his/her direct commute tours in the week.

By adding the two components together, the average travel time for non-work activities is found to be approximately 2.5 hours in the week. In addition to the 33 individuals with no non-work activities reported (and consequently no non-work trips), there are another 27 individuals with non-work travel duration computed as 0 and 7 individuals with negative values. The 27 individuals reported the same travel time for their multipurpose commute tours as for their direct commute tours, which is possible because the non-work location is situated along their commute route. For example, stopping to buy an easy breakfast before entering the subway station would not actually increase travel time relative to direct commute trips. For the 7 individuals with negative travel time computed, these negative values suggest that adding non-work stops does not necessarily increase commute duration and may even lead to a reduction in travel time. This phenomenon was also found in our previous study (Mao et al. 2016), and a detailed inspection reveals that possible reasons for this include personal strategies for multi-purpose trips, such as mode shift, departure adjustment and a longer direct travel time reported due to traffic or out-of-vehicle waiting time.

Table 2.2 Endogenous variables

Car ownership and modality style indicators		**No.**	**Pct. (%)**	**Note**
Household car ownership	0 = No car household	188	49.47	--
	1 = Car owner	192	50.53	--
Habitual mode	0 = Other	278	78.16	--
	1 = Other	102	26.84	--
Multimodal behaviour	0 = Monomodal	151	39.74	--
	1 = Multimodal	229	60.26	--
Non-work Activity Participation (mins per week)		**Avg.**	**Std.**	**Zero-Obs.**
PH Dur	Duration of personal/household activities	187.52	231.64	92
SR Dur	Duration of social/recreational activities	209.05	241.29	110
OT Dur	Duration of other activities	35.02	83.80	259
NW Travel	Travel time of non-work activities	158.82	169.70	--

2.3.3 Methodology

Our research aim requires investigation of how car ownership and modality indicators can directly and indirectly influence non-work activity participation in daily practice and how they mediate the impacts of the personal, household, spatial and work-related variables on non-work activity participation. As structural equation modelling (SEM) is a powerful multivariate modelling tool that can handle multiple endogenous variables simultaneously, this modelling approach is adopted in the following analysis, using the computer program LISREL 8.8 (Jőreskog and Sőbom, 2001).

The SEM model requires modification of some variable types in our analysis. First, many people who did not participate in a certain type of out-of-base activity, resulting in zero-observations for activity participation variables, were defined as “censored below” in LISREL (Jöreskog, 1990). Second, the indicators for endogenous car ownership and the modality variables are dichotomous. Additionally, exogenous variables include dichotomous variables (e.g., gender, income, age group) as well as continuous variables (e.g., H-W distance, density and mixture levels). The full model thus includes dichotomous, continuous and left-censored continuous variables. Consequently, the correlation matrix required in the analysis must include three correlation types or weighted combinations thereof, namely, product-moment correlations between continuous variables, polychoric correlations between categorical variables, and polyserial correlations between categorical and continuous variables. To handle these different types of variables, PRELIS 2 (Jöreskog and Sörbom 1996) is used to produce the optimal maximum likelihood correlation matrix of all variables included in the analysis. This correlation matrix is used in the estimation of the full model in LISREL 8.8, also by means of the maximum likelihood method.

The structural equation model that forms our conceptual model is presented in Figure 2. In the causal structure that links the exogenous and endogenous variables, car ownership, the modality variables and the activity participation variables are all affected by the personal/household attributes and spatial factors listed below. The causal relations between endogenous variables include the following: 1) car ownership determines one’s habitual travel mode (car or other) and mono-/multimodality; 2) habitual travel mode influences individuals’ modality and potentially mediates the impact of car ownership on modality; 3) car ownership and the modality indicators influence time spent on different activity types as well as travel time spent on them; 4) participation in personal/household affairs can affect participation in social/recreational and other activities, and participation in social/recreational activities can affect other activity participation; and 5) non-work activity duration determines travel time to participation locations.

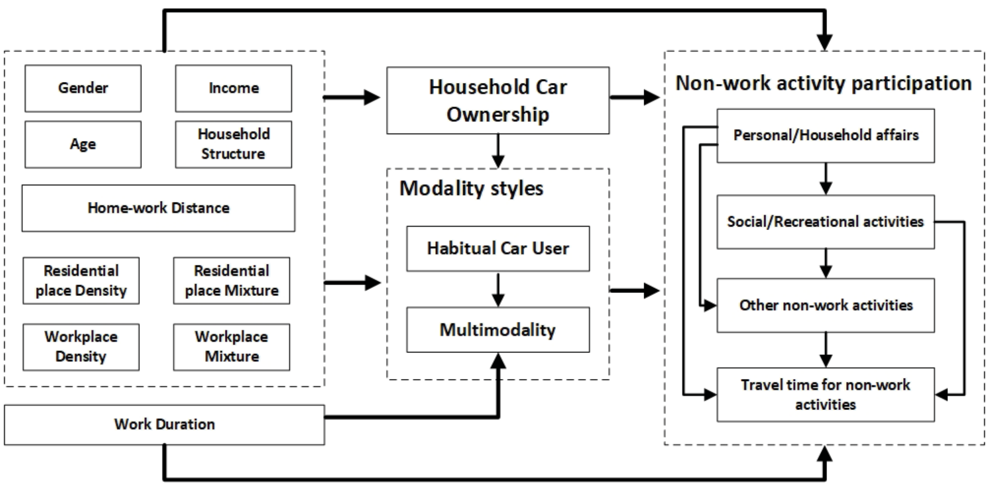

Figure 2.2 SEM model structure

2

2.4 Results

This section presents the estimated effects of car ownership, habitual car use and multimodality on out-of-base activity participation in the SEM model while controlling for the effects of sociodemographic and environmental attributes (see Table 2.3). In general, the SEM model fits the data well, as indicated by a RMSEA=0.047, CFI=0.999 and AGFI =0.912. In Section 2.4.1, we first discuss the influential factors on modality style and then, in Section 2.4.2, the direct and indirect effects on out-of-base activity participation.

Table 2.3 Structural equation model of modality and non-work activity participation

		Car Owner	Habitual Car	Multi	PH dur	SR dur	OT dur	NW Travel
Control variables								
Male	Direct	***-0.107****	***0.166*****	***0.206*****	***-0.122****	0.032	***-0.135****	***0.146*****
	Indirect	- -	***-0.103*****	***-0.223*****	***0.071*****	***0.092*****	***0.160*****	-0.017
	Total	***-0.107****	0.063	-0.017	-0.051	***0.124****	0.025	***0.129*****
Age>30	Direct	***0.431*****	***-0.102*****	***-0.330*****	0.117	0.124	***0.319*****	0.088
	Indirect	- -	***0.416*****	***0.192*****	-0.061	***-0.131*****	***-0.245*****	0.026
	Total	***0.431*****	***0.314*****	***-0.138****	0.055	-0.007	0.074	0.114
Personal Income (ref.=low)	Direct	0.082	***0.089*****	***0.287*****	-0.09	-0.106	-0.053	***0.130*****
	Indirect	- -	0.079	***-0.099*****	***0.101*****	***0.144*****	***0.163*****	0.037
	Total	0.082	***0.168*****	***0.188*****	0.011	0.038	0.11	***0.167*****
Extended Household	Direct	***0.161*****	***-0.228*****	***-0.153*****	-0.057	0.027	0.085	***-0.275*****
	Indirect	- -	***0.155*****	***0.309*****	-0.061	***-0.093*****	***-0.173*****	-0.002
	Total	0.161**	-0.073	***0.156*****	***-0.118****	-0.066	-0.088	***-0.278*****
Work Dur	Direct	- -	- -	***-0.190*****	***-0.117****	0.006	-0.043	***-0.202*****
	Indirect	- -	- -	- -	***-0.052*****	***-0.115*****	***-0.069*****	***-0.122*****
	Total	- -	- -	***-0.190*****	***-0.168*****	-0.108	***-0.112****	***-0.325*****
H-W distance	Direct	***0.129*****	***-0.076*****	***-0.177*****	0.030	0.053	***0.175*****	***-0.085*****
	Indirect	- -	***0.124*****	***0.114*****	***-0.047****	***-0.083*****	***-0.125*****	0.000
	Total	***0.129*****	0.048	-0.063	-0.017	-0.03	0.05	-0.085
Home Density	Direct	0.015	***-0.118*****	-0.07	-0.005	0.056	0.066	-0.034
	Indirect	- -	0.015	***0.150*****	-0.036	-0.044	***-0.087*****	0.020
	Total	0.015	***-0.104****	0.08	-0.042	0.012	-0.021	-0.014

Cont'd		Car Owner	Habitual Car	Multi	PH dur	SR dur	OT dur	NW Travel
Home Mix	Direct	-0.084	0.092**	0.126**	-0.040	-0.132**	-0.136**	0.093*
	Indirect	- -	-0.081	-0.128**	0.040*	0.060**	0.122**	-0.036
	Total	-0.084	0.012	-0.002	0.000	-0.072	-0.014	0.057
Workplace Density	Direct	-0.038	-0.016	0.137**	0.047	0.016	-0.065	0.028
	Indirect	- -	-0.037	0.014	0.031*	0.074**	0.045	0.067*
	Total	-0.038	-0.053	0.151**	0.078	0.090	-0.02	0.096*
Workplace Mix	Direct	-0.019	0.052**	0.179**	0.017	-0.069	-0.087	0.018
	Indirect	- -	-0.018	-0.068*	0.055**	0.096**	0.105**	0.037
	Total	-0.019	0.034	0.111**	0.072	0.027	0.018	0.055
Dependent variables								
Car Ownership	Direct	- -	0.964**	1.353**	-0.418**	-0.634**	-1.168**	0.18
	Indirect	- -	- -	-1.204**	0.523**	0.695**	1.061**	-0.131
	Total	- -	0.964**	0.150**	0.104	0.061	-0.107	0.049
Habitual Car (Hab car)	Direct	- -	- -	-1.248**	0.500**	0.631**	1.039**	-0.191
	Indirect	- -	- -	- -	-0.340**	-0.559**	-0.626**	-0.042
	Total	- -	- -	-1.248**	0.16	0.072	0.413**	-0.233*
Multimodality (Multi)	Direct	- -	- -	- -	0.272**	0.468**	0.488**	0.137*
	Indirect	- -	- -	- -	- -	0.042*	-0.099**	0.264**
	Total	- -	- -	- -	0.272**	0.510**	0.388**	0.401**
PH dur	Direct	- -		- -	- -	0.154**	-0.024	0.323**
	Indirect	- -	- -	- -	- -	- -	-0.028*	0.029*
	Total	- -	- -	- -	- -	0.154**	-0.052	0.351**
SR dur	Direct	- -	- -	- -	- -	- -	-0.182**	0.235**
	Indirect	- -	- -	- -	- -	- -	- -	-0.026*
	Total	- -	- -	- -	- -	- -	-0.182**	0.209**
OT dur	Direct	- -	- -	- -	- -	- -	- -	0.145**
	Indirect	- -	- -	- -	- -	- -	- -	- -
	Total	- -	- -	- -	- -	- -	- -	0.145**
Goodness-of-fit indicators								
R^2		0.297	0.792	0.467	0.114	0.204	0.185	0.467
RMSEA/CFI/AGFI		0.047/0.999/0.912						

Note: * p<0.05, ** p<0.01

2.4.1 Modality indicators

(1) Car ownership and modality indicators

As expected, household car ownership is strongly related to habitual car use; thus, the R^2-value for car use is high. The estimation results show that household car owners are more likely to travel by car, while habitual car users are less likely to be multimodal. The impact of car ownership on multimodality is modelled both directly and indirectly. The direct impact is positive, as car ownership offers an extra choice for travellers. The indirect impact is negative, as it encourages habitual car use, which negatively affects multimodality. Although the direct impacts are diminished by the indirect ones, the total impact nevertheless entails that car ownership positively impacts multimodality. Hence, in the aggregate, car ownership does not appear to cannibalize travel by other modes but lead to a more diverse mix of travel modes in the Beijing context. The availability of a household car offers an extra choice for travellers to be multimodal, while the limited number of cars per household, existing vehicle restriction policies and the fine-grained public transport system prevent car dependency.

(2) The impact of control variables

In our sample, females are more likely than males to have a household car[1]. Males are more likely to be habitual car users but also to be multimodal, indicating that male commuters are more likely to be the driver/user of the household car, with more choice and consequently more opportunities to be multimodal. However, given the negative indirect impact (due to its association with car ownership), the gender difference in habitual car use and multimodality is not significant overall.

Younger working adults (< 30) have lower car ownership and higher multimodality levels. Younger commuters are less likely to have a car, as it is less affordable and less necessary for unmarried young workers to have cars (McDonald 2015). Although as a direct effect of age, younger commuters are more likely than older commuters to travel by car, as an indirect effect, older commuters (> 30), with higher accessibility to cars, are more likely to be habitual car users. In terms of the overall effect of age, older commuters are more likely to be habitual car users. Additionally, as a direct effect of age, younger commuters are more likely to be multimodal than older commuters. However, as an indirect effect, younger commuters are less likely to be multimodal, due to higher car ownership among commuters above 30. Nevertheless, in terms of the total impact, younger commuters are more multimodal in daily life than older commuters.

1 Several explanations are explored. 1) among our respondents, a slightly higher percentage of women are local residents (with Beijng “***Hukou***”) than men (66% vs 64%), which makes cars and license plates more affordable; 2) women are equally educated as men—the shares of women completing high school and below, college and university, and postgraduate school are 9.43%, 75.94% and 14.62%, respectively; and the shares of men completing high school and below, college and university, and postgraduate school are 9.52%, 72.62% and 17.86%, respectively. Given the tradition that women are usually married to men with higher or similar economic/educational statuses in China (through 2013), we may make the bold assumption that the household income of female respondents may be slightly higher than that of male respondents, making a household car more affordable.

Personal income, but not household income data, were collected and used in our analysis. Although personal income has a positive direct effect on household car ownership, this effect is not statistically significant. However, personal income directly and positively encourages habitual car use as well as multimodality, as higher income provides the financial means to cover higher transport costs, consequently offering travellers more choices. Its total impact on habitual car use is enhanced through the indirect impact. The total impact on multimodality is also significantly positive, even given the negative indirect impact through the encouragement of habitual car use.

Cars may be more affordable as well as more necessary for larger households, which is seen in the positive relationship between an extended household structure and household car ownership. On the other hand, there also may be more family members to share a household car in an extended household. Therefore, the direct impact of household structure on habitual car use is negative. However, due to the mediating role of household car ownership, in total, no significant impact of household structure on car use is found. As a direct effect, commuters living in extended households are less multimodal. However, this direct effect is counteracted by the indirect positive impact due to car ownership, so that overall, individuals in extended households show higher multimodality.

Previous studies show that fully employed individuals are less multimodal than part-time workers or unemployed persons (Buehler and Hamre, 2014; Heinen and Chatterjee, 2015; Nobis, 2007), findings explained by the facts that commuting travel tends to involve a single transport mode and that full-time work leaves little time for other travel. In line with this explanation, we found that work duration is negatively associated with multimodality, as longer work duration leaves individuals less time to travel and become familiar with other transport modes.

Consistent with studies of car ownership, longer home-work distance encourages commuters to have a car in the household (Potoglou and Kanaroglou, 2008). However, the direct impacts of longer home-work distance on habitual car use and multimodality are negative. First, individuals with longer home-work distances are less likely to be habitual car users. In our case, with individuals selected from the inner-suburban area, longer distance is associated with a higher likelihood of commuting to an urban area with higher density/congestion and vehicle restrictions but also convenient public transport facilities. Combined, these factors make it easier for the commuter to choose public transport, especially a reliable subway system, rather than a car for commuting purposes. Second, people with longer home-work distances are also less multimodal, which could be related to the fact that they rely on motorized (car, public transport) but not active modes to cover longer commute distances and, as a result, are less familiar with alternative modes of transport in daily life. However, the total impact is not significant, given the negative indirect impact due to car ownership.

While car ownership is affected by many personal attributes, no spatial factor is found to have a significant influence. A high density of facilities around the home discourages car use, as it may reflect the provision of adequate public transport services as well as more congested traffic for car users. However, a higher mix of facilities around the residence and workplace, reflecting greater diversity, is found to encourage habitual car use. One possible explanation for this positive impact is that high-mixture areas with more diverse facilities are also likely to provide better car parking facilities. Additionally, although the sample was limited to 120 respondents, those who reported fixed parking places (95 individuals) are also found to have higher mixture levels (0.360 around home and 0.337 around the workplace), while those without fixed parking places (25 individuals) reported lower mixture levels (0.350 around home and 0.323 around the workplace). These attributes related to high mixture levels probably encourage car use to some extent.

Density around the home has a positive indirect impact on multimodality, due to its negative influence on habitual car use. Density around the workplace and mixture levels around both the residence and the workplace have positive direct impacts on multimodality. The explanation for this could be that a higher density of facilities is associated with a more walkable/cyclable environment and better accessibility to public transport facilities. Furthermore, a higher mixture level is associated with the presence of different facilities within walking distance around bases, which makes it possible for individuals to use active modes for different activity purposes in daily life. However, the mixture indicators' impacts are discounted by their negative indirect influences. The total impact of mixture around the home on multimodality turns out to be insignificant, while the total impact of mixture around the workplace is significantly positive.

2.4.2 Non-work activity participation

(1) Causal relations between endogenous variables

The results indicate that longer total activity duration is associated with longer non-work travel time. More specifically, personal/household affairs require a longer travel time than other activity types. This is consistent with previous Travel Time Ratio (TTR) and Travel Time Price studies indicating that travel time for each unit of discretionary activities is relatively low (Chen and Mokhtarian 2006, Dijst and Vidakovic 2000, Mao et al. 2016). Furthermore, when participating in out-of-base activities, especially on weekends with fewer time constraints, individuals might be likely to combine several activities in one tour/destination. Participation in personal/household activities directly encourages more time spent on social/recreational activities. However, participation in social/recreational activities reduces time spent on personal/household activities. Consequently, an indirect negative influence is found for personal/household activities.

The total effects of car ownership and the modality indicators are as follows: 1) car ownership does not significantly affect non-work activity participation; 2) habitual car users spend more time on other activities and have less non-work travel time, probably due to the higher speed and flexibility of car use; and 3) multimodal group members spend more time on all non-work activity types but also, consequently, spend more time in travel. More specifically, the direct and indirect influences of car ownership on non-work activity participation are opposed to one another. Living in a household with a car directly leads to less non-work activity, but car ownership also leads to habitual car use and more multimodality, which facilitates non-work activity participation[2]. In total, having a car in the household does not lead to greater participation in non-work activities in itself but only if it influences individuals' modality styles.

As a direct effect, habitual car use fosters greater participation in non-work activities, which could be explained by the fact that car use is fast and highly flexible, as an "all-around solution", facilitating participation in activities in different locations. However, the positive direct impact is discounted by the negative indirect ones, as habitual car use also discourages individuals from using diverse transport modes. Therefore, in total, car users are only found to participate more in other non-work activities and to save travel time for non-work activities. This could be because the speed of cars is generally higher than that of other modes, especially during non-peak hours for non-work activities, which facilitates saving in travel time.

In contrast to the other two indicators, multimodal travellers are found to engage more in out-of-base non-work activities of all types. Multimodal travellers benefit from their familiarity with and the availability of multiple modes, which can be used to reach different activity locations. However, the impacts of multimodality on non-work travel time are also significantly positive. This might imply that multimodal travellers combine multiple travel modes, including active travel modes with lower speed, in their daily practices. For each unit of activity duration, they require more travel time.

(2) The impact of control variables

Regarding personal attributes, as a direct effect, males spend less time than females on personal/household affairs, due to their role in the household. On the other hand, being male has a positive indirect impact on all three activity durations, due to the higher mobility level of males, with higher habitual car use and higher multimodality. However, overall, there is no gender difference in activity duration. The total influence of age on activity duration is also non-significant. Although age has a positive influence on the "other" activity type, the negative indirect influence of age is significant among all three activity types, due to the lower multimodality of older commuters. While high income has a direct negative effect on participation in other activities, overall, high income commuters participate in more social/recreational activities, given their higher mobility levels. Furthermore, we find that male commuters, commuters above 30 and higher income commuters are likely to travel longer for non-work activities, probably implying that they travel more often or in a larger urban area.

Individuals from extended households participate less in out-of-home personal/household activities and spend less time travelling to non-work activities. The reason could be that there are extra helpers in an extended household, especially retired grandparents, who can help in the conduct of some

2 The direct influence of car ownership is likely related to the attributes of families with private cars. Individuals in car ownership households are more likely than others to be married (88.89% vs 57.30%) and substantially more likely to have children in the household (57.67% vs 22.16%). The responsibility to care for and accompany more family members may decrease out-of-base non-work activities.

of the out-of-home non-work activities. The indirect effects of living in an extended household are also negative, mainly because of its positive effects on car ownership. Longer work duration directly decreases personal/household activity duration as well as travel time to non-work activities (Zhang, 2005). Furthermore, the indirect impacts of longer work duration are also significantly negative, due to its association with reduced multimodality. In total, longer work duration results in less time spent on non-work activity participation. Similarly, a longer H-W distance reduces time spent in non-work travel. However, although it has no significant overall influence, H-W distance is found to positively encourage other activities directly. A plausible reason for this is that, as commuters' activity space is largely shaped by their home-work locations (Pendyala et al., 2002), H-W distance may reflect the fact the individual is exposed to a larger urban space with more opportunities. Its negative indirect impacts are related to its association with less habitual car use and less multimodality.

Generally, out-of-home activities are largely explained by the socio-demographic variables but do not vary (in terms of total effects) with the spatial factors included in our estimations. For density around the home, no direct impact is found, but there is a negative indirect influence due to its impact on habitual car use, and the overall impact is also not significant. The mix of facilities around the home has a negative direct impact on participation in social/recreational activities and other activities but encourages longer travel time. This is the opposite of the hypothesis that diverse facilities provide diverse opportunities and facilitate greater activity participation. However, the finding might be explained by spatial development in the studied area. The facilities provided around the neighbourhoods in the research field, such as retail facilities, are usually low-price stores that cannot fulfil the needs of high income residents (Tana et al., 2015). In that case, such individuals are restricted to participating in activities around the residence and are likely to travel longer for non-work activities, requiring longer travel times. Given the contrasting indirect effects, the total impact of the mix of facilities around the home is also not significant. Previous studies exploring environmental factors mainly concentrate on residential locations but focus very little on workplace attributes. In our analysis, density around the workplace does not affect non-work activities directly, but it has positive indirect influences on personal/household affairs and social/recreational activities. Additionally, it positively influences travel time indirectly, mainly because greater multimodality is associated with higher density. The total effect, however, is not significant. Similarly, the mix of facilities around the workplace has no significant direct impact on non-work activity participation but a positive indirect impact due to its impact on habitual car use and multimodality. Again, however, the total effect is not significant.

2.5 Conclusion and Discussion

Encouraging multimodality is regarded as an alternative way of decreasing car use and stimulating more sustainable travel patterns. At the same time, it is important for policy making not to diminish urban residents' quality-of-life when trying to influence their transport mode choices. Although the number of cars has risen sharply in the past decades, Beijing remains a city dominated by public transport, with household car ownership limited relative to its Western counterparts. In this context, we developed a structural equation model to estimate the determinants of modality style and how they influence commuters' out-of-base non-work activity participation at the weekly level.

One significant contribution of this study is an investigation of the interaction between car ownership, car use and multimodality. Consistent with previous studies, household car ownership is found to encourage individuals to travel more often by car. Compared with other mode users, car users are also more likely to be monomodal. Nevertheless, car ownership also encourages multimodality by offering an extra choice to travellers, although this effect is impeded indirectly due to increased car use. Overall, in contrast to the "monopolizing" effect of car ownership found in previous studies (Buehler and Hamre 2014b, Chatterjee et al. 2016, Kuhnimhof et al. 2012), car ownership is found, in the context of Beijing, to lead to a diverse mixture of travel modes but not car dependency.

Furthermore, in addition to previous studies that focused on the influence of cars on activity participation, we examined the influence of car ownership, car use and multimodality simultaneously in the model structure. In total, household car ownership itself does not influence commuters' non-work activity participation but matters only when it leads to car use or multimodality. Car use benefits individuals by saving on travel time for non-work activities, but it does not result in higher activity participation. On the other hand, multimodal travellers who use multiple travel modes in daily life benefit from participating in diverse activities, while they also require more travel time to participate in these activities.

Additionally, we explored how modality styles are shaped by socio-economic/environmental factors and how they mediate the effects of these exogenous variables on non-work activity participation. Generally, the overall effects show that habitual mode choice and multimodality are likely to be affected by age, income, household structure and work duration. For spatial factors, higher density of facilities around the residence discourages car use, while higher density and diversity of facilities around the workplace encourages the use of multiple travel modes. Non-work activity participation itself is not influenced by spatial factors but is mainly affected by gender, income, household structure and work duration. These effects are mediated by the modality indicators.

Although not representative of the population in Beijing, our study indicates that instead of depending on one mode, even if they own a car, individuals benefit, in terms of activity participation, from access to and use of diverse transport modes in this densely populated area that contains an extensive public transport system. A possible policy implication is that, in addition to restrictions on car ownership and car use, it could be helpful to provide multiple choices for individuals by enlarging their modal choice “basket”. This may require providing more satisfying public transit services but also encouraging private transit (e.g., car-sharing, Uber cars, public bikes). This would not only benefit those with low access to transport options but could also guide car dependents towards reduced car use.

It should be noted that our findings are closely related to the features of the specific context studied. In previous studies of contexts with high car ownership, multimodal behaviour is regarded as related to travellers’ preferences and their increased awareness of automobile-related environmental issues (Buehler and Hamre 2014a, Kuhnimhof et al. 2006, Vij et al. 2011). In Chinese cities, on the one hand, car deficiency in households and vehicle restriction policies are likely to affect the role of car ownership in shaping multimodality in the sense that travellers are forced to be multimodal due to limited car availability. On the other hand, the expansive public transport system and high-density urban environment encourages the use of multiple travel modes and facilitates activity participation by multimodal travellers. To fully understand the role of multimodality in activity participation, the higher participation of multimodal groups in non-work activities found in our research must be examined in other contexts, where restrictions on car ownership and car use and the availability of public transport options differ. Such studies should place more emphasis on recording the availability of travel modes for specific trips to distinguish between forced and voluntary multimodality.

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3. Drivers of social interaction: exploring the effect of modality styles on face-to-face contacts

This chapter is based on a manuscript under review for a peer-reviewed journal. Co-author: Dick Ettema

ABSTRACT

Face-to-face interactions with social contacts are important for an individual's well-being. Car use facilitates the integration of social interactions into workers' daily activity patterns but is discouraged to reduce traffic congestion and environmental damage. Against this background, this paper investigates how individuals' modality styles are related to commuters' face-to-face interactions with their family members, friends and colleagues. One-week activity diary data collected in Beijing is used for the analysis, which shows that commuters spend more time on solo activities or with colleagues out-of-base on commute days, while they spend more time with family members and friends on the non-commute days. Multivariate Tobit regression models of joint activity time show that the interactions with friends are positively correlated with interactions with family members and colleagues on the commute days, while no significant relation is found among the interactions on non-commute days. Solo activities and social interaction with different companions are also significantly constrained by the work duration. On commute days, solo activities and interactions with colleagues are less influenced by modality styles, although monomodal car users have more interactions with family members and friends than those with other modality styles. However, this advantage disappears on the non-commute days. With fewer time constraints imposed by work and commuting, multimodal travellers display more interactions out-of-base with family members and friends.

Keywords: face-to-face interaction, multimodality, companion type, commuters

3

3.1 Introduction

Social interactions are crucial for the overall well-being and happiness of individuals (Helliwell and Putnam, 2004; Tilahun and Levinson, 2017). Meeting with family members is an important component of family solidarity (Rubin, 2015), and contact with non-household members is important to facilitate the exchange of instrumental and emotional support and the generation of social capital and to significantly improve individuals' mental health (Lin and Wang, 2014; Martin and Westerhof, 2003; Rook, 1987). Given these benefits to both individuals and society, one aim of the transport system is to facilitate social interaction (De Vos et al., 2013; Rubin and Bertolini, 2016). Previous research has addressed the role of the transport system in social exclusion, social segregation and social capital (Currie and Stanley, 2008; Lucas, 2012; Preston and Rajé, 2007; Boniface et al., 2015). It has been found that car use may encourage "social sustainability" (Tilahun and Levinson, 2017) by facilitating independent activities (Srinivasan and Bhat, 2006), meetings between family members (Rubin, 2015), and social/discretionary/leisure activity with companions (Sharmeen and Ettema, 2010).

However, the social benefits of car use come at the cost of negative impacts on the environment. In addition, the development of car-dependent land use and transport systems hampers the social interactions of those without access to a car. Additionally, driving a car is often a solo activity, whereas using public transport or active travel modes is associated with encounters with others during travel. Against this background, the use by travellers of multiple transport modes in a specified period has received much attention in recent studies in Western Europe (Kuhnimhof et al., 2006; Nobis, 2007) and the U.S. (Block-Schachter, 2009; Buehler and Hamre, 2014). This phenomenon has been termed "multimodality" (Kuhnimhof et al., 2006; Nobis, 2007). Multimodality is more sustainable than reliance on a car only and offers the potential to reduce car dependency. Although knowledge has been accumulating on how multimodality is associated with individuals trip making and activity participation (Blumenberg and Pierce, 2014; Buehler and Hamre, 2014), it remains unknown how multimodality is associated with individuals' interactions with different companions.

Although significant information is accruing regarding the relationship between transport and face-to-face social interactions, there is a lack of diverse contexts of these studies. Empirical studies are mainly performed in developed countries with high rates of car ownership and car dependence (Carrasco and Cid-Aguayo, 2012; Delmelle et al., 2013; Farber and Li, 2013; Rubin and Bertolini, 2016). However, the relationship between transport and social interaction may play out differently in land use and transport systems in other parts of the world. For example, Beijing is still a public transport-dominant city, where trips by public transport account for 44.0% of all trips (Beijing Transport Research Center, 2013). Although private car ownership increased sharply from 1.8 million cars to 4.2 million cars between 2005 and 2012, it is still markedly lower than that in Western countries. For example, there were still only 63 private cars for every 100 households in Beijing at the end of 2014, compared to 206 vehicles for every 100 households in the U.S. in 2013 (Davis et al., 2013). Another characteristic of China is that family is still an important institution, and individuals have a more collectivist orientation

(Dijst, 2014; Zhao et al., 2016). This focus on family affects people's social interactions. For example, Feng et al. (2013) hypothesized that this collectivism can be manifested in the choice of people with whom one undertakes activities and that residents with collectivist value systems have more activities with family members or colleagues, while people with individualistic value systems interact with more diverse companions. While empirical studies in Beijing show that most activities are undertaken with nuclear and extended family members (Zhao et al., 2016), more time is spent on in-home non-work activities rather than out-of-home, especially during the weekends (Chen and Chai, 2014). Against this background, the question can be raised regarding how transport options influence social interaction in a family-oriented and collectivist culture with relatively low car ownership levels. To address the above issues, this paper explores, based on one-week activity-travel data collected in Beijing, how individuals' modality styles associate with their social interactions among different companions (solo, family members, friends and colleagues) in the context of a developing country with a family-oriented and collectivist culture (Beijing, China).

The remainder of this paper is organized as follows: the next section reviews the literature on transport and the individuals' interactions with others. Section 3.3 presents the research design for this study, including data collection, operationalization of key concepts and methodology. Descriptive analyses are shown in Section 3.4, accompanied by discussion of multivariate Tobit regression models of social interaction for commute days and non-commute days. The conclusion and discussion are presented in the final Section 3.5.

3.2 Literature review: face-to-face interaction and transport

Being a social species, humans in contemporary societies "socialize or seek solitude, negotiate our identity and perform a range of social roles" (te Brömmelstroet et al., 2017), while their personal access to and use of transport resources is assumed to facilitate or impede their interactions with their social contacts. The effect of travel options on social interaction has been investigated in the context of joint activities (Fan and Khattak, 2008; Lin and Wang, 2014; Srinivasan and Bhat 2006); activity companion choices (Sharmeen and Ettema, 2010; Zhao et al. 2016); and face-to-face contact with multiple types of social network members (Rubin, 2015; van den Berg et al. 2009). These previous studies have been mainly conducted in Western countries with high car ownership levels. According to their findings, the car can be considered a "great enabler" (Farber and Páez, 2009) of mobility, and a positive impact of car availability on independent activity participation is reported (Srinivasan and Bhat, 2006). Rubin (2015) found in the Netherlands that high automobility is positively associated with the frequency of face-to-face contact between parents and their adult children. Based on a Swiss survey of egocentric social networks, Frei and Axhausen (2009) show that car availability increases the frequency of face-to-face meetings with friends. Sharmeen and Ettema (2010) identified different effects of car ownership within the household: a single car leads to joint engagement in social and cultural activities, while two cars allow for more independence between household members. Other studies find insignificant or even negative influences of car ownership on individuals' face-to-face interactions. In a developing economy (Chile), Carrasco and Cid-Aguaya (2010) studied the role of car ownership in emotional and material support from social networks and found that car ownership did not directly influence the frequency of social interactions. Van den Berg et al. (2009)'s study in the Netherlands found that people with two or more cars have less frequent face-to-face contact with their social network members. However, for Portland, USA, Farber and Páez (2009) found that automobility is associated with more "asocial and sedentary lifestyles," because car-reliant respondents were found to participate in fewer out-of-home amusement activities and evidenced shorter activity durations.

Multimodality is a concept surrounding transport options and mode use in travel. It is generally defined as the use of at least two modes in a specified period (Block-Schachter, 2009; Nobis, 2007), while monomodality is the exclusive use of one transport mode in that period. Modality reflects the individual's modal mix and his or her familiarity with different modes (Diana and Mokhtarian, 2009). Modality is also defined as a behavioural predisposition, which suggests that it reflects higher-level orientations or lifestyles hypothesized to influence all dimensions of an individual's travel and activity behaviour (Vij et al., 2011; Vij et al., 2013). However, there are only a few studies that link modality to activity participation. Ralph (2016) carried out a latent profile analysis based on the United States National Household Travel Survey (NHTS). Compared to monomodals, who essentially use the car for all their trips, the group of multimodals (car users who use alternative modes for half of their trips) and the car-less group are regarded as "limited" and "very limited" mobility groups, respectively. The multimodal group's "limited mobility did not, however, appear to limit their activity participation", while the car-less group are likely "stuck in places."

In addition to the transport system, social interactions are found to be affected by time use, activity patterns, and associated time constraints. For example, Christian (2012) found that commute duration negatively affects the time spent on social activities with spouses, children and friends. Work duration is negatively associated with individuals' contact frequency with their parents (Rubin, 2015), social interaction through social activities (Farber and Páez, 2009), discretionary activities (Farber and Li, 2013) and face-to-face contact frequency with social network members (van den Berg et al., 2009). In addition, socioeconomic variables including gender, employment characteristics, household characteristics (Delmelle et al., 2013; Srinivasan and Bhat, 2008; Tilahun and Levinson, 2017), and residential built environment attributes (Fan and Khattak, 2008; Lin and Wang, 2014; Sharmeen and Ettema, 2010) are found to influence how often/how long/with whom individuals interact. Furthermore, the influence of the transport system and built environments on social interaction varies by the type of social interaction and across interactions with different companions. For example, while a household car increases the chance of having family members/relatives as companions (Lin and Wang, 2014) or the frequency of meeting with parents (Rubin, 2015), for a fellow resident in the local neighbourhood, car ownership could decrease the likelihood of interaction, with less time spent in the residential area (Van den Berg et al. 2015). For our research context, two competing hypotheses can be raised for the influence of modality: 1) Monomodal car users would benefit from the flexibility and capacity conferred by the car and are more likely to have interactions with different companions out of base. 2) Given the high-density context, the use of multiple travel modes can facilitate individuals gaining access to locations at various scales. Multimodality may overtake the advantage of car use and positively affect individuals' social interactions out of base.

3.3 Research Design

3.3.1 Dataset

The data used in this study are from the "Daily Activity and Travel Survey of Beijing, 2012" collected from October to December 2012 in the Shangdi-Qinghe area of Beijing. The Shangdi-Qinghe area is located northeast of Beijing's 5th ring road. As one of the largest sub-centres in Beijing, this area covers a 16 square-kilometre area with mixed land use that includes residential, commercial, industrial and retail functions. It serves as a residential centre with 240,000 residents and as a job sub-centre with more than 5,000 companies and 160,000 jobs. The survey first collected the socio-demographic characteristics of the respondents, and then, activity diaries filled out by the respondents for one week along with data from GPS loggers carried by the respondents were collected. The complete dataset contains responses from 709 respondents. As this study defines modality style at the weekly level and requires non-work activity participation data for a whole week, only those commuters with complete travel and activity diaries for a whole week are included in the study. The dataset for the current analysis includes 410 commuters with 2870 days and 2064 out-of-base non-work activity episodes. Their personal/household attributes and the spatial factors of home and workplace are presented in Table 3.1.

There are more female commuters involved in the survey than male. The average age is 33.41, and the majority are married (72.4%). Car ownership in the sample is lower than the average of Beijing at the end of 2012 (63 cars for every 100 households). Commuters are only included in the analysis when they commute at least once a week. On average, they commuted approximately 5 days of the week, with only a few commuting only one day (0.2%) or all days (2%) in the week. To take the influence of work and the commute into consideration, the recorded days are split into commute days (2020 days) and non-commute days (848 days). Generally, there is a large overlap between weekday and commute days, with 93.9% of the commute days being weekdays (1897 days) and 82% of the non-commute days occurring on weekends. On average, the respondents commute 4.93 days in the week.

As all respondents are commuters, spatial attributes around their residences and workplaces are included. Spatial attributes include the number of facilities within 1 km of the bases, including commercial facilities (e.g., grocery shops, supermarkets, pharmacies, clothing shops), restaurants, and public recreational spaces.

Table 3.1 Personal attributes of the commuters

Socio-economic attributes		**No.**	**Pct. (%)**
Gender	Female	225	54.9
	Male	185	45.1
Age	Age < 30	184	44.9
	Age 30 – 49	205	50.0
	Age >= 50	21	5.1
Marriage	Unmarried (single, divorced, widowed)	113	27.6
	Married	297	72.4
Personal Income	Low income (<4000 RMB /Month)	212	51.7
	Middle income (4000 -10,000 RMB/Month)	169	41.2
	High income (>=10,000 RMB/Month)	29	7.1
Education	Under college	41	10.0
	Colleague and university	305	74.4
	Above college	64	15.6
Household structure	Other household structures	356	86.8
	Extended household (i.e., three or more generations living together)	54	13.2
Household car ownership	No car	188	45.9
	At least one car	192	46.8
	Missing values	30	7.3
Work and commute related factors		**No.**	**Pct. (%)**
Employment status	Part-time employed	14	3.4
	Full-time employed	396	96.6
Commute days in the week	1 day	1	0.2
	2 days	4	1.0
	3 days	15	3.7
	4 days	65	15.9
	5 days	252	61.5
	6 days	65	15.9
	7 days	8	2.0
Work and commute related factors		**Avg.**	**Std.**
Work Duration	Weekly work duration (min)	2338.90	632.00
H-W distance	Straight-line distance between home and work place(km)	7.73	6.58
Commute duration	Average duration for direct commute tours	84.42	43.32
Number of facilities within 1 km from residence		**Avg.**	**Std.**
Commercial facilities	Number of commercial facilities	63.05	48.36
Restaurants	Number of restaurants	77.02	47.15
Public recreational spaces	Number of public recreational spaces (e.g. parks, squares)	0.91	1.00
Number of facilities within 1 km from workplace		**Avg.**	**Std.**
Commercial facilities	Number of commercial facilities	60.38	55.17
Restaurants	Number of restaurants	110.07	69.40
Public recreational spaces	Number of public recreational spaces (e.g. parks, squares)	0.96	1.07

3.3.2 Measurements of key concepts

(1) Face-to-face interactions out of base

Face-to-face interactions are defined as spending time together with others at out-of-base locations (i.e., home and workplace) not related to work. Respondents are required to recall and report all their activities and trips in the whole week with start and end times. For each activity episode, ten types of activity companions were provided for respondents to choose from, grouped into four types: family members (including nuclear, extended and other family members), colleagues, friends, and other. As there are only 16 activity episodes performed with exclusively “other,” they are excluded from the analysis. Activities performed alone are included for comparison.

Based on these data, the total amount of time allocated to activities with different types of company was computed (alone, with family member, with colleagues and with friends).

(2) Measurement of modality styles

Modality styles are measured by observing individuals’ uses of different transport modes during an entire week. Three types of transport modes are identified in our analysis: car, public transport (bus and subway) and active travel modes (biking and walking). For each commuter, the most frequently used travel mode is defined as the habitual travel mode. Multimodality is defined as the mixing of modes across trips (rather than within trips, which can be termed intermodality). Predominantly using a single mode for multiple trips is defined as monomodality. The threshold value used for monomodality differs across studies. In the following analysis, the threshold of 90% is adopted, which indicates that monomodal travellers show a high tendency toward relying on a single mode in daily practice, and on average, they use an alternative mode for less than one trip in one week. Commuters’ habitual travel modes and mono-/multimodality options can generally be divided into 6 subgroups: Mono Car, Mono PT, Mono Act, Multi Car, Multi PT and Multi Act travellers.

3.3.3 Methodology

Multivariate Tobit models were used to model the effect of modality and personal characteristics on social interaction in our analysis. There are many days in which individuals do not participate in any out-of-base activity with a certain companion type. For example, if a commuter did not spend any time with friends out of home on a given day, his or her interaction duration with friends is zero in our case. Thus, the proposed model structure should treat zero as a boundary and not allow negative values as a solution (which is referred to as censoring). Furthermore, for the commute day and the non-commute day models, there are repeated observations for each individual in the models. As Table 3.1 shows, the number may vary among individuals, but there are on average 5 observations for each person in the commute day model and 2 in the non-commute day model. Therefore, the observations are not independent within the individual level.

The present paper employs a multivariate Tobit model originated by Amemiya (1979) who extended the univariate Tobit model to multivariate and simultaneous equation models. The multivariate Tobit model is a discrete-continuous model (Fang, 2008; Liu et al. 2015) that can manage censoring of the activity durations, which is necessary as some respondents do not engage in certain types of social interaction. By using a system of Seemingly Unrelated Regressions in the model, the error correlations among individual's interactions with different contact groups can be incorporated. This is needed, as the time budget is fixed for each individual and the durations of interaction with different companion types may be correlated (Sharmeen and Ettema, 2010; Lin and Wang, 2014; Schwanen et al., 2007). Furthermore, with the "mvtobit" command developed by Barslund (2007) in STATA, the cluster-robust variance estimation is applied, which separates variance within and between clusters and allows for unbiased estimation of coefficients in the case of repeated observations (in this study multiple days per respondent) (StataCorp, 2015).

The multivariate Tobit model is formally expressed in the following system of equations, where the observed variable, Y_{ijk} , is equal to the latent variable whenever positive and is zero otherwise:

$$Y_{ijk} = \begin{cases} Y_{ijk}^{*}, if\ Y_{ijk} > 0 \\ 0, if\ Y_{ijk} \leq 0 \end{cases}$$

where Y_{ijk}^{*} is a latent variable:

$$Y_{ijk}^{*} = \beta_{0k} + \beta_k X_{ij} + \Gamma_k X_j + \varepsilon_{ijk}$$

and where Y_{ijk} indicates the time spend each day (i) by each individual (j) with companion type k (K=4, including time spent alone, with family members, friends, and colleagues). The latent variable is a function of explanatory variables including X_{ij} and X_j ,which represent vectors of daily (e.g., work duration) and individual-level (e.g., gender, income) variables, respectively. ε_{ijk} stands for the cluster-robust estimated error terms that incorporated the independence within the groups (StataCorp, 2015). $\varepsilon \sim N(0, \Sigma)$, Σ is the variance-covariance matrix of the error terms. Furthermore, $\boldsymbol{\varepsilon} = (\varepsilon_{ij1}, \varepsilon_{ij2}..\varepsilon_{ijk})$ is assumed to be jointly normal distributed but not independently. By estimating the cross-equation error correlations and the variance of the error terms, this model can reveal the relation between the time spent with different companions.

3.4 Results

This section presents an overview of the results. First, we present the descriptive results of individuals' interactions with different companions and the distribution of modality styles. In the second section, we discuss how the interactions are affected by individuals' personal attributes, the spatial settings around the residence and workplace, and work and daily attributes, as well as how they are associated with individuals' modality styles. Finally, we investigate how the influences differ between the commute and non-commute days. Two multivariate Tobit models are performed for commute and non-commute days respectively. Four types of companionship (including no interaction with others, i.e., alone) are included in the commute days models. However, for the non-commute days, there are only 53 days included with contacts with colleagues. Therefore, the non-commute day model excludes the category of colleagues and we present the model with only three types of interactions.

3.4.1 Descriptive results

(1) Interaction with different companions

Table 3.2 summarizes the frequency and duration of interaction with different types of company for commute and non-commute days. Because there are 99 activities conducted with more than one companion type, the number does not sum to 100% across companion types. Generally, individuals participate more frequently in activities alone (17.9%) but spend more time when they have companions. The percentage of days with interactions with colleagues is much higher during commute days, while interactions with family members and friends are more frequent on non-commute days.

Table 3.2 Description of interactions in commute and non-commute days

Non-Zero obs. of days		Commute days (2020 days)	Non- Commute Days (850 days)	All days (2870 days)
alone	No.	342	158	500
	Pct.	16.93%	18.59%	17.42%
	Avg. Dur. (min)	74.44	156.46	100.36
family members	Obs.	183	227	410
	Pct.	9.06%	26.71%	14.29%
	Avg. Dur. (min)	89.25	203.00	152.23
friends	Obs.	132	91	223
	Pct.	6.53%	10.71%	7.77%
	Avg. Dur. (min)	123.11	215.96	161.00
colleagues	Obs.	315	53	368
	Pct.	15.59%	6.24%	12.82%
	Avg. Dur. (min)	84.78	255.32	109.34

We further investigated the types of activities facilitating the interactions with different types of company. Table 3.3 shows that personal affairs (e.g., going to the hospital, getting a haircut, exercising) are usually performed alone but also sometimes in the company of family members. More than 60% of the household affairs occur with family members. As the most frequent out-of-base activity type, dining out is mostly done with colleagues, followed by with family members and alone. Shopping, which is partly related to household affairs, is mostly performed alone and with family members. Social and recreational activities outside the bases mostly encourage individuals' interactions with family members and friends.

Table 3.3 Activity types for different companions

No. of activity episodes[1]	Alone		Family members		Friends		Colleagues		Total
	No.	Pct. (%)	No.	Pct. (%)	No.	Pct. (%)	No.	Pct. (%)	No.
Personal affairs	165	44.35	128	34.41	42	11.29	42	11.29	372
Household affairs	15	15.31	62	62.24	12	12.24	16	16.33	98
Eating-out activities	164	22.22	197	26.69	117	15.85	292	39.57	738
Shopping	139	43.03	130	40.25	22	6.81	36	11.15	323
Social and recreational affairs	38	12.75	119	39.93	106	35.57	64	21.48	298
Other activities	112	52.83	42	19.81	19	8.96	37	17.45	212

(2) Distribution of modality styles

Among all 410 commuters, almost 50% use public transport modes more often in their daily life (196 individuals), followed by car users (112 individuals) and active mode users (102 individuals). With the 90% threshold applied, more than 60% of individuals are assigned to the multimodality styles, and the remaining 40% show a high intendancy to rely on one certain mode.

As shown in Table 3.4, Multi Pt users are the largest group in our dataset (28%), while Mono Act users are the smallest, with less than 8% of the sample; a total of 12% depend mainly on car use.

Table 3.4 Description of individuals' modality styles

Modality styles		No.	Pct. (%)	No.	Pct. (%)
Mono modal	**Mono Car**	51	12.44	163	39.76
	Mono PT	81	19.76		
	Mono Act	31	7.56		
Multi modal	**Multi Car**	61	14.88	247	60.24
	Multi PT	115	28.05		
	Multi Act	71	17.32		

1 The number sum to be higher than 100% across columns (companion types) as individuals can undertake multiple episodes with different companion type arrangements during the course of the day.

3.4.2 Multivariate Tobit model results

(1) Correlations between the interactions with different companions

The Rho correlations in Tables 3.5 and 3.6 show that interactions with different social contacts are correlated on commute days but not non-commute days. More specifically, the Rho correlation indexes show that instead of a trade-off effect, interaction with friends is positively correlated with interaction with family members and colleagues on commute days. This is probably related to the joint activities with multiple companion types. Of 99 activities with multiple companions, 59 are conducted on commute days, among which 53 activity episodes are conducted with a combination of friends and family members/colleagues. One explanation is that it is more time-efficient to meet social contacts together on commute days. Another explanation is that the role of friends in individuals' personal networks is in part to "share activities and interests and to bring people into contact with new ideas" (Rözer et al., 2016), which includes introducing friends, family and colleagues to each other. However, on non-commute days, the interactions are not statistically correlated to each other.

(2) The relation with modality styles

The group of Mono Car users are adopted as the reference category in all the models. The association between social interaction and modality differs between companionship types and between commute and non-commute days. Generally, the advantage of car use is mainly shown in facilitating interactions with family members and friends on commute days, while this advantage is overtaken by multimodality on non-commute days. These findings correspond to our two competing hypotheses: 1) monomodal car users would benefit from the flexibility and capacity conferred by the car, but mainly on commute days with work and commute activities required; 2) with the high-density context, the use of multiple travel modes can facilitate individuals gaining access to locations at various scales, but mainly on non-commute days when the commuters are not time-constrained due to work and the commute.

On commute days, Mono Car users engage in more out-of-base non-work activities with family and friends compared to Mono PT, MONO Act, Multi PT and Multi Act users. Apparently, coordination with family and friends and the locations visited together requires a degree of flexibility that is best provided by a car. On commute days, time spent alone and with colleagues is not affected by the modality indicators. As time spent alone is less subject to "coupling constraints" and includes a large share of personal affairs, the use of a car does not show much advantage compared to other modes. Compared to the other companions, time spent with colleagues is more likely to be chained between work activities, e.g., dining-out activities over the lunch hour. Furthermore, many social activities with colleagues are likely required by the work contents, but not the individuals' preferences, and are thus less likely to be affected by his or her mobility levels.

On non-commute days, with fewer time constraints, the advantages of car use are overtaken by multimodality. Those employing multiple travel modes, regardless of their habitual modes, spend more time in out-of-base activities alone, with family and with friends. However, Mono PT travellers seem to be more constrained and less flexible, with a significant negative influence on their interactions with family members.

(3) Work and daily attributes

On weekend commute days, more time is spent with friends, and on weekend non-commute days, less time is spent alone. This may be due to greater flexibility of work arrangements on weekends and to greater availability of friends. Further, people spend more time with family members and colleagues out of base on Friday compared to other weekdays, probably because they do not need to work/get up early the next day. Similarly, on non-commute days, individuals spend less time with friends on Sunday, likely because they need to work next day.

Commute distance does not show any significant influence in the models. However, on commute days, time constraints imposed by longer work duration significantly reduce both the time spent alone and time to interact with all the social contacts. During non-commute days, work duration still has a significantly negative influence on all time spent out of base. A possible explanation is that longer work hours imply that more obligatory household activities in home must be completed on non-commuting days, leaving less time for out-of-base activities.

(4) Personal and spatial factors

Generally, female commuters spend more time with family members out of base on commute days, while male commuters spend more time with friends both on commute and non-commute days. Additionally, male commuters are found to spend more time with colleagues on commute days. Dining-out activities represent most of the time spent with colleagues, and women are less likely to be involved in these activities both because they are regarded as male activities in a Chinese context and due to home and family responsibilities (Bedford, 2015).

Personal income shows no significant influence in the commute day model but encourages meeting with family members on the non-commute days. This is likely since out-of-base activities with family members such as dining out and shopping come with financial costs. Education level shows no significant influence in the non-commute day model, but on commute days, the respondents with high education levels are likely to spend more time with colleagues, which might be because their job positions are relatively higher and involve more collaboration with colleagues and business partners.

For the household attributes, married people spend more time with family members outside the base, less time with friends and colleagues on commute days, and more time with family members during the non-commute days. Living in an extended household has a negative influence on out-of-base interactions with both friends and colleagues during the commute days, probably because a larger household size requires more time spent at home with the family members.

The spatial factors around both residence and workplace are considered in the commute day model. First, restaurants near the home encourage more time with family members on the commute days.

As dining out accounts for almost 30% of the activities with family members, restaurants near the home clearly facilitate this. Public recreational spaces around the workplace, such as parks and squares, encourage more time spent with friends. This can be understood from the data showing that social and recreational activities account for 33% of all the activities with friends. On non-commute days, restaurants near the home are found to encourage meeting with friends, as dining out is the second most frequent activity with friends (37%). Commercial facilities are found to have no significant impact.

Table 3.5 Commute day model of social interactions

Variables	Alone		Family members		Friends		Colleague	
	Coef.	Z-stat.	Coef.	Z-stat.	Coef.	Z-stat.	Coef.	Z-stat.
Cons.	-2.57	-0.07	***-133.34 *****	***-2.55***	6.96	0.10	***-82.95****	***-1.92***
Modality indicators (ref. = Mono Car)								
Mono PT	6.45	0.25	***-146.20 ******	***-4.42***	***-161.00 ******	***-3.29***	11.67	0.36
Mono Act	-24.12	-0.80	-51.86	-1.38	***-293.80 ******	***-4.46***	-50.28	-1.21
Mult Car	-4.31	-0.17	-38.10	-1.27	-34.60	-0.70	33.42	0.97
Mult PT	37.39	1.45	***-51.71****	***-1.77***	***-70.34****	***-1.76***	30.23	0.99
Mult Act	-15.37	-0.59	***-116.86 ******	***-3.65***	***-72.92****	***-1.65***	14.70	0.44
Work and daily attributes								
Weekend	3.74	0.17	6.41	0.20	***95.71 *****	***2.46***	-3.68	-0.13
Friday	17.93	1.41	***37.70 *****	***2.51***	34.23	1.32	***22.69 *****	***1.97***
Work duration	***-0.31 ******	***-5.42***	***-0.29 ******	***-5.18***	***-0.40 ******	***-4.93***	***-0.19 ******	***-3.54***
H-W distance	-1.74	-1.48	-0.65	-0.41	-3.63	-1.51	0.73	0.58
Personal attributes								
Male	11.23	0.88	***-39.18 *****	***-2.13***	***56.58 *****	***2.13***	***30.19****	***1.88***
Married	-9.77	-0.62	***114.45 ******	***3.44***	***-146.85 ******	***-4.62***	***-47.32 ******	***-2.60***
Middle and high income	-15.56	-1.04	12.20	0.58	-43.12	-1.51	-0.34	-0.02
Middle and high education	-12.17	-0.54	-14.18	-0.46	-70.68	-1.38	***-57.01****	***-1.63***
Extended household	-21.16	-1.04	-37.40	-1.44	***-87.95 *****	***-2.06***	***-53.43****	***-1.94***

Cont'd	Alone Coef.	Family members Z-stat.	Friends Coef.	Colleague Z-stat.	Alone Coef.	Family members Z-stat.	Friends Coef.	Colleague Z-stat.
Home_ Commercial	0.18	1.00	-0.34	-1.29	-0.57	-1.46	-0.16	-0.71
Home_ Restaurants	-0.19	-0.85	***0.50****	***1.91***	0.43	1.21	0.25	1.10
Home_ Public recreational	-4.95	-0.56	-16.69	-1.37	21.03	1.31	-11.00	-1.10
Work_ Commercial	-0.17	-0.94	0.35	1.60	-0.28	-0.73	-0.34	-1.44
Work_ Restaurants	0.16	1.12	-0.09	-0.49	-0.10	-0.36	0.24	1.27
Work_ Public recreational	7.79	1.22	7.77	0.88	***19.69****	***1.63***	5.25	0.66
Summary statistics								
Sigma	***151.62 ******	***11.27***	***166.21 ******	***14.94***	***233.49 ******	***15.33***	***159.88 ******	***13.96***
Rho Correlation	--	--	--	--	--	--	--	--
Family members	0.01	0.16	--	--	--	--	--	--
Friends	0.04	0.44	***0.25 ******	***3.07***	--	--	--	--
Colleague	0.00	0.03	0.08	1.34	***0.16*****	***2.51***	--	--
Wild Chi-squared (80)	406.83***							
LR test	19.49***							
Total Observations	2020 obs. 410 clusters							

Note: *p<0.1, ** p<0.05, *** p<0.01

Table 3.6 Non-Commute day model of social interactions

Variables	Alone		Family members		Friends	
	Coef.	Z-stat.	Coef.	Z-stat.	Coef.	Z-stat.
Cons.	***-186.77****	***-2.59***	***-474.99****	***-6.45***	***-481.57****	***-4.18***
Modality indicators						
Mono PT	28.62	0.41	***-134.26***	***-2.22***	27.95	0.31
Mono Act	-45.67	-0.57	-20.91	-0.29	-81.43	-0.55
Mult Car	77.69	1.11	***126.46***	***2.51***	77.22	0.79
Mult PT	***127.82***	***2.10***	33.37	0.69	103.07	1.29
Mult Act	***151.97****	***2.64***	34.60	0.63	***255.69****	***2.68***
Work and daily attributes						
Weekend	***-124.22****	***-2.98***	***70.78****	***1.67***	-45.48	-0.66
Sunday	-13.95	-0.49	-27.87	-1.06	***-108.55***	***-2.38***
Work duration	***-0.62***	***-1.96***	***-0.55***	***-2.15***	***-1.42***	***-2.28***
H-W distance	-2.65	-0.87	2.63	1.14	3.40	0.77
Personal attributes						
Male	31.58	0.96	-10.21	-0.35	***105.07***	***2.17***
Married	-53.31	-1.37	***272.20****	***5.64***	***-239.84****	***-4.40***
Middle and high income	27.31	0.76	***69.45***	***2.13***	-16.99	-0.34
Middle and high education	13.28	0.23	-52.54	-0.98	-105.43	-1.06
Extended household	-1.64	-0.04	-59.27	-1.58	-49.77	-0.61
Spatial facilities						
Home_ Commercial	-0.15	-0.33	-0.15	-0.41	0.73	1.05
Home_ Restaurants	-0.20	-0.46	0.16	0.38	***1.24****	***1.93***
Home_ Public recreational	6.20	0.27	-21.35	-0.98	-46.76	-1.60
Summary statistics						
Sigma	***292.57****	***11.55***	***283.88****	***19.52***	***383.54****	***16.19***
Rho Correlation	--	--	--	--	--	--
Family members	0.10	1.47	--	--	--	--
Friends	0.08	1.06	0.08	1.08	--	--
Wild Chi-squared (51)	***253.44****					
LR test	4.18					
Total Observations	850 obs. 402 clusters					

Note: *p<0.1, ** p<0.05, *** p<0.01

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3.5 Conclusion and Discussion

Face-to-face interactions with different companions are key to individuals' mental health and quality of life. The question addressed in this paper is how individuals' common travel arrangements, as well as spatial and household factors, influence social interaction. Using a one-week diary dataset collected in the Shangdi-Qinghe area in Beijing, our data analysis shows that commuters are more likely to spend much more time with colleagues than other companions out of base on commute days, while they spend more time with family members on the non-commute days. This confirmed the previous assumption (Dijst 2014, Feng 2013, Zhao et al. 2016) that the collectivism-orientation can be shown in activity companion choices. On average, approximately 2.5 hours per week are spent out of base with family members and friends, and approximately 1.5 hours are spent alone or with colleagues. Furthermore, our sample commuters are divided into different modality styles.

A significant contribution of this study is that we investigated how multimodality is associated with social interactions in the Chinese context. Our findings reveal that the relationship differs across companion types, as well as between commute and non-commute days. During commute days, with more time constraints imposed by work and commute durations, the use of a car facilitates interactions with family member and friends. This is probably related to the flexibility of the car, which makes it easier to add non-work stops to the commute as needed for chauffeuring companions to joint activities. This finding is consistent with previous studies in Western contexts, noting that the use of a car can help commuters accommodate non-work locations in their daily prism (Srinivasan and Bhat, 2006; Rubin, 2015). However, car use shows no advantage in terms of participating in solo activities with fewer coupling constraints, or in interactions with colleagues that are more likely to be work-related or for the development of workplace relationships ("*Guanxi*" in Chinese) (Han and Altman, 2009). During non-commute days with fewer time constraints, there is no advantage to a car for interaction with any companion type, whereas multimodal travellers participate in out-of-home activities more on non-commute days. This could probably be facilitated by the high density and mixed landscape in Beijing's inner suburban area, where activity opportunities can be accessible by alternative travel modes. However, Mono PT travellers appear to be more constrained in social interactions on both commute and non-commute days. Similar to the findings of previous studies, work duration strongly constrains individuals' out-of-base activities with different companions. Further, there are gender and marital status differences in the interactions with family members, friends and colleagues, while personal income and education levels are found to affect the interactions with family members on non-work days and interactions with colleagues on commute days, respectively. For the spatial factors, restaurants near the home can encourage interactions with family members on commute days and with friends on non-commute days because dining out is the most frequent activity type for joint activities.

There are several limitations to our study. First, our data are not representative of the full Beijing population. We mainly focus on the commuters, while the non-commuter population can show different distributions of modality styles and social interactions. Additionally, due to the differences between city sizes and landscapes, the influence of transport on social interactions in medium or small-sized cites in China may differ from our findings here. For example, the advantage of car use may be undermined for residents in small cities who travel shorter distances more frequently and rely more on non-motorized travel modes (Wang et al. 2015, Zhang 2015). Additionally, the physical distances to social contacts are also likely to be shorter due to the difference in city scales.

Second, for the interactions with different companions, we only include face-to-face interactions performed out of base, while there could be trade-offs between in-home and out-of-home social interactions (Tilanhun and Levinson 2017, Zhao et al 2016) and between different interaction modes (e.g., face-to-face, phone, email) (Frei and Axhausen 2009). The impacts of modality styles on the interaction locations and modes can be further explored. Furthermore, as we mentioned above, modality is also defined as a behavioural predisposition in previous Western studies which suggests that it reflects higher-level orientations or lifestyles (Vij et al., 2011; Vij et al., 2013). Such lifestyle choice may influence all dimensions of an individual, including both travel and activity participation. However, our analysis examined the relation between modality styles and social interaction without considering the existence of a higher level of latent classification to indicate the lifestyle choices. This can be further examined in studies using approaches such as a latent class modelling approach (e.g., Ralph, 2016).

From a policy point of view, the findings here highlight differences between car users and the other modality style travellers. While car use has advantages during commute days, encouraging and facilitating multimodality may also contribute to out-of-base social interactions, especially for the Mono Public transport users. The transport policy in Beijing has always highlighted the importance of public transport (Beijing Transport Institute, 2013), but it does not indicate that everyone should rely solely on public transport in practice. It is important to offer more urban mobility services (e.g., car- or bike-sharing, ride-sharing) to all urban residents in order to achieve more sustainable travel modes and higher quality of life. Additionally, facilities provided around the neighbourhoods in the research field, especially retail facilities, are usually low-price stores without high-quality goods (Ta et al., 2015) and are found to have limited influence on the residents' interactions outside the home. Further exploration of the location choices of the sample commuters can help reveal if the local commercial facilities cannot fulfil the higher-level demands of the residents, encouraging them to travel longer distances in practice.

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4. Analysis of Travel Time and Mode Choice Shift for Non-work stops in Commuting: case study of Beijing, China

This chapter is based on the article: Mao Z., Ettema D., Dijst M. (2016). Analysis of travel time and mode choice shift for non-work stops in commuting: case study of Beijing, China, Transportation: 1-16

ABSTRACT

This paper investigates travel time attributed to non-work stops in multi-purpose commuting trips. Travel time is explained by socio-demographics and spatial attributes, mode shift is also included to analyse the extra travel time, and its trade-off with activity time for four types of non-work stops—eating out, shopping, leisure/social activities, and family/personal/other. Data come from the "Daily Activity and Travel Survey of Beijing, 2012". Descriptive analysis shows that almost 20% of the multi-purpose commuting trips include a mode shift toward a more motorized transport mode than their direct counterparts. Regression results indicate that extra travel time due to detours is significantly related to the activity durations. Regardless of the activity type, longer work duration reduces the travel time. Furthermore, the interaction terms between personal/trip/spatial factors and activities durations show the impacts differ across the activity types. Gender difference is found only for eating out, which suggests that male commuters travel longer for the same amount of activity time. Concerning spatial factors, a greater mix of facilities near workplaces helps to reduce the extra travel time invested for a time unit of shopping and family/personal/other activities. Compared with public transit users, active mode users have shorter travel time for eating out. Timing, work duration and commuting duration as time-budget-related variables show negative impacts on the extra travel time for eating-out, shopping and family/personal/other activities. However, mode shift does not show any significant impact as the hypothesis proposed. Instead of rebalancing the trade-off between travel and activity time, commuters may relocate activity with an expanded opportunity choice set given by a higher mobility level.

Keywords: Commuting; Non-work stops; Travel time; Mode shift; Travel time price; Beijing

4

4.1 Introduction

Commuting behaviour has been an important topic in transport research for decades (Cervero and Kang-Li Wu, 1998; Horner, 2004; McGuckin and Murakami 1999; Sultana and Weber 2014). In addition to direct commute trips, extra stops added to the commute journey have recently received increased attention (Bhat, 1999; Bhat and Sardesai, 2006; Cao et al., 2008; Currie and Delbosc, 2011; Ma et al., 2014; McGuckin et al., 2005; Portoghese et al., 2011; Susilo and Kitamura, 2008; Van Acker and Witlox 2011). The increasing presence of dual-earner households and the growing acceptance of sharing household tasks between spouses (Levinson and Kumar, 1995; Soo et al., 2008) increase time pressure for urban families and consequently encourage trip-chaining behaviour. For example, a household travel survey in metropolitan Washington, DC showed that multi-purpose commute trips increased from 1.5% to 15% between 1968 and 1988 (Levinson and Kumar, 1995). This trend was confirmed on a national scale for the USA from 1995 to 2001, with a 9% increase in commuters who chained trips as part of their commutes (McGuckin et al., 2005). For individuals, trip chaining behaviour may provide greater efficiency and convenience in their daily lives (Hensher and Reyes, 2000; Ye et al., 2007), and for households, frequent multi-purpose commute trips play a major organizational role in their overall travel patterns (Hanson, 1980). However, for urban transport systems, the substantial increase in non-work stops in commuting may result in severe problems; for example, pressure in peak hours can increase because of the extra travel time for the stops (Bhat, 1997).

Although previous studies have addressed many aspects of commute trip chains, such as occurrence (Cao et al., 2008; Nishii and Kondo, 1992), stop frequency (Bhat, 1997; Portoghese et al., 2011), stop duration (Bhat, 1996a; Bhat, 1996b; Brunow and Gründer, 2013), tour scheduling (Islam and Habib, 2012; Ma et al., 2014) and location choice (Wang et al., 2013), the impacts of trip chaining on travel time have received little attention. Trip chaining in the context of commuting implies detours and extra travel time, the amount of which is likely to depend on the salience and duration of the secondary activity, geographical locations of the activity sites and increase in the efficiency of daily activity schedules. Soo et al. (2008) and Susilo and Dijst (2009, 2010) developed an analytical model to relate extra travel time (as compared with direct commute trips) to the duration of the secondary activity, expressed in the so-called travel time ratio (TTR). They found that the value of the TTR is affected by the journey types (to work or from work), trip purposes, socio-demographics of the travellers and built-environment opportunities. However, travel mode choices were assumed to be the same for direct trips and trip chains in their studies. In this paper, we argue that commute trip chains may in fact be the results of more complex behavioural adjustments, in which commuters may not only decide to include secondary destinations in their commute trips but also change the travel modes or timing of the commute trips. These strategies may have a considerable bearing on the extra travel time needed for trip chaining. Neglecting these strategies may lead to wrong conclusions regarding daily time use and travel times and consequently the sustainability and well-being implications. The aim of this paper is to investigate travel time attributed to non-work stops in commuting and examine the possible factors that affect the extra travel time and its trade-off with activity time in multi-purpose commute trips in Beijing, China.

A series of socio-demographic and spatial attributes (at the residence and workplace) will be included. Specifically, one aspect of our research is to explore the influence of transport mode shift on extra travel time. The availability of multi-day travel and activity data in Beijing allows us to make these detailed comparisons between direct and multi-purpose commute trips at the individual level.

The study area for this research is Beijing, China. Empirical studies on trip chaining behaviour have largely focused on European or American cities. With rapid urbanization occurring in China, traffic congestion and accessibility deficiencies have become primary challenges (Chai, 2013). As for transport mode choices in Chinese cities, public transit dominates, whereas urban residents have become increasingly dependent on automobiles. In Beijing, trips by public transit accounted for 44.0% of all the trips (trips on foot excluded) by the residents in 2012, whereas trips by private car accounted for 32.6%. Specifically, private car ownership increased sharply from 1.8 million to 4.2 million between 2005 and 2012 (Beijing Transport Research Center, 2013). A deeper understanding of trip chaining behaviour with this state of transport mode choices will enrich the travel behaviour research and may contribute to better policy making in the context of developing economies (Ma et al., 2014, Yang et al., 2007).

The rest of this paper is organized as follows. The next section presents a brief review of previous studies on the trade-off between travel and activity time and the formulation for travel time attributed to non-work stops in this study. Section 4.3 introduces the data source, dataset preparation, and method for the analysis. The model estimation results are discussed in Section 4.4. The conclusion and discussion are presented in the final section.

4.2 Travel time for non-work stops in multi-purpose trips

Previous studies have identified the influential factors on travel time for non-work activities. Personal and household attributes such as gender, age, income, household (worker) member numbers have been found to influence travel time (Golob et al., 1995; Schwanen et al., 2002; Tarigan et al. 2011). Regarding trip attributes, while shopping travel time decreases as their accessibility to vehicles increases in Canadian cities (Farber et al, 2011), in Dutch cities that discourage car use, drivers takes a relatively long time (Schwanen et al., 2002), Among the built environment factors, residential context has especially been examined (Schwanen et al., 2002; Cao et al., 2009; Chatman 2009).

Another factor influencing travel time is the duration of the activity at the destination. With respect to the direct relation between activity and travel time, some studies show that travel time increases with activity duration (Kitamura, 2002; Kitamura et al., 1998; Levinson and Kumar, 1995). However, individuals' activity-travel behaviour in urban space is constrained to the inseparability and scarcity of space and time (Dijst, 1999; Hägerstrand, 1970; Kondo and Kitamura, 1987; Neutens et al., 2011). In other words, there is a trade-off between travel and activity time given the limited time budget of each individual (Dijst and Vidakovic, 2000). Travel time ratio (TTR) developed by Dijst and Vidakovic (2000) and the travel time price (TTP) by Chen and Mokhtarian (2006) are defined to investigate this trade-off between travel time and activity time. TTR is defined as a ratio of travel time allocated to the total amount of travel time and activity time, whereas TTP is a ratio of travel time allocated to activity time, and the two concepts can be converted as TTP= TTR/1-TTR. The formulation for TTP can be transferred as (eqn. 1):

$$T_j=\varphi_j D_j \qquad (1)$$

In this expression, T_j is the total travel time used for activity j, D_j is the duration of activity type *j* and φ_j is the TTP value.

This trade-off relation differs across different activity types, and this has been explored in various empirical studies. Dijst and Vidakovic (2000) first applied the TTR concept to non-work activities for a small sample of dual-earner families, and found that the ratio for maintenance activities ranged between 40% and 50% versus 20% to 30% for discretionary activities. Then, the travel time ratio for work activities was discussed and calculated to be 10.5% based on data from the 1998 Dutch National Travel Survey (Schwanen and Dijst, 2002). Chen and Mokhtarian (2006) compared not only the TTP values for maintenance and discretionary activities but also their elasticity. Their findings indicated that travel time spent on maintenance activities was less elastic than that spent on discretionary activities.

With the exception of Dijst and Vidakovic (2000), the studies noted above examine the trade-off in single-purpose trips. Because trip chaining is now a common practice in our daily lives, the TTR and TTP concepts have been extended to explore the trade-off of activities in multi-purpose trips. Susilo and Dijst (2009, 2010) calculated TTR values for both mandatory and discretionary activities for multi-purpose trips. They first computed the travel time related to the secondary activity by deducting "the travel time needed for a direct trip between bases" from the "actual total travel time". In the case of commute trips with more than one additional activity location, their solution was to distribute the TTR value based on the weighted durations of the activities. They employed multilevel regression models to explore the determinants of TTR on journey episode, individual, household and environmental levels. Their results show the efficiency of multi-purpose trips, as the number of activities chained has a negative influence on TTR. Soo et al. (2008) provided a more general approach for the TTP for multi-purpose trips, in which time spent in each activity contributes independently to the total travel time in the trip. Importantly, the impact of activity duration on travel time may in their formulation depend on socio-demographic or contextual factor, which is represented by interaction terms.

Our purpose here is to examine the trade-off between travel and activity time for secondary activities when adding non-work stops to commuting, therefore, we focus on the extra travel time added to commuting trips. The travel time attributed to non-work stops ($T_{non\text{-}work}$) is computed by deducting the travel time for the direct commute trip (T_{direct}) from the total travel time for multi-purpose commute trips (T_{total}). As mentioned above, compared to travel time calculated on road network, actual travel time can be affected by more complicated traffic conditions (e.g. congestions) and also individuals' choices (e.g. departure in the rush hour, switching to a different travel mode). When using actual travel time recorded for direct and indirect trips in practice, it is possible for this additional travel time to be negative values. We assume that $T_{non\text{-}work}$ is related to the duration of the non-work stops as follows:

$$T_{non-work} = T_{total} - T_{direct} = \alpha_i X_i + \sum_{j \epsilon C} \beta_j D_j + \sum_i \gamma_{ji} X_i D_j \qquad (2)$$

In this expression, D_j is the duration of activity type *j*, C is the choice set for activity types, and the variable X_i represents personal, trip and spatial characteristics. As travel time could be affected by the personal and household, trip and spatial attributes (e.g. Schwanen et al. 2002; Cao et al. 2009; Tarigan et al. 2011), this direct impact could also apply to the extra travel time in multi-purpose trips, and the direct impacts of these attributes (X_i) will be estimated in our analysis. In line with the TTR/TTP literature, we assume also that extra travel time may be influenced by the duration of the secondary activity of type j (D_j). Finally, we assume, in line with Soo et al. (2008) that the effect of duration (D_j) may be modified by personal, household or spatial attributes (Xi), expressed in the interaction term $X_i * D_j$. Because for each multi-purpose commute trip we know the duration of the non-work stops D_j, the model can be estimated as a regression model with X_i, D_j and the interaction $X_i D_j$ as explanatory variables. By including explanatory variables related to the recorded actual trips (i.e., timing, modal shift), this model structure is flexible to analyse $T_{non\text{-}work}$ values whether they positive or negative.

Our model has some specific innovative characteristics. In previous studies concerning the trade-off between travel and activity time, spatial variables discussed include the density of inhabitants (Schwanen and Dijst, 2002; Soo et al., 2008), density of retail or service facilities (Soo et al., 2008; Susilo and Dijst, 2009), and location or urbanization level (Schwanen and Dijst, 2002; Susilo and Dijst, 2009). These studies show that spatial variation may offer a better explanation than socio-demographic variables for the TTR value of work activities; for example, higher density and residing in suburbs tend to result in a higher TTR. However, only spatial attributes in the vicinity of the place of residence have been included. Although Schwanen and Dijst (2002)'s descriptive analysis confirmed that TTR varies with the location of the workplace, this indicator has not been included in multivariable analyses. Because commute trips are anchored by two bases rather than the place of residence, the spatial attributes in this study will include both the anchors.

Another important addition to previous studies here is allowing for mode shifts between the direct trips and the trip chaining behaviour. Thus far, mode choice has been regarded as an invariant decision in studies concerning the relation between mode choice and trip chaining behaviour (Strathman et al., 1994; Vande Walle and Steenberghen, 2006; Ye et al., 2007). This is because their data are mostly based on one-day observation rather than multi-day, and the difference in mode choice has been explored mostly from an inter-personal rather than an intra-personal perspective. A few studies have shed light on the intra-personal variation of trip chaining behaviour, such as Bhat (1999), in which the unobserved heterogeneity for non-work stop-making in evening commuting with multi-day data were accommodated. Despite the reorganization of the day-to-day variation of stop-making in this study, the work-related explanatory variables (work duration, departure time, travel time for direct trip, mode choice) were still regarded as pre-determined. Moreover, a very high fraction of individuals in their sample used the car mode and had little penetration for other modes; consequently, the mode choice showed no significant impact on the variation of stop-making. However, given their desired activities and time-space opportunities, some population categories have choice opportunities for their travel behaviour (Dijst et al., 2002) or may need to negotiate the allocation of vehicles on a day-to-day basis. As a result, there is an opportunity to use different travel modes for a direct trip and a multi-purpose trip, which may significantly impact the TTP as expressed in eqn. 2. For example, by shifting from a slower (e.g., bicycle) to a faster mode (e.g., car), one may be able to minimize extra travel time to conduct the secondary activity or even save time compared with the direct trip. Additionally, by shifting (part of) the multi-purpose trip in time, travel time might be reduced. For example, by engaging in a secondary activity after work, the trip from the secondary activity site to the place of residence may be postponed until after the peak period, leading to an overall shorter travel time. Therefore, this paper aims to include these strategies into the analysis of the travel time invested in non-work stops in commuting to obtain greater insight into the trade-offs and outcomes of trip chaining behaviour in such a rapidly developing city as Beijing.

4.3 Data

The data come from the “Daily Activity and Travel Survey of Beijing, 2012”. Since public transport dominates in the city of Beijing, on the one hand, the lack of flexible transport modes (i.e. private car) may make against the complex tour making behaviour of residents (Yang et al., 2007). On the other hand, the traditionally high density, mixed land use pattern due to the heritage of Work-unit (*Danwei*) can encourage complex tour patterns. For example, Ma et al. (2014)’s study in Beijing found that higher density in residential neighbourhood leads to more home-based tours with fewer stops, while mixed land use at workplace with higher density and accessibility leads to more stops within one work tour or a more complex tour pattern.

This survey was conducted from October to December 2012 in the Shangdi-Qinghe area, which is located northeast of Beijing’s 5th ring road. This suburban area serves as a residential centre, with 240,000 residents, and also as a job sub-centre, with more than 5,000 companies and 160,000 jobs (Figure 4.1). The survey first collected the socio-demographic characteristics of the respondents and then activity diaries filled out by the respondents for one week and GPS data from GPS loggers carried by the respondents. The complete dataset contains responses from 709 respondents. Based on the research aim, the sample for the current analysis comprises 275 multi-purpose commute trips conducted by 178 commuters, who reported both direct and multi-purpose commute trips in the diaries. Sixty-five commuters contributed more than one multi-purpose commute trip; thus, the number of multi-purpose trips is larger than the number of commuters and is not evenly distributed among the commuters.

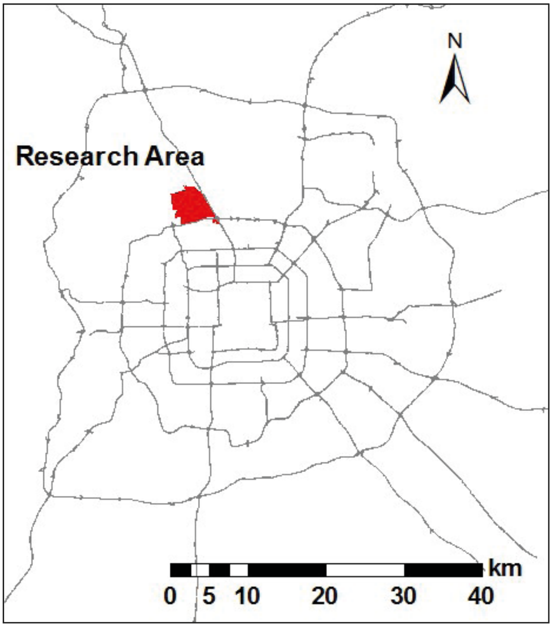

Figure 4.1 Research field location

Table 4.1 provides a list of the explanatory variables used in the regression model, their definitions, and associated descriptive statistics. For these non-work stops in multi-purpose commuting trips, we distinguished 4 types of secondary activities of the commuters including eating out, shopping, recreation/social activities, and family/personal/other activities as secondary activities. Of the multi-purpose trips, 52.9% are combined with eating out activity, 28.6% with leisure or social activity, 20.3% with shopping activity and 14.1% with family/personal/other activity. 15.6% of the trips (43 cases) have included stops for more than one activity types. Furthermore, the duration for each activity has been extracted from travellers' activity dairies. Particularly, the standard deviation for family/personal and other activities is large at 62.7 minutes, which is likely related to its diversity because it includes family activities, such as picking up or dropping off family members, and personal affairs, such as seeing doctors and visiting hairdressers.

Of the multiple-purpose commute trips, 78.0% (215) are trips from work and the other 60 trips are to work. The mode share in the sample is as follows: 43.3% car, 42.9% public transit and 13.8% active modes (i.e., foot and bicycle). For all the commuting trips in the complete dataset, the largest proportion belongs to public transit trips (51.0%), and the proportion for car trips is much lower at only 21.8%. The difference in mode shares is consistent with the previous finding that multi-purpose trips are more car-oriented (Bhat 1997, Islam and Habib 2012).

Commute duration (for direct commute) as a constraint-related variable was subtracted from the diary data reported. For those commuters who had reported more than one direct commute trip, the value was computed by averaging the trip durations with the most frequently used mode. As for spatial factors, Points of Interest (POIs) data in Beijing were used to assess the density and mix level in 1km around the two bases. In this paper, POIs density stands for the density level, and the mix level is indicated by the diversity of POIs as shown in eqn. (3) (Frank et al. 2004, Long and Liu 2013):

$$M = -\sum_{i=1}^{n} p_i \times log\ (p_i) \qquad (3)$$

In the equation, p_i is the proportion of the POIs of type I; n denotes the number of POI types under consideration. The POI types (n=4) here include commercial, public service, public recreation, and transport facilities.

Table 4.1 Variables in regression for travel time attributed to non-work stops

Variable	Definition	Distribution	Mean	SD
Non-work stop activity duration (zero-observations excluded)				
Eating out Duration	Duration of eating out activity in non-work stops (min)	—	68.0	59.4
Shopping Duration	Duration of shopping activity in non-work stops (min)	—	47.1	48.1
Leisure/Social Duration	Duration of leisure/social activities in non-work stops (min)	—	127.4	68.2
Family/Personal/ Other Duration	Duration of family/personal/other affairs in non-work stops (min)	—	53.5	62.7
Socio-demographic and Trip-related Attributes				
Gender	1 if the individual is male (female as the reference category)	42.5%	—	—
Extended household	1 if the commuter lives in an extended household	12.0%	—	—
Timing	1 if the trip is a work-home trip	78.2%	—	—
Active Mode	1 if the main transport mode is active (foot or bicycle), public transit as the reference category	13.8%	—	—
Car	1 if the main transport mode is car, public transit as the reference category	43.3%	—	—
Mode shift	1 if the mode is more motorized than that for direct trips	19.3%	—	—
Commuting Duration	Duration of average direct commute (min)		48.3	24.8
Spatial Factors				
Workplace Density	Facility density within 1 km of workplace of individual	—	315.4	170.0
Workplace Mix	Facility diversity within 1 km of workplace of individual	—	0.3	0.0
Home Density	Facility density within 1 km of home of individual	—	244.7	141.4
Home Mix	Facility diversity within1 km of home of individual	—	0.4	0.0

NOTE: —not applicable

4.4 Results

This section presents an overview of the results. In the first section, we present the descriptive results of the extra travel times for different types of trips. In the second section, we discuss how extra travel time is affected by activity time, the spatial settings around the residence and workplace, socio-demographics, and strategies such as travel mode switching. To this end, a regression model according to eqn. 2 was estimated with the data outlined above.

4.4.1 Travel Time Attributed to Non-work Stops

To compute the travel time for non-work stops, the total travel time for multi-purpose trips (T_{total}) and the direct travel time (T_{direct}) have been subtracted from the multi-day diary for each commuter. T_{total} is the travel time spent on that multi-purpose trip as reported, while T_{direct} for its direct counterpart is based on the travel time for same trip type (i.e. journey to and from work) reported in other days. With multiple observations, T_{direct} is the average value of direct commute durations with their most frequently used transport mode. As Table 4.2 shows, the average T_{total} is 76.8 minutes, and the average travel time attributed to non-work stops ($T_{non\text{-}work}$) is 28.5 minutes. With an average activity duration of 89.6 minutes, the general TTP value for chained non-work stops is 0.3. It is lower than the value of 0.4 revealed in Susilo and Dijst (2010) (the original TTR value for two-base journeys in their findings has been converted to the TTP value here), which may suggest a high efficiency of trip chaining behaviour in Chinese cities.

Based on the travel times reported, there are 40 negative values for $T_{non\text{-}work}$. These negative values suggest that adding non-work stops does not necessarily increase the commute duration but may lead to a reduction in travel time. A detailed inspection of these cases reveals that the reasons include personal strategies for multi-purpose trips, such as mode shift (9 cases), departure adjustment (12 cases with departure times more than 30 minutes earlier or later than direct trips) and a longer direct travel time reported due to traffic or out-of-vehicle waiting time.

As for the average $T_{non\text{-}work}$ for multi-purpose commute trips with different secondary activity types (for multiple activities chained, the one with the longest duration is identified as the secondary activity in this calculation), trips with leisure/social activity have the longest duration of 40.2 minutes. Trips with eating out have the shortest $T_{non\text{-}work}$, at 20.6 minutes, and the longest T_{direct} of 51.9 minutes. Family/personal/other activities are also travel-time-consuming, especially with their shorter average duration taken into consideration. Shopping activity has the shortest activity duration as shown in Table 4.2, and trips with shopping as secondary activity also have the shortest duration for T_{direct} and $T_{non\text{-}work}$. Because 15.6% (43 cases) of the trips chained more than one non-work activity as part of the commutes, the TTP value for each activity type chained must be examined in the regression model.

Table 4.2 Calculation of travel times for trips with different secondary activities

	Eating out		**Shopping**		**Leisure/Social Activity**		**Family/Personal/ Other Activity**		**All non-work Activities**	
	Mean (min)	**Std. (min)**	**Mean (min)**	**Std. (min)**	**Mean (min)**	**Std. (min)**	**Mean (min)**	**Std. (min)**	**Mean (min)**	**Std. (min)**
T_{total}	72.5	35.8	71.1	39.3	85.5	48.0	83.6	31.6	76.8	39.8
T_{direct}	51.9	22.7	44.1	23.0	45.3	27.1	47.4	28.8	48.3	24.8
$T_{non\text{-}work}$	20.6	33.2	27.0	33.9	40.2	36.5	36.2	33.4	28.5	35.1

According to the simple regression model with the interactions between activity duration and activity type as the only explanatory variables (Model 1 in Table 4.3), the TTP values for different activity types can be identified. Generally, family/personal/other activities have a higher TTP value than others. This is presumably because some categories of these activities, such as picking up or dropping off a family member, do not require much activity time but may have a specific location requirement. Leisure/ social activities have a relatively lower TTP value, which is related to the longer duration of these types of activities. Shopping activity has a similar TTP value to leisure/social activities. From the literature (Susilo and Dijst, 2010) we know that differences exist between different types of shopping activities; for example, grocery shopping is characterized by a higher TTR than non-daily shopping. However, in our dataset, we are not able to distinguish between these shopping categories. The TTP value for eating out activity is the lowest and not statistically significant, which implies that there is no systematic relationship between activity duration and detour time. Thus, TTP would not be a meaningful concept in the context of eating out as a secondary activity. One possible explanation is that eating out as a maintenance activity is geographically highly clustered around the bases. Additionally, the activity duration of eating out may vary more than for other activity types. Despite the different classification of activity types, the TTP values in this paper are generally lower than those for discretionary and other activities in the one-base multi-purpose trips in Soo et al. (2008). This is because only the additional travel time is attributed to activity duration, rather than the total travel time.

4.4.2 Effects of Travel, Socioeconomic and Spatial Factors on Extra Travel Time

With other explanatory variables included, Table 4.3 presents an extended regression model (Model 2) considering socio-demographic attributes, spatial factors, trip attributes and their interaction with activity duration. Due to missing values for the spatial attributes (6 trips by 6 individuals), Model 2 includes 266 trips travelled by 171 commuters. Several other socio-demographic variables, such as age, monthly income were included but did not significantly impact the travel time for any activity type. The interaction terms are retained in the model when they are significant at the 10% level.

Table 4.3 Regression results for travel time attributed to non-work stops

	Model 1 (275 trips, 177 individuals)		Model 2 (266 trips, 171 commuters)	
	Coefficient	t-Stat.	Coefficient	t-Stat.
Activity durations				
Eating out Duration	0.051	1.290	0.50[b]	2.57
Shopping Duration	0.152[b]	2.129	2.98[a]	3.13
Leisure/Social Duration	0.138[a]	4.419	0.14[a]	3.35
Family/Personal/Other Duration	0.224[a]	3.207	1.89[a]	3.34
Personal /trip /environmental attributes				
Gender (ref.= female)	—	—	—	—
Extended household	—	—	—	—
Work duration	—	—	-0.04[b]	-2.10
Timing (ref.= home-to-work trip)	—	—	—	—
Active mode (ref.= public transport)	—	—	-15.02	-1.96
Car	—	—	—	—
Mode shift	—	—	—	—
Direct commute duration	—	—	—	—
Workplace density	—	—	—	—
Workplace Mix	—	—	—	—
Home Density	—	—	—	—
Home Mix	—	—	—	—
Interaction terms				
Eating out Duration*Gender	—	—	0.30[a]	3.94
Eating out Duration*Work duration	—	—	-0.00	-1.75
Eating out Duration*Active mode	—	—	-0.24	-1.82
Eating out Duration*Direct commute duration	—	—	-0.01[a]	-3.69
Shopping Duration* Timing	—	—	-0.64[b]	-2.47
Shopping Duration*Direct commute duration	—	—	-0.01[b]	-2.20
Shopping Duration*Workplace mix	—	—	-5.75[a]	-2.60
Social/Leisure duration*Car	—	—	-0.10	-1.67
Family/Personal/Other Duration* Timing	—	—	-0.35[a]	-2.69
Family/Personal/Other Duration* Direct commute duration	—	—	-0.01[a]	-3.40
Family/Personal/Other Duration*Workplace Mix	—	—	-2.77[b]	-2.04
R^2	0.098		0.339	
Sig.	0.000		0.000	

NOTE: *=multiplication required by eqn. (2); [a] p<0.01; [b] p<0.05

Generally, activity durations still significantly and positively affect travel time after controlling all the other explanatory variables. As for the personal /trip /environmental attributes, regardless of the activity types and durations, longer work duration reduces the time budget for travelling and shows a significantly negative impact. In this Chinese context, the other household members (e.g. retired parents) in an extended household were expected to alleviate the time constraints for out-of-home activities, which may influence time allocation to travel. Descriptive analysis reveals that commuters from extended households significantly travel longer (46.7 mins) than the other commuters (32.6 mins). However, it shows no significant influence in the regression model after controlling other explanatory variables. Active mode commuters may also travel shorter time than public transport users to non-work stops, although only significant at the 10% level. This could be because that active mode users locate their destinations closer to their commute routes.

Consistent with the hypothesis proposed in the second section, some population categories have the option to adapt their transport modes to their desired activities and activity-travel agendas. To examine its influence, mode shift is defined as a dummy variable whether the mode adopted for this multi-purpose trip is more motorized than its direct counterpart. According to our observations, 52 multi-purpose commute trips (19.3%) were identified with mode shifts. Compared with the direct counterparts, 42 of them switched to cars (29 from public transit, 13 from active modes) and 10 switched to public transit from active modes. However, there were also 4 individuals who used public transit for multi-purpose commuting trips but cars for direct trips. They likely took this action due to Beijing's traffic restriction policy, which forbids cars to enter the 5th ring road from 7 am to 8 pm on one specific workday according to the last digit on their car plates. However, the variable of mode shift shows no significance across all the activity types. Switching to a more motorized transport mode does not significantly change the trade-off between travel and activity time for non-work stops. This finding contradicts our hypothesis that a mode shift would increase the travel speed and thereby reduce the extra travel time. A possible explanation is that commuters relocate activities when they get access to a car. As a larger travel speeds increases commuters' space-time prisms (Chen and Kwan, 2012; Dijst et al., 2002; Nishii and Kondo, 1992; Van de Walle and Steenberghen, 2006) individuals may locate their non-work stops farther from the bases.

Although only two attributes are found to directly affect the extra travel time, a further examination of the interaction terms reveals that the impacts of these explanatory variables differ across various activity types. For the socio-demographic attributes, we found that male commuters are inclined to travel longer for each time unit of an eating out activity stop during their commutes. This may be because that eating out can be different as a socializing (relation-building) activity or a maintenance activity for different genders. For male commuters, many eating out activities are likely to be a social eating for the development of workplace relationships, while due to entailing male activities or intruding on home and family responsibilities, women are less likely to be involved in these activities in a Chinese context (Bedford, 2015). For these situations, the male commuters may have to socialize with colleagues and also clients/customers, other people external to their organizations located dispersedly, in which they may have less freedom in choosing the locations. Then, they have to travel to farther locations for a specific eating out activity and result in a higher TTP for eating out activity. However, gender-based differences have not been found in other activity types.

Transport mode choice significantly impacts the extra travel time for eating out and leisure/social activities. Given the same amount of activity time, commuters who use active modes spend less time traveling for eating out than public transit users. This finding indicates that active mode commuters choose the activity locations with shorter distances from the bases or commuting routines because the speed of the active mode is apparently lower. For leisure/social activities, although only significant at the 10% level, car users spend significantly less travel time per time unit of the activity. As a more motorized mode with higher speed and more flexibility, the car could help commuters reduce their travel time for the same amount of leisure/social activities duration.

As for the influences of other trip-related variables, longer commute duration encourages shorter travel time for eating, shopping and family/personal/other activities. It has been found that longer travel time to work results in tighter time constraints and consequently appears to reduce the number of stops made by individuals (Bhat 1997). Similarly, having a longer direct commute also reduces the travel time spent for the stops within the limited time window.

Additionally, the majority of multi-purpose commuting trips (78.0%) are journeys from work. This finding is highly related to the time window available to commuters. Typically, morning commuting may have a smaller time window, whereas evening commuting may provide larger potential action space (Susilo and Dijst, 2010). In the extended regression model in Table 3, having non-work stops in work-to-home journeys shows a negative effect on shopping and family/personal/other activities. In other words, people travel shorter for each time unit for these activities, when they are conducted after work. This may be caused by longer activity duration, given that time constraints are less binding after work. In our sample, the average duration for shopping is 47.1 minutes; however, the value is 48.4 minutes for those on work-to-home journeys and 36.3 minutes for those on home-to-work journeys. As for family/personal/other activities, the average duration is 53.5 minutes, and the values are 58.9 for the work-to-home journeys and 49.2 for the home-to-work journeys.

Finally, the built-environment attributes have been indicated by the density and mix level of facilities within a radius of 1 kilometre from the place of residence and workplace. Density level does not have a significant influence on the TTPs for the residence or workplace. The only significant spatial factor is the mix index around the workplace, with negative effects on both the shopping activity and family/personal/other activities. Thus, less travel time is invested in one time-unit of these activities if the workplace area has more mixed land use, which can be understood as a greater proximity of stores to the workplace.

4.5 Conclusion and discussion

This research focused on the non-work stops in commuting trips by using the dataset of the "Daily Activity and Travel Survey of Beijing, 2012". Compared with previous studies, which were mostly based on single-purpose trips, this study shows that chaining a stop to commuting trips reduces the travel time expenditure for non-work activities for commuters, which can benefit urban residents with tight time-budgets. The extra travel time for non-work stops and the trade-off between travel and activity time for non-work stops has been examined, and it varies among the different types of non-work stops.

For policy making, lowering the extra travel time for non-work stops can be a way to increase commuters' utility and at the same time release the pressure imposed on the urban transport system by the extra travel time for those stops. Of the spatial factors that can be influenced by policies, mix level is more important than density, and the workplace plays a more important role than the residential environment for commuters according to the model estimation results. Therefore, a possible implication of this finding for planning practice is that raising the diversity rather than only the density of facilities will better fulfil commuters' needs. The workplace merits particular attention in this respect.

Generally, longer work duration reduces the time budget for commuters, and consequently decreases their travel time for non-work stops, regardless of activity types. However, the impacts of socio-demographics and trip-related attributes vary across the activity types. For example, gender difference is found only for eating out, which suggests that male commuters are inclined to travel longer for the same amount of activity time. As a constraint-related variable, timing (i.e., chaining a non-work stop to a work-home journey) negatively influences the travel time attributed to shopping and family/personal/other activities as the larger time-window after work is used for a for longer activity duration. Commute duration (for direct trips) negatively influences extra travel time for eating-out, shopping and family/personal/other activities, because it results in a tighter time-budget for non-work activities.

Specifically, the descriptive analysis shows that almost 20% of the multi-purpose commute trips adopted a more motorized transport mode (compared with their direct counterparts) to adapt to the more complex agendas. Although the regression results show that active mode users and car users have lower travel time for each time unit of eating out and leisure activities, respectively, the variable of mode shift does not help reduce the proportional travel time for non-work activities. Thus, the hypothesis of shorter travel time due to reduced travel time and increased activity duration is rejected. Given a higher level of mobility and relaxed time constraints, the space-time prism for commuters is expanded with a larger choice set of non-work activities (Chen and Kwan, 2012), and commuters may then relocate their non-work activity.

While our study is in line with previous studies on TTR (Soo et al., 2008; Susilo and Dijst, 2009; Susilo and Dijst, 2010), it also shares with these studies the limitation that certain choice dimensions are regarded as exogenous, such as destination of the secondary destination, mode choice and the decision to engage in a secondary activity in the first place. While our study provides insight in the factors influencing the travel time in multi-purpose commute trips, it does not account for the fact that commuters may change mode, destination or activity participation in response to the explanatory factors used in this study. Adding these dimensions would be important if one's goal is to develop comprehensive forecasting models, and is seen as an important future activity.

It should be noted that this research has considered extra travel time rather than travel distance for non-work stops. Measuring travel expenditure in distance could be a useful addition to examine the assumption that individuals will locate their non-work stops farther when they have a higher mobility level and, consequently, a larger choice set. Another relevant future analysis may concern other possible choices for commuters, such as the adjustment of departure/arrival times, which has been proved to affect the stop-making propensity (Bhat, 1999) and which may affect the travel times and travel time prices for chained activities.

Additionally, the influence of spatial factors in the current study focuses on the two anchors of commute trips, namely the place of residence and the workplace. However, a previous study based on a GPS dataset from 34 drivers in south-eastern Michigan described the spatial configuration of non-work activities and found that non-work activities chained to home-to-work commutes are mainly located along commuting paths (Wang et al., 2013). Future explorations can take the attributes of home-to-work corridors into consideration rather than the two ends alone. Furthermore, the built environment in Chinese cities is deeply shaped by the institutional and economic transition. Variables such as community type, which has been widely discussed in previous studies concerning the built environment and travel behaviour in China (Ma et al., 2014; Zhao and Chai, 2013), could be taken into account in a future study. Lastly, additional research is required to examine whether the mode shift phenomenon is common for multi-purpose trips and whether its impact on travel time is similar in other contexts with different distributions of transport mode use.

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5. Commuting trip satisfaction in Beijing: Exploring the influence of multimodal behaviour and modal flexibility

This chapter is based on the article: Commuting trip satisfaction in Beijing: Exploring the influence of multimodal behavior and modal flexibility, Transportation Research Part A: Policy and Practice, 94: 592-603.

ABSTRACT

In the past decade, many studies have explored the relationship between travellers' travel mode and their trip satisfaction. Various characteristics of the chosen travel modes have been found to influence trip experiences; however, apart from the chosen modes, travellers' variability in mode use and their ability to vary have not been investigated in the trip satisfaction literature. This current paper presents an analysis of commuting trip satisfaction in Beijing with a particular focus on the influence of commuters' multimodal behaviour on multiple workdays and their modal flexibility for each commuting trip. Consistent with previous studies, we find that commuting trips by active modes are the most satisfying, followed by trips by car and public transport. In Beijing, public transport dominates. Urban residents increasingly acquire automobiles, but a strict vehicle policy has been implemented to restrict the use of private cars on workdays. In this comparatively constrained context for transport mode choice, we find a significant portion of commuters showing multimodal behaviour. We also find that multimodal commuters tend to feel less satisfied with trips by alternative modes compared with monomodal commuters, which is probably related to their undesirable deviation from habitual transport modes. Furthermore, the relationship between modal flexibility and trip satisfaction is not linear, but U-shaped. Commuters with high flexibility are generally most satisfied because there is a higher possibility for them to choose their mode of transport out of preference. Very inflexible commuters can also reach a relatively high satisfaction level, however, which is probably caused by their lower expectations beforehand and the fact that they did not have an alternative to regret in trip satisfaction assessments.

Keywords: Trip satisfaction; commute; multimodality; modal flexibility; Beijing

5

5.1 Introduction

Studying trip satisfaction is valuable for transport policy making. For instance, policies aiming at a shift towards sustainable transport modes will be more effective when travellers are more satisfied with their new travel mode. The relationship between trip satisfaction and transport modes has been examined extensively in recent studies (Abou-Zeid and Ben-Akiva, 2014; Eriksson et al., 2013; Ettema et al., 2013; Olsson et al., 2013; Páez and Whalen, 2010; Turcotte, 2006). Mode-related attributes of cars (e.g., driving conditions), public transport (e.g., reliability of service) and active modes (e.g., crowdedness) have been found to influence trip satisfaction. A common feature of these studies is that they treat trip satisfaction in the context of a single trip made by a single given mode. Hence, they neglect the fact that trip satisfaction may also depend on the choice context. This choice context includes the fact that travellers may use various travel modes for a given trip over a longer time period, as well as their perception of alternative modes for that trip. This paper sets out to test the influence of this choice context on trip satisfaction.

The use by travellers of multiple transport modes in a specified period has received much attention in recent studies in Western Europe (Frändberg and Vilhelmson, 2014; Kuhnimhof et al., 2006; Nobis, 2007) and the U.S. (Block-Schachter, 2009; Buehler and Hamre, 2014) and has been termed ‘‘multimodality” (Kuhnimhof et al., 2006; Nobis, 2007). It has been found that multimodal travellers generally have more realistic perceptions of available choices and their attributes than single mode travellers (Diana and Mokhtarian, 2008). Additionally, individuals may compare a trip experience by one travel mode with experiences of other travel modes (Schwartz, 2004; Schwarz and Strack, 1999). Hence, due to different reference levels, multimodal travellers may experience the same trip differently than monomodal travellers; however, the extent to which and direction in which this mechanism works has not yet been determined.

In addition to the actual use of multiple travel modes, modal flexibility (i.e., travellers’ perceived ability to vary transport modes) may also affect travellers’ trip satisfaction because it indicates whether the mode is chosen out of preference or due to a lack of other options. Although the influence of owning a car and living close to public transport facilities on trip satisfaction have been explored (Bergstad et al., 2011; De Vos et al., 2014; Ettema et al., 2011), these variables cannot be equated with individuals’ perceived ability to switch transport modes for a single trip because the latter is also affected by factors such as individuals’ attitudes, busy daily activity agendas on specific days or the unavailability of household vehicles due to use by the spouse.

Hence, in regard to trip satisfaction, the effects of neither multimodality nor modal flexibility have been investigated. Exploring the influence of using or having multiple mode choices may provide insights into predicting individuals’ satisfaction levels and consequently their behavioural changes when certain transport modes are encouraged or improved in policy making. The current paper will address this gap in the existing literature by investigating urban residents’ commuting trip satisfaction in Beijing in relation to commuters' multimodal behaviour and modal flexibility based on multiday activity and travel diaries.

The remainder of this paper is organized as follows. The next section reviews the literature on modality and trip satisfaction research and raises hypotheses concerning the relationship between them. Section 5.3 presents the research design for his study, including data collection, measurements of key concepts and methodology. Descriptive analysis results are shown in Section 5.4. Further, five two-level regression models have been conducted for trips by specific modes, and the model estimation results are also discussed in Section 5.4. The conclusion and discussion are presented in the final section.

5.2 Theoretical background and expectations

5.2.1 Multimodality and modal flexibility

Although the definitions vary across studies (Block-Schachter, 2009), multimodality is generally defined as the use by a traveller of various transport modes rather than a single mode in a certain time period, usually one week (Buehler and Hamre, 2014; Kroesen, 2014; Kuhnimhof et al., 2006; Molin et al., 2016). Monomodality thus means that a traveller did not change his or her transport mode in a given time period. There are also studies incorporating intensity measures (e.g., frequency of using different modes) and thresholds to distinguish the degree of multi- and monomodality (Diana and Mokhtarian, 2009; Kuhnimhof et al., 2012, 2006). Many studies further identify various modality groups based on the combinations of transport modes that travellers use. For example, Buehler and Hamre (2014) distinguished 3 groups in the U.S. ranging from monomodal car users, multimodal car users, and those who only walk, bike, and/or use public transport, while Kroesen (2014) excluded walking trips and identified five mode profiles in the Netherlands including strict bicycle users, strict car users, immobile traveling (i.e., who travel little by car, public transport or bicycle), joint car and bicycle users, and public transport users. In an empirical study in Germany, Nobis (2007) found that mono car users represent the majority of modality groups.

To a certain extent, multimodal behaviour indicates the degree to which an individual deliberately chooses a mode (Kroesen, 2014), and a multimodal traveller is more likely to be flexible in his/her mode choice (Vij et al., 2011). Individuals may also engage in multimodal behaviour due to constraints, however, such as limitations in car availability or budget reasons. For example, more multimodal car travel among young people in Germany is related to lower car availability and incomes among this group (Kuhnimhof et al., 2006; Nobis, 2007). The possibility to vary one's travel mode can be investigated with self-reported modal flexibility. In some studies, researchers investigated the self-reported number of modes that respondents consider available/feasible for travel (Lavery et al., 2013), and some asked about the limitations regarding traveling by certain modes at a certain time of a day and the availability of an automobile when desired (Ory and Mokhtarian, 2005). These self-reported indicators of mode availability reflect commuters' perceptions of feasible options or their perceived ability in travel mode decisions to a certain extent. Mode availability does not equal modal flexibility, however, because individuals' perceived travel mode options are not only related to the number of available transport modes but also may be affected by personal attitudes towards transport modes, activity agendas on specific days and other constraints such as traffic management measures. In this study, we will investigate modal flexibility based on self-reported perception concerning switching mode choice for each commuting trip.

5.2.2 Trip satisfaction

Many approaches have been developed in recent studies to measure trip satisfaction. Some studies mainly focus on the cognitive part or utilitarian appraisals (i.e., the quality of travel) (Stradling et al., 2007), especially for driving conditions and public transport services. Other studies concentrate on the affective part (i.e., feelings and emotions) of trips like commuting stress (Gatersleben and Uzzell, 2007; Novaco and Gonzalez, 2009). Additionally, concepts such as the Satisfaction with Travel Scale (STS) (Ettema et al., 2010, 2011) and travel well-being (Abou-Zeid and Ben-Akiva, 2014) are proposed as a combination of cognitive and affective evaluations. For example, STS has three components: a cognitive evaluation of the quality of travel, an affective evaluation of feelings during travel ranging from stressed to relax and an affective evaluation of feelings during travel ranging from bored to excited. In this study, we will mainly focus on a general cognitive assessment of individuals' travel experiences. Similar to previous studies, the measurement will use the means of Satisfaction With Life Scale (SWLS) (Diener et al., 1985), which asks respondents to rate statements like 'I am satisfied with my life' on a 7-point Likert scale ranging from ''totally disagree" to ''totally agree." In our case, the scales will be applied at the trip level and only for the general cognitive assessments (see Section 5.3.2).

Explanatory factors of travel satisfaction at the individual level include socio-demographic attributes such as age, gender, income, household type, mode availability, individuals' personalities and attitudes towards different modes (Bergstad et al., 2011; Olsson et al., 2013; Páez and Whalen, 2010; Paige Willis et al., 2013; Susilo and Cats, 2014), and the spatial attributes (e.g., urban or suburban neighbourhoods) of individuals' residence (De Vos et al., 2014). Individual subjective well-being is also found to be related with trip satisfaction, that travellers who generally feel glad/passive or with high life satisfaction are more likely to enjoy their trips (Susilo and Cats, 2014; St-Louis et al., 2014). As for the trip level, trip attributes such as trip purpose, travel time and in-vehicle activities (Ettema et al., 2012; Gatersleben and Uzzell, 2007), as well as mode-related attributes for different transport modes (Eriksson et al., 2013; Friman and Gärling, 2001) have been examined. For example, driving conditions including crowdedness, road layout, maintenance works for car drivers (Ettema et al., 2013; Novaco and Gonzalez, 2009), attribute-specific factors such as treatment by employees, reliability of service, simplicity of information (Friman and Gärling, 2001) and ''soft" factors like personal safety, cleanliness and atmosphere and specific incidents (Stradling et al., 2007) for public transport users, and crowdedness and air quality for pedestrians (Stradling et al., 2007) have been studied respectively. Comparative studies of trip satisfaction across different commuting modes indicate that active modes (i.e., walking and cycling) commonly show a positive effect on trip satisfaction (Friman et al., 2013; Páez and Whalen, 2010; Turcotte, 2006). This effect may be explained by the fact that these commuters tend to live closer to work, which makes their commute less time-consuming, and also the physical exercise provided by active modes (Friman et al., 2013; Jain and Lyons, 2008). Car trips were ranked higher than bus trips for commuting trip satisfaction in an experimental simulation in Sweden (Eriksson et al., 2013), and car users also scored higher in trip satisfaction than public transport users in a population-based sample in Switzerland (Friman et al., 2013) and the General Social Survey in Canada (Turcotte, 2006).

As for the frequency of using multiple modes, Susilo and Cats (2014)'s study found that the more repetitively one travels by the current mode (twice in a week or more), the lower satisfaction level reported with the trip, especially for car and public transport travellers. However, no significant relation was found in the study by Diana (2012), which examined the relationship between satisfaction with public transport trips and the frequency of using public transport among Italian multimodal users (i.e., users of both car and public transport). The research provides a comparison among travellers with different mode use frequencies, but has not addressed the difference between multimodal and monomodal travellers. Additionally, it is not clear how trip satisfaction can be affected by modal flexibility, while its relation with the context for mode choices have been explored from both objective and subjective aspects. For the objective observations of modal availability, some studies show that trip satisfaction can be positively affected by access to bus stops (Ettema et al., 2011) and drivers' licenses (De Vos et al., 2014), while other studies found no significant influence of variables like the number of household cars (Bergstad et al., 2011).

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5.2.3 Hypotheses

In this section, we develop hypotheses regarding the influence of multimodal behaviour and modal flexibility on trip satisfaction, respectively. As the hypotheses regarding trip satisfaction are context specific, we first provide information regarding the study location (Beijing).

First, Beijing is still a public transport-dominant city, where trips by public transport accounted for 44.0% of all trips while trips by private car account for 32.6% (trips on foot excluded) in 2012 (Beijing Transport Research Center, 2013). Instead of the dominance of car user in previous studies in the western contexts, a larger group of multi/mono public transit users can be expected in our dataset. Secondly, although private car ownership increased sharply from 1.8 million cars to 4.2 million cars between 2005 and 2012, it is still markedly lower than that in Western countries. There were still only 63 private cars for every 100 households in Beijing at the end of 2014, while the number was 206 vehicles for every 100 households in the entire U.S. in 2013 (Davis et al., 2013). Car could be unavailable for many individuals, and consequently lower modal flexibility for those lower income travellers. Furthermore, individuals, especially car users could be more likely to engage in multimodal behaviour due to necessity or constraints compared to European and North American cities. In addition to the lower car/household member number ratio, a strict vehicle restriction policy has been implemented in Beijing since 2008. According to this policy, private cars are forbidden to enter the 5th ring road on one specific workday based on the last digit on their license plate. Within this specific context, we can assume that a deviation from the habitual mode (i.e., most frequently used mode) could be involuntary. Multimodal travellers' use of an alternative mode may lead to a lower trip satisfaction compared to monomodal travellers who constantly use that mode. Moreover, compared to monomodal travellers, multimodal travellers have the experience of using various modes. Because people may compare their current commuting trip to a previous commuting trip and evaluate their satisfaction accordingly (Abou-Zeid et al., 2012), we can assume that multimodal travellers may rate a trip less satisfying (compared to monomodal traveller) when they have experienced a more satisfying travel mode and vice versa.

As for the possible influence of modal flexibility, two opposite hypotheses can be raised. First, having more options offers a higher probability of finding an alternative that complies with one's wishes (Botti and Iyengar, 2006; Van Hees, 2004), and consequently, travellers' trip satisfaction increases as modal flexibility increases. Second, in opposition to hypothesis one, trip satisfaction may decrease with higher modal flexibility. There are two possible explanations: (1) the absence of alternatives leads to lower expectations and no alternative to regret. The existence of ''forgone" alternatives (i.e., alternative that were considered but not chosen) can have a significant impact on post-choice valuation (Inman et al., 1997). When trips are unsatisfying, travellers who have alternative choices tend to assess the trip as being less satisfying compared to those without alternatives. In addition, satisfaction depends on our expectations surrounding choices (Schwartz, 2004). If the experience with the choices does not match clients' expectations, satisfaction will be low and vice versa (MORI, 2002). (2) As mentioned in the introduction, unlike objective observations of modal availability, self-measured modal flexibility is a subjective assessment of mode choice. For such a subjective assessment, the response of ''no choice" can refer to different situations (Hannes et al., 2008). An assessment of having no choice not only refers to a situation of having no feasible alternative within monetary and spatial-temporal constraints, but also to a situation in which strong habits or preferences exclude alternatives from consideration, leaving the habitual travel mode as the only option. For the latter case, reporting low or no modal flexibility could result in a high satisfaction with travel by that mode.

5.3 Research design

5.3.1 Data collection

The data are from the ''Daily Activity and Travel Survey of Beijing, 2012," which was collected from October to December 2012 in Beijing. This survey included socio-demographic characteristics of the respondents, an activity diary filled out for one week and data from GPS loggers carried by the respondents. The sample for the current analysis comprises 3308 direct commuting trips made by 404 commuters over multiple days. Multi-purpose commuting trips have been excluded because an extra stop for non-work activities may influence commuters' mode choice, route choice or departure time and consequently satisfaction with the entire trip. Five transport modes have been identified as the main modes for the trips: walking, bike, bus, subway and car. As for the definition of main modes, trips are regarded as walking trips or cycling trips if the commuters walked or biked at all stages. For the multi-stage trips with different travel modes, the more motorized mode is selected as the main mode for the whole trip. For trips with both active modes and public transport stages reported (283 cases), the main mode is defined as PT (public transport). Among these 283 cases, the average durations for active mode stages and PT stages are 19.7 and 52.3 min respectively. Active modes are likely to be used for the access or egress trips to the public transport facilities. For trips combining active modes and car (31 cases), the main mode is defined as the car. The average durations for active mode stages and car stages are 26.2 and 43.5 min respectively. This could be observed in the households with only one car, where one of the household members needs to complete the whole trip by alternative modes before/after the pick-up/drop-off by the driver. For trips combining car and public transport (73 cases), the mode used for the longest stage has been identified as the main mode. According to these rules, public transport has been identified as the main mode for 60 trips and car for 13 cases. The distribution of modes choices is shown in Table 5.1, while public transport is the dominant travel mode.

Table 5.1 Mode choice distribution for all trips

Mode Choice	No.	Pct. (%)	Notes
Walk	243	8.1	—
Bike	511	17.0	—
Public transport	1580	52.5	Bus 826 cases (27.5%) Subway 754 cases (25.1%)
Car	672	22.3	—
Other	2	0.1	—
Total	3008	100	This is the sample size for descriptive analysis; the sample for regression mode is smaller due to the missing values for certain explanatory variables. Details will be marked in the model.

Our sample is not representative for the Beijing population. The survey was conducted in the Shangdi-Qinghe area of Beijing, which is located northeast of Beijing's 5th ring road. This suburban area is a residential centre with 240,000 residents, and also functions as a job sub-centre with more than 5000 companies and 160,000 jobs. Respondents have been selected from the communities and companies in this area. Trips by public transport accounted for 52.5% of all direct commuting trips in our dataset, and household car ownership was 50.4%. Therefore, our sample shows lower car availability (63% in Beijing) and also less influence (as located outside the 5th ring road) from the vehicle regulation policy compared to the general situation in Beijing.

5.3.2 Measurements

(1) Trip satisfaction

Trip satisfaction is in this study regarded as a cognitive evaluation of the trip. Commuters were asked to rate their satisfaction with their commuting trips on a 5-point scale ranging from ‘‘very unsatisfied” to ‘‘very satisfied.” This method has been widely used to provide a cognitive evaluation of subjective well-being during travel (e.g., Bergstad et al., 2011; Abou-Zeid et al., 2012; Paige Willis et al., 2013). Respondents stated their satisfaction with each stage of the trip. Among the 3008 commuting trips, 597 trips (19%) are reported as multi-stage trips. The duration-weighted averaging rule, which calculates the sum of all the satisfaction level of all stages weighted by the duration of the stage relative to the total duration, is selected in this study. We are aware that other aggregation rules can be used such as the peak-end rule (Kahneman et al., 1997) or a mechanism by which more painful or longer episodes have a larger weight (Fredrickson, 2000; Redelmeier et al., 2003). However, in the context of commute satisfaction, Suzuki et al. (2014) tested several aggregation rules. Their results show that duration-weighted averaging rule gives a better fit than other aggregation rules for the repetitive commute trips. With this study also focused on direct commute trips, the duration-weighted aggregation rule has been applied in the following analysis.

(2) Commuter’s modality behaviour

Commuters have been classified into two categories: monomodal commuters, who have not varied their main commute mode over a time period, and multimodal commuters, who have varied their commute mode at least once over a time period. Intermodal travel (i.e., combining multiple travel modes in one commuting trip) has not been regarded as multimodal behaviour. As shown in previous studies, the probability of multimodality is related to the time period under examination (Nobis, 2007). Longer time periods show a higher likelihood of variability in mode choice. Although the examination period in our survey is 1 week (5 workdays), the included days in our analysis differ between individuals after excluding telecommuting, multi-purpose commuting trips and also invalid recorded days. In the end, we have 31.2% commuters with 3 workdays, 30.4% with 4 workdays and 38.4% with 5 workdays included among all the 404 commuters. Almost 32.2% of these commuters varied their main commute modes in the observed period.

Furthermore, we divide the two categories into subgroups according to their habitual commute modes (i.e., most frequently used mode). For example, if a commuter constantly uses his or her car for all commuting trips in the week, he or she would be classified as a mono car user. Then, we have 4 subgroups for monomodal commuters, namely, mono walker, mono cyclist, mono PT user and mono car user. For multimodal commuters using multiple travel modes, the most frequently used mode (with more trips travelled than others) will be regarded as their habitual commute mode. Consequently, there are also 4 subgroups for multimodal commuters, namely, multi walker, multi cyclist, multi PT user and multi car user. In total, 8categories of modality behaviour groups can been distinguished.

(3) Modal flexibility

Commuters were asked ‘‘how hard/easy is it to adjust your transport mode” for each specific trip in the survey, according to categories: ‘‘very hard”, ‘‘hard”, ‘‘medium”,” easy” and ‘‘very easy.” Hence, modal flexibility assessments are based on commuters’ subjective perception of their ability to switch modes for each commuting trip.

5.3.3 Model specification

Because there are multiple observations at the commuting trip level (3308 trips) and for each individual level (404 commuters), multilevel regression modelling is adopted to explore the determinants of trip satisfaction. The random-intercept model is used to control for individual specific unobserved factors that influence multiple trip evaluations of a single individual.

Explanatory variables at two levels are shown in Table 5.2, and specific descriptions of trip satisfaction, multimodal behaviour and modal flexibility will be given in the next section.

(1) Commuting trip (level I)

Based on previous empirical studies of trip satisfaction and the explanatory variables in our dataset, trip characteristics include departure time (peak or non-peak hour), commuting duration, trip type (journey to work or from work), and self-perceived modal flexibility (medium level as the reference category). The trip companion variable (with or without companion) has been excluded with no significant influence found.

(2) Individual commuter (level II)

At this level, commuters’ socio-demographic attributes include gender, age, marriage status and income. Other variables such as driving license and household car ownership have been tested and removed due to insignificant results. For commuters’ residence and work locations, we include dummy variables whether they are located inside the 4th ring road in Beijing. As a typical mono-centric city, the urban structure of Beijing is marked by its ring road system. The urban areas inside the 4th ring road are likely to have a better connectivity for public transit (Ji and Gao, 2010), higher density of population and also commercial and facilities (Tian et al., 2010), and therefore offer better conditions for using active travel modes and public transport. Furthermore, we have included commuters’ modality behaviour with monomodal groups serving as the reference categories.

Table 5.2 Variables in Regression Models

Variables	Definition	Walking trips Pct. (%)	Walking trips M.	Cycling Trips Pct. (%)	Cycling Trips M.	Bus Trips Pct. (%)	Bus Trips M.	Subway Trips Pct. (%)	Subway Trips M.	Car Trips Pct. (%)	Car Trips M.
Trip Level											
Departure time	Depart in Peak hour (ref.=non-peak hour)	79.8	—	73.2	—	73.5	—	84.1	—	71.7	—
Commute Duration	Duration of the entire commuting trip (min)	—	23.5	—	28.3	—	63.5	—	68.9	—	50.8
Trip timing	Journey from work (ref.= journey to work)	44.0	—	48.3	—	45.6	—	44.7	—	48.4	—
Commute mode choice flexibility	Very inflexible	32.5	—	22.1	—	26.8	—	31.0	—	32.4	—
	Inflexible mode	11.9	—	23.5	—	28.5	—	39.3	—	26.6	—
	Medium (as ref. Category)	10.3	—	22.5	—	25.3	—	12.9	—	20.4	—
	Flexible	24.3	—	11.5	—	10.5	—	7.0	—	11.8	—
	Very flexible	8.6	—	8.8	—	3.4	—	0.4	—	4.2	—
Individual Level											
Gender	Male (ref.=female)	38.7	—	40.1	—	46.7	—	45.4	—	50.0	—
Age	Age>=40	34.2	—	31.1	—	15.5	—	8.6	—	21.1	—
Marriage	Married (ref.=unmarried)	74.1	—	80.6	—	63.2	—	61.3	—	85.4	—
Income	Income above RMB4,000/Month	34.2	—	35.0	—	50.6	—	55.0	—	61.2	—
Home Location	Home located inside 4th ring road	0.4	—	2.2	—	3.8	—	13.1	—	6.3	—
Work Location	Workplace located inside 4th ring road	2.1	—	10.6	—	21.3	—	32.8	—	19.5	—
Multimodal walker	Multimodal commuter with walking as the habitual mode	29.6	—	0.6	—	1.0	—	0.0	—	1.6	—
Multimodal cyclist	Multimodal commuter with cycling as the habitual mode	3.3	—	30.7	—	2.2	—	0.7	—	3.0	—
Multimodal PT user	Multimodal commuter with bus as the habitual mode	4.1	—	0.8	—	20.2	—	17.4	—	12.4	—
Multimodal car user	Multimodal commuter with subway as the habitual mode	6.6	—	2.0	—	3.9	—	2.8	—	30.1	—
Monomodal commuter	commuters with a single mode for all commute trips	56.4	—	65.9	—	72.8	—	79.2	—	53.0	—

NOTE: —, not applicable

5.4 Results

5.4.1 Descriptive results

(1) Modality behaviour

As stated above, almost 32.2% of the commuters have varied their main commute modes in the recorded workday period and can be regarded as multimodal commuters. The distribution of different modality groups is shown in Table 5.3. Generally, car users show the highest variation while PT users show the lowest. For car users, almost 44% of them have shifted towards other modes of transport at least once. The relatively higher percentage of multimodal car users is probably related to the traffic regulation policy and low car ownership described above. They have to switch modes when their private car is not allowed to reach the destination (inside the 5th ring road), or the only car is occupied by another household member. Comparatively, public transport users seem to be most constant in mode use: monomodal PT users are the largest group in our dataset, and only 23.9% of PT users have switched their main commute mode. This is probably related to the characteristics of public transport trips and the PT users' characteristics, which make it difficult to switch to either active modes or car. On the one hand, the average duration of PT commuting trips is twice as long as active mode trips, which indicates a relatively long commuting distance. This makes it difficult for commuters to travel by active modes. On the other hand, monomodal PT users have much lower car availability (34.7% with a car in the household) compared to monomodal car users (92.7%), thus being constrained in switching their mode towards cars. For walkers and cyclists, the distribution of multimodal behaviour is time of less than 30 min) and have more satisfying commuting trips (as trips by active modes are ranked higher than others), but their mode use is likely to be affected by factors such as weather, personal conditions (e.g., sickness) and daily schedules (e.g., chaining a non-work activity).

Table 5.3 Modality for specific mode users

Habitual Mode		No.	Pct. (%)	Total
Walker	Monomodal Walker	20	64.5	31
	Multimodal Walker	11	35.5	
Cyclist	Monomodal Cyclist	45	63.4	71
	Multimodal Cyclist	26	36.6	
Public transport User	Monomodal PT user	162	76.1	213
	Multimodal PT user	51	23.9	
Car User	Monomodal Car user	50	56.2	89
	Multimodal Car user	39	43.8	

(2) Modal flexibility

The distribution of modal flexibility across various modes has been presented in Table5. 2. Generally, commuting trips are constrained in mode choice. More than 60% of the trips were reported as hard to perform by another mode. Less than 5% of the trips can be easily completed using by other modes and in total only 16.7% trips can be labelled as flexible. More than 60% of the public transport trips have little freedom in mode choice. Especially for subway trips, this rate reaches nearly 80%. This finding is consistent with the relatively monomodal behaviour of public transport users revealed in Table 5.3. Although car users rank higher in performing multimodal behaviour, however, the perception of modal flexibility for car trips is not very prominent. This indicates that on the one hand, at least some car users must perform their commuting trips by other modes (multimodal behaviour), but on the other hand, they probably do not perceive the other modes as viable alternatives.

Further, the distribution of perceived modal flexibility among different modality behaviour groups has been examined (Table 5.4). It seems that monomodal commuters tend to assess their trips as more inflexible. Mono walkers, PT users and car users assess more than 70% of their trips as inflexible. This indicates that these commuters may have few feasible alternative choices in practice, and likely engage in monomodal travel by necessity. Of the multimodal commuters, multi walkers have the highest modal flexibility, which suggests that there is high possibility for them to conduct multimodal behaviour by choice; however, inconsistencies can be observed between modality behaviour and modal flexibility. This suggests that commuters can also deliberately choose monomodal behaviour with high modal flexibility, while multimodal behaviour may be conducted by constraints related to low modal flexibility. For example, for multi PT users, occasionally switching to other modes may relate to car sharing with colleagues or a taxi trip when running late, neither option being a typical one for most trips. For multi car users, occasionally switching to other modes may relate to the household car being occupied by the spouse or car regulation policy on a specific day, while these modes may not be taken into consideration when the person makes car trips on ordinary days.

Table 5.4 Modal flexibility of different multimodality groups

Commuter Type	Trip Modal flexibility						
	Very hard (%)	Hard (%)	Sum (%)	Medium (%)	Easy (%)	Very Easy (%)	Sum (%)
Multi walker (75 trips)	9.3	9.3	**18.7**	**8.0**	45.3	28.0	**73.3**
Mono walker (122 trips)	55.7	15.6	**71.3**	**8.2**	20.5	0.0	**20.5**
Multi cyclist (180 trips)	11.1	26.1	**37.2**	**27.8**	26.1	8.9	**35.0**
Mono cyclist (303 trips)	31.7	26.4	**58.1**	**23.4**	7.3	11.2	**18.5**
Multi PT user (362 trips)	28.2	27.1	**55.2**	**25.1**	16.3	3.3	**19.6**
Mono PT user (1116 trips)	32.9	38.1	**71.0**	**19.8**	7.4	1.8	**9.2**
Multi car user (265 trips)	29.1	25.7	**54.7**	**25.3**	17.0	3.0	**20.0**
Mono car user (348 trips)	37.4	33.0	**70.4**	**19.3**	6.3	4.0	**10.3**
Multi user (882 trips)	23.4	24.9	**48.3**	**24.3**	21.0	6.5	**27.4**
Mono user (1889 trips)	35.0	33.8	**68.8**	**19.5**	8.0	3.6	**11.6**

(3) Trip satisfaction

Commuters generally have a positive assessment of their commuting trips. The average score for direct commuting trips is 3.63, which suggests that commuters tend to assess their trips between neutral and satisfying. For trips with specific modes (Table 5.5), the findings are consistent with previous studies. Trips by active modes are more satisfying, particularly walking: the satisfaction level of walking trips is 4.23 and it also has the lowest standard deviation. Trips by bicycle are rated in second place, followed by trips by car. As for public transport trips, the subway seems more satisfying than the bus.

Table 5.5 Trip satisfaction with different travel modes

Travel Mode	No.	Mean	Std.
Walk	243	4.23	0.67
Bicycle	511	3.81	0.75
Bus	826	3.44	0.88
Subway	754	3.49	0.90
Car	672	3.69	0.89
Total	3006	3.63	0.88

Trip satisfaction assessed by different modality groups is shown in Table 5.6. For multimodal commuters, walkers are more satisfied with their habitual modes while PT users are less satisfied. This may relate to the finding above that trips by active modes are most satisfying while PT trips are most unsatisfying. Comparing multimodal and monomodal travellers with the same habitual travel modes, a significant difference can only be found for PT users. This could be because PT users' experiences with other (more satisfying) modes negatively affect their assessment of PT trips. Furthermore, we can compare the trips made by habitual modes and alternative modes of the multimodal travellers. With walking as the habitual mode, the reference point for multimodal walkers to assess trips by alternative modes could be higher, and the satisfaction levels with those trips are significantly lower. On the contrary, the reference point for multimodal PT users when assessing trips by alternative modes could be lower given their experience with unpleasant PT trips; consequently, their satisfaction levels are rated as significantly higher. For multimodal cyclists and car users, switching to alternative modes does not affect their trip satisfaction significantly compared to their habitual modes.

Table 5.6 Trip satisfaction of different modality groups

Modality group	Trips by most frequently used modes		ANOVA test Sig.	Trips by alternative modes		ANOVA test Sig.
	No.	Trip satisfaction		No.	Trip satisfaction	
Multi walker	72	4.25	0.651	22	3.79	0.028
Mono walker	137	4.29		—	—	—
Multi cyclist	157	3.80	0.852	51	3.66	0.195
Mono cyclist	338	3.81		—	—	—
Multi PT user	298	3.34	0.012	97	3.63	0.008
Mono PT user	1198	3.48		—	—	—
Multi car user	202	3.75	0.347	79	3.76	0.878
Mono car user	357	3.67		—	—	—

Fig. 5.1 describes the change of average satisfaction level as modal flexibility increases. Instead of a linear trend, a U-shaped line is found to describe the relationship between modal flexibility and trip satisfaction. Therefore, the two hypotheses proposed in Section 5.2.3 have been supported to a certain extent. On the one hand, the fact that very flexible trips are most satisfying can be explained through the higher utility derived from a larger choice set. With higher modal flexibility, it is possible for commuters to choose an alternative mode out of personal preference, which consequently increases their satisfaction level. On the other hand, the finding that inflexible trips are more satisfying than medium flexible trips can be explained by two possible reasons: low expectations and no alternatives to regret for individuals with limited choices; or lower self-measured modal flexibility reported because of no perceived choice options related to individuals' preferences, attitudes or beliefs. The latter factor cannot be clearly identified by our dataset, however, as there is no variable indicating individuals' preferences.

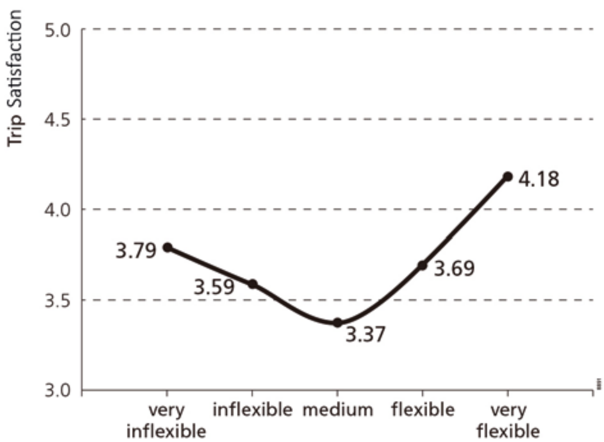

Figure 5.1. Modal flexibility and trip satisfaction level

5.4.2 Multilevel regression results

To further investigate the explanatory variables' influence, 5 multilevel regression models have been conducted for trips with different main transport modes. Table 5.7 shows the regression results on commuting trip satisfaction.

(1) Trip characteristics and modal flexibility at trip level

Generally, satisfaction with commuting trips by motorized modes could be affected by trip characteristics. As we expected, a longer duration makes motorized trips less satisfying. However, the travel time variables are not significant for the active travel modes, which may relate to people's enjoyment of a mode itself (St-Louis et al., 2014). Páez and Whalen (2010)'s study found that, as the most satisfied group, active commuters even prefer longer commute times. Departure in the peak hour significantly reduces bus and car commuters' satisfaction with their trips, due to the crowdedness and congestion in the transport system. The negative impact of departure in the peak hour on subway trips is significant at α =0.1 but not at α = 0.05. This is probably because that the subway system has higher time reliability compared to the other two modes, and commuters are less likely to be delayed or trapped in traffic congestion and are consequently less sensitive to commute durations. Additionally, for subway trips, the journey from work is more satisfying than the journey to work. One explanation is that the time window is larger in journeys from work, which lessens time pressure for commuters. However, these trip characteristics show no significant impact on walking or cycling trips.

As for perceived modal flexibility, the ''U line" phenomenon revealed in Fig. 1 also appears in the regression model and is significant for walking, bus and car trips. Because these variables are given on a five-point ''very hard-medium-very easy" scale, the coefficients indicate the direction and magnitude of the effect with respect to the medium level. Generally, the most unsatisfying trips are those with a medium flexibility level. For bus trips, only ''very inflexible" trips are significantly more satisfying than medium level trips, while the other extreme of ''very flexible" is not significant. Therefore, bus users are easier to satisfy with their trips when they clearly identify no other alternative modes. From one perspective, this may be explained by low expectations caused by a lack of other options. From another perspective, for an unsatisfactory trip like a bus trip, the existence of alternative choices can diminish the post-choice evaluation with the experience. Modal flexibility, however, shows no significant influence for cycling or subway trips. This may be caused by subway trips, which are the most constrained with 77.7% of them being inflexible (15.5% higher than the average level for all trips). In contrast, cycling trips are very flexible, and the rate for very inflexible trips is the lowest (25.0%) across all the transport modes.

(2) Socioeconomic attributes and modality behaviour at the individual level

In regard to socioeconomic attributes at the individual level, their influences are found to be significant for cycling and subway trips. Table 5.2 shows that cycling trips are more often conducted by low income commuters, while the regression results reveal that high-income cyclists are more satisfied with their trips. A possible explanation is that Individuals with higher income tend be more appreciative of the intrinsic qualities of active mobility (Lanzendorf, 2002), which could be related to their lifestyles and motivations for choosing the mode. A research on longer-distance commuters cyclists (>5 km) also found that these commuters actually have higher income and more choices for mobility, and revealed the importance of the motivations, such as physical exercise as a main motive, for these cyclists (Hansen and Nielsen, 2014). Moreover, married commuters are less satisfied with cycling trips. Compared to unmarried commuters, married commuters may have more household obligations such as grocery shopping or picking up family members, and the relatively lower speed and capacity of cycling could make it difficult for them to combine these activities with their commute. Having a home located inside the 4th ring road (urban area) significantly increases satisfaction with cycling and bus trips. On the one hand, traveling in urban areas with higher density can help active mode users and PT users to gain higher satisfaction because there are more pedestrian/cyclist friendly environments and higher access to public transport facilities in these areas. On the other hand, our sample commuters were selected from a suburban area, and having a home located in an urban area indicates that they must work in our suburban research area. These people experience a reversed commute compared to the major commuting flow between the urban and suburban area. As a consequence, these commuters could suffer less from congestions in peak hours.

For trips by alternative modes, multimodal behaviour can negatively influence multimodal commuters' satisfaction with their trips compared with monomodal commuters, especially for walking and bus trips. For walking trips, although they are ranked as the most satisfying trips (Table 5.5), we find that multimodal commuters are less satisfied than mono walkers, which is significant for multimodal cyclists. The reason may be that for a commuting trip habitually done by bike, switching to walking costs more time and energy. For bus trips, we find that multimodal walkers are significantly less satisfied. Because walking trips are more satisfying than bus trips in general, we can assume that decisions by habitual walkers to switch modes may be due to specific reasons, such as bad weather, thus resulting in a lower assessment of their bus trips. St-Louis et al. (2014)'s comparison in a longer term also confirms that people compare the different modes or commutes they have experienced. Their results also show that, those who use active mode users in the summer, but switches to public transport in the winter may be less satisfied with their transit commute than those who consistently use public transport in the year. The difference between multimodal and monomodal commuters can be explained from the perspective of multimodal travellers' experiences with other modes or their undesirable deviations, and also from the perspective of monomodal commuters who may become familiar with their transport modes and regard these trips as more pleasant themselves. Generally, these finding are consistent with our hypothesis that multimodal commuters are less satisfied than monomodal commuters when deviating from their habitual modes.

For subway trips, compared with mono subway users, multimodal commuters with public transport as the habitual model find subway trips less satisfying. One possible explanation is that public transport trips are the most unsatisfying trips in empirical studies, and experience with other modes can provide a higher reference point for these multimodal PT users; consequently, their satisfaction with the subway trips is lower.

Table 5.7 Regression on trip satisfaction of trip with different modes

Fixed part	Walking trips 207 obsv. 46 groups		Cycling trips 452 obsv. 72 groups		Bus trips 780 obsv. 172 groups		Subway trips 678 obsv. 133 groups		Car trips 641 obsv. 143 groups	
	Coef.	SD	Coef.	SD	Coef.	SD	Coef.	SD	Coef.	SD
Intercept	**4.14****	**0.27**	**4.08****	**1.99**	**3.86****	**0.16**	**3.88****	**0.18**	**4.21****	**0.19**
Level I (trip)										
Depart in Peak hour (ref.= non-peak hour)	0.06	0.11	-0.06	0.06	**-0.16****	**0.06**	-0.13	0.07	**-0.32****	**0.07**
Journey from work (ref.= journey to walk)	-0.05	0.07	-0.01	0.04	0.08	0.05	**0.17****	**0.04**	-0.04	0.05
Commute duration	0.00	0.00	0.00	0.00	**-0.01****	**0.00**	**-0.01****	**0.00**	**-0.01****	**0.00**
Very inflexible mode choice(ref.=medium)	**0.34***	**0.16**	0.02	0.09	**0.30****	**0.09**	-0.05	0.09	**0.30****	**0.09**
Inflexible mode choice	0.22	0.16	0.10	0.08	-0.01	0.08	0.02	0.08	**0.23****	**0.09**
Flexible mode choice	**0.29***	**0.15**	0.14	0.09	0.10	0.11	-0.03	0.11	0.04	0.12
Very flexible mode choice	**0.65****	**0.23**	0.19	0.14	0.28	0.17	0.22	0.34	**0.50****	**0.19**
Level II (commuter)										
Male (ref.=female)	0.03	0.16	-0.25	0.14	-0.05	0.11	0.11	0.14	-0.15	0.11
Age>=40 (ref.= under 40)	-0.21	0.18	0.03	0.16	-0.05	0.16	**-0.44***	**0.23**	-0.01	0.13
Married (ref.=unmarried)	-0.07	0.21	**-0.35***	**0.18**	0.04	0.12	0.01	0.16	-0.07	0.15
Income above RMB4,000/Month (ref.= below RMB4000/m)	0.04	0.19	**0.53****	**0.14**	-0.01	0.11	0.23	0.15	0.04	0.12
Home location in urban area	0.04	0.72	**1.12****	**0.42**	0.30	0.27	**0.40***	**0.19**	-0.04	0.22
Work location in urban area	0.67	0.45	-0.26	0.24	-0.01	0.14	-0.28	0.15	-0.22	0.14
Multimodal walker	-0.16	0.24	0.56	0.67	**-0.94***	**0.48**	—	—	0.57	0.32
Multimodal cyclist	**-0.94****	**0.31**	-0.14	0.15	-0.11	0.28	0.65	0.42	-0.07	0.26
Multimodal PT user	-0.15	0.34	0.72	0.42	-0.05	0.13	**-0.60****	**0.17**	-0.08	0.15
Multimodal car user	-0.40	0.26	-0.38	0.29	0.21	0.20	0.04	0.24	0.14	0.14
Monomodal walker	Ref. Category		—	—	—	—	—	—	—	—
Monomodal cyclist	—	—	Ref. Category		—	—	—	—	—	—
Monomodal PTuser	—	—	—	—	Ref. Category		Ref. category		—	—
Monomodal car user	—	—	—	—	—	—	—	—	Ref. Category	
Random part										
Variance at level 1	0.20	0.02	0.13	0.01	0.38	0.02	0.25	0.02	0.40	0.03
Variance at level 2	0.18	0.06	0.23	0.04	0.32	0.05	0.45	0.06	0.27	0.05
Deviance	319.07		665.27		1701.09		1278.86		1413.02	

Note: * $p < 0.05$, ** $p < 0.01$

5.5 Conclusion and discussion

Using activity travel diary data collected in Shangdi-Qinghe area of Beijing, this paper presented an investigation of the commuting trip satisfaction of urban residents by different transport modes in Beijing. Consistent with previous studies (Friman et al., 2013; Olsson et al., 2013; Páez and Whalen, 2010), our results show that commuting trips by active modes are generally more satisfying, followed by car trips and public transport trips. It is shown that trip characteristics including trip duration and departure in the peak commuting hour can negatively influence trip satisfaction with motorized modes, and commuting trips from work are more satisfying than trips to work for subway users. As for personal attributes, female, unmarried and higher income commuters are more satisfied with their cycling trips, while older commuters are comparatively less satisfied with bus trips. In addition to previous studies, we further explore the relationship between transport modes and trip satisfaction by examining the influence of commuters' multimodal behaviour and their modal flexibility.

A significant contribution of this study is that we investigate the effect of multiday variability in travel mode use (multimodality) and modal flexibility on trip satisfaction. We found a significant portion (33.2% in our dataset) of commuters showing multimodal behaviour in practice. Furthermore, we found that multimodal behaviour can negatively affect commuters' trip satisfaction with alternative modes. For walking and bus trips, multimodal cyclists and multimodal walkers tend to be less satisfied than monomodal commuters. The reasons could be the multimodal travellers' experiences with multiple modes or their undesirable deviation from habitual modes, as well as the repetitive nature of mode choice. In addition, for those less satisfying trips such as subway trips, multimodal subway users could be less satisfied compared to monomodal ones, and their reference point when assessing subway trips could increase after using alternative modes (because PT trips are rated as most unsatisfying trips). We also found that modal flexibility in decision-making can influence commuter's trip satisfaction. More specifically, it presents a U-shaped relationship. According to the ''U line", commuters are most satisfied with very high flexibility in mode choice because they are more likely to choose out of their preferences; however, commuters with very low modal flexibility, especially bus users, can achieve a relatively high satisfaction level. This could be explained by the fact that highly constrained commuters would have no or lower expectations for those trips or have no alternative to regret when assessing trip satisfaction. It is also possible that the self-reported low flexibility of some commuters may be due to their habits or preferences.

To conclude, from a theoretical perspective, our research shows that trip satisfaction is not only affected by transport modes themselves but also by the context of travellers' mode choices including travellers' experiences with other modes (due to multimodal behaviour) and their freedom in decision making (with different modal flexibility levels). While multimodal behaviour in Western countries is regarded as being related to travellers' personal preferences and their increased awareness of automobile-related environmental issues (Buehler and Hamre, 2014; Kuhnimhof et al., 2006; Vij et al., 2011), lower car ownership in Chinese households and vehicle restriction policies in Chinese cities are more likely to affect urban residents' modality behaviour and also their modal flexibility.

However, there are several limitations to our study. Subjective factors, such as attitudes towards different modes, travellers' personalities (Lavery et al., 2013; Páez and Whalen, 2010), may play a role in their travel mode usage, their assessments of modal flexibility assessment and further the trip satisfaction. It would be valuable to test if the subjective factors can offer additional explanations in future studies. Another limitation of our study is that, when aiming at the cognitive component of trip satisfaction, we were not able to control the quality of services for the trips across different travel modes. Given the dataset available, we could only test trip characteristics reported by the commuters. These characteristics may indicate the service qualities to certain extent (e.g. crowdedness and congestion when departure in peak hour), but more direct indicators should be collected in further surveys exploring trip satisfaction. Furthermore, our findings could be specific in the studied area, but not representative for the situation in Beijing.

Possible policy implications can be proposed across different segments of commuters in Beijing. Consistent with previous studies, we find that commuters do compare their trips with different modes. Therefore, to encourage the use of more sustainable travel modes, it is crucial to improve commuters' experience with them. For public transport users, relatively high satisfaction level with inflexible trips may indicate that the transit service has fulfilled constrained commuters' basic needs in Beijing at the current stage. However, it is inevitable that more and more constrained public transport users could switch to cars as an alternative mode, with the rapid increase of household car ownership in Chinese cities. Their satisfaction with public transport trips may decrease as their modal flexibility increases. It is important that the public transport infrastructure keeps evolving to higher levels in Beijing. It has been planned that over 100 km of new subway lines will be built in Beijing before 2020, and the public transport system is still heavily subsidized (Zhao, 2014). With the efforts improving public transport service, it could help attracting those multimodal travellers to adopt more PT trips. For the car users, according to the preliminary results in description analysis (Table 5.6), there is no significant difference between multimodal travellers' car trips and their trips by alternative modes. In other words, it is feasible to encourage occasional mode switches of car users without decreasing their satisfaction levels. We can promote this by raising travellers' environmental awareness in the long term, and also by restrictive travel demand management measures with appropriate limitations, such as the vehicle restriction policy implemented in our research context. Furthermore, a dramatic decline of bicycle ownership and using has been witnessed in Beijing in recent decades. However, our results show that cycling is still ranked as a more satisfying mode of transport by commuters. With cycling trips appreciated by its users, building bicycle facilities and also improving the natural environment (e.g., better air quality, less smog) in the long term, could not only benefit the current commuter cyclists, but also attract more multimodal travellers with satisfying experiences.

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6. Accounting for activity satisfaction: how is it associated with space-time flexibility and individuals’ modality styles

This chapter is based on a manuscript under review for a peer-reviewed journal. Co-authors: Dick Ettema, Martin Djist.

ABSTRACT

The literature to date have explored the determinants of activity satisfaction from both individual factors and activity attributes, while individuals’ travel options and the spatial-temporal flexibility of activities may be related to their accessibility to more attractive activity locations and subsequently higher activity satisfaction. This study presents an investigation of the episode well-being with non-work activities, and further explore how they are associated with activity flexibility, and also the individuals’ modality styles. By using a weekly activity diary dataset collected in Beijing, we confirm that activities at leisure/recreational facilities are generally more satisfying than other non-work activities. Furthermore, our analysis shows that, activity satisfaction in not only related to the objectively observed activity attributes (e.g., start time, companion, facility types), but also the flexibility attributes for activity decisions, and the mobility attributes at the individual level. A “U-shaped” relation is revealed between activity flexibility (both temporal and spatial) and activity satisfaction. More specifically, compared to those with neutral flexibility levels, activities that are more fixed/flexible are also more satisfying. This could be explained by the fact that highly constrained activities are likely to be pre-planned or routinized with more realistic expectations, while more flexible activities offer the individuals a larger choice set for both start time and activity location decisions. Although multimodality has been found to encourage non-work activity participation in previous studies, it does not show significant effect of facilitating more satisfying activities. Whereas, car users are likely to have more satisfying non-work activities, especially compared to public transport users, which is probably because of the travelling experiences associated with car trips.

Keywords: Activity satisfaction; modality styles; spatial-temporal flexibility; Beijing

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6.1 Introduction

Subjectively experienced well-being (SWB) has recently attracted increased attention in transport and mobility studies (De Vos et al., 2013; Ettema et al., 2010; Nordbakke and Schwanen, 2014). In addition to demographic attributes and personality factors explored in previous sociology and psychology studies (Diener et al., 1985; Kahneman et al., 2006; Lyubomirsky et al., 2005), mobility and transport researchers have examined how travel contributes to the life satisfaction of individuals in general (Ballas and Tranmer, 2012; Bergstad et al. 2011b; Morris and Guerra, 2014; Nordbakke and Schwanen, 2014). Moreover, they have examined the satisfaction "in the moment" while traveling or participating in activities (Abou-Zeid and Ben-Akiva, 2014; Ettema et al., 2010; Morris and Guerra, 2014). This momentary-level well-being is related to life satisfaction from two perspectives: momentary well-being is assumed to promote the life satisfaction of individuals (Ettema et al., 2010; Schwanen and Wang, 2014), and vice versa; travellers who generally feel glad/passive are more likely to enjoy their trips (Susilo and Cats, 2014), and a happy person is more likely to feel more satisfied with the activities performed (Schwanen and Wang, 2014). While SWB serves as an important indicator of personal health and quality of life in general (Wang and Wang, 2016), measuring well-being at the episode level can reflect more momentary changes and the effects of immediate environmental circumstances (Csikszentmihalyi and Hunter, 2003).

Compared to in-depth explorations of trip satisfaction (Abou-Zeid et al., 2012; Deutsch-Burgner et al., 2014; Gatersleben and Uzzell, 2007; Stradling et al., 2007), there are few empirical studies investigating satisfaction with activity episodes in transport studies. The literature so far has explored the determinants of activity satisfaction from both individual factors and activity attributes (Csikszentmihalyi and Hunter, 2003; Kahneman et al., 2004; Raveau et al., 2016; Schwanen and Wang, 2014). A few studies have explored the influence of the built environmental attributes on episode satisfaction, and expected that greater density and diversity of activity sites can offer more opportunities for "satisfaction of an individual's needs for social interaction, mental stimulation, and confirmation of status and taste" (Kennedy and Adolphs, 2011; Schwanen and Wang, 2014). Although individuals' access and use of transport resources have been closely linked with their overall life satisfaction and momentary well-being with trips (Ballas and Tranmer, 2012; Ettema et al., 2011; Morris and Guerra, 2014), it has not been fully explored how travel can affect satisfaction with activity episodes. Whereas, given the space-time constraints imposed on the individuals in the urban environment (Bergstad et al., 2011a; Hägerstrand, 1970), their travel options are important to determine their accessibility to urban opportunities and the ease of reaching desired or more attractive activity locations (Bergstad et al., 2011; Geurs and Van Wee, 2004; Næss, 2006), which consequently can affect their activity satisfaction assessments. Additionally, recent studies show that travel can also affect activity satisfaction with "spill-over effects", that the travel experience can affect the performance of and satisfaction with activities at the destination of the trip (De Vos, 2017). To further investigate the impacts of travel on activity satisfaction, individuals' modality styles can be measured as an alternative choice to travel mode availability. More specifically, multimodality is generally defined as the use of (as main modes for different trips) in a specified period (Block-Schachter, 2009; Kuhnimhof et al., 2006; Nobis, 2007), while monomodality is the exclusive use of one transport mode during that period. Compared to vehicle ownership or proximity to transport infrastructures, measuring modality styles can better reflect the individuals' modal mix in practice and their familiarity with different modes (Diana and Mokhtarian, 2009).

In addition to the spatial factor and individuals' travel options, the self-reported activity flexibility can indicate the space-time constraints imposed on and also the perceived opportunities offered to the individuals (Hägerstrand, 1970; Schwanen et al., 2008; Shen et al., 2015). Regarding the concept and measurement of activity flexibility, the classic time-geographic framework adopted the fixity-flexibility dichotomy to denote activities according to their purpose or type (Hägerstrand, 1970; Tim Schwanen and Martin Dijst, 2003). While recently, the temporal and spatial flexibility of activities have also been defined as the ease with which the location or timing of the activity can be changed (Cullen and Godson, 1975; Schwanen et al., 2008; Shen et al., 2015), indicated by a degree of fixity/flexibility reported subjectively by the individuals. This definition of activity flexibility could also be employed in activity satisfaction studies. While momentary well-being can be affected by the temporal (e.g., the day of the week and hour of the day) and spatial (e.g., physical and social environments of activity sites) determinants (Birenboim, 2017; Csikszentmihalyi and Hunter, 2003; Schwanen and Wang, 2014), the analysis of activity flexibility can contribute to the execution of activities (e.g., start time and location choices) (Cullen and Godson, 1975; Doherty, 2006; Næss, 2006), and also a better explanation of satisfaction with the performed activities.

Therefore, this study aims to explore satisfaction with non-work activity episodes and further explores how they are associated with the more salient activity attribute, activity flexibility, and the individuals' modality styles. A weekly activity diary dataset collected in Beijing will be used for the analysis, with activity satisfaction and temporal and spatial flexibility characteristics reported for each out-of-base, non-work activity episode, and modality styles identified from weekly observations.

The remainder of this paper is organized as follows. The next section reviews the literature on the core concepts in our analysis and raises hypotheses concerning the relationship between them. Section 6.3 presents the research design for this study, including data collection, measurement of key concepts and methodology. Descriptive analysis results are shown in section 6.4. In addition, a two-level ordered logit model was conducted for non-work activity satisfaction, and the model estimation results are also discussed in Section 6.4. The conclusion and discussion are presented in the final section.

6.2 Literature review

From the perspective of measurements, subjective well-being (SWB) has two components: affective well-being (AWB) and cognitive well-being (CWB) (Schimmack et al., 2008). From the perspective of different scales, subjective well-being is thought to be composed of three components: life satisfaction (as a whole); satisfaction with specific areas of life (family, work); and satisfaction, emotions, or feelings associated with episodes of life (Diener, 2000). The third component is also conceptualized as the momentary-level well-being (Csikszentmihalyi and Hunter, 2003; Kahneman et al., 2004). Measuring the momentary well-being with trip episodes has been widely discussed in the studies of travel behaviour, and many approaches have been developed for this measurement (Abou-Zeid and Ben-Akiva, 2014; Ettema et al., 2011; Gatersleben and Uzzell, 2007; Novaco and Gonzalez, 2009; Stradling et al., 2007). Comparatively, there are fewer discussions specifically focusing on activity episode satisfaction. To measure activity satisfaction, some studies mainly focus on the affective parts, such as mood variables (Happy vs. Sad, Strong vs. Weak, Proud vs. Ashamed, Sociable vs. Lonely, Excited vs. Bored, Active vs. Passive) used by (Csikszentmihalyi and Hunter, 2003), while in the U.S. General Social Survey (GSS), respondents were asked to rate a set of activities and trips using a 5-scale indicator of the degree to which they like/dislike them (Turcotte, 2006). The measurement has more components in the American Time Use Survey (ATUS), where the module sampled three activities per respondent on the study day and asked about the five emotions and how meaningful the activity was (Morris and Guerra, 2015).

Although the measurements vary, the empirical studies so far have mainly examined the determinants of activity satisfaction from the perspective of individual factors (e.g., gender, age, education level, income, employment status, and household structure) (Csikszentmihalyi and Hunter, 2003; Schwanen and Wang, 2014; Xiong and Zhang, 2016) and activity attributes (e.g., type of activity, duration, companion, and time of the day) (Csikszentmihalyi and Hunter, 2003; Kahneman et al., 2004; Raveau et al., 2016; Schwanen and Wang, 2014). For example, (Schwanen and Wang, 2014) found that participants aged fifty or older experience the highest level of well-being, and similarly, Blanchflower and Oswald (2008) showed that younger respondents tend to experience less momentary well-being. Additionally, geographic attributes matter to momentary well-being, including the spatial attributes around the activity locations (Schwanen and Wang, 2014) and the residential locations (Abou-Zeid and Ben-Akiva, 2011). At the activity level, there are various attributes that have been found with significant effects. For example, “doing it together is better than doing it alone” (Walker, 2010); most empirical studies confirm the positive effect of companionship in affective assessments of activity episodes (Csikszentmihalyi and Hunter, 2003; Schwanen and Wang, 2014). Activity duration was found to have a significant effect on real-time happiness but a less significant effect on retrospective happiness (Raveau et al., 2016). Scheduling-related attributes of the activities have also been explored, such as day of the week, time of the day, and the position in the daily sequence (Csikszentmihalyi and Hunter, 2003; Raveau et al., 2016). Furthermore, positive emotions have been found to initiate upward spirals toward increasing emotional well-being, by “broadening the scopes of attention and cognition” (Fredrickson and Joiner, 2002). In other words, if the individuals have positive assessments of earlier activities in their schedule, they are also likely to be more satisfied with the following activity episodes. This possible "spill-over effect" of satisfaction with previous activities (Bakker and Oerlemans, 2016) during the day will also be examined in the following analysis. In particular, among all the activity attributes, activity type is the most widely discussed factor. Working and commuting are regarded as the least-enjoyable activities (Csikszentmihalyi and Hunter, 2003; Kahneman et al., 2004; Raveau et al., 2016), while leisure and social activities are likely to be associated with higher effect indicators (Kahneman and Krueger, 2006; White and Dolan, 2009).

Activity type mainly indicates the function of the activities, but there are also other salient attributes, such as activity flexibility, which contributes to the scheduling and execution of activities (Cullen and Godson, 1975; Doherty, 2006) and subsequently affect satisfaction with activities. For the definition and measurement of activity flexibility, following the classic time-geographic framework (Hägerstrand, 1970; Tim Schwanen and Martin Dijst, 2003), activities can generally be denoted using the fixity-flexibility dichotomy based on their activity type or purpose. For example, education and paid employment are usually regarded as fixed, while leisure activities are flexible. However, with the differences within activity categories noted, there are also studies defining activity flexibility (mainly temporal and location) as the ease with which the location or timing of the activity can be changed (Cullen and Godson, 1975; Schwanen et al., 2008; Shen et al., 2015). As an indicator of individuals' subjective assessment, on the one hand, activity flexibility is related to the individuals' personal (e.g., gender and household) and activity schedule attributes (e.g., work schedule, activity purpose, companions, time-of-day), which can indicate constraints imposed on the individuals. For example, the spatial and temporal fixity of activities is higher for older respondents, respondents with more children or respondents who are formally employed (Schwanen et al., 2008). For the schedule attributes, activities with non-household members are more likely to be temporally and spatially fixed (Srinivasan and Bhat, 2008), and social activities tend to be more flexible in time but not in space than other non-work activities (Shen et al., 2015). Also, pre-planned activities are more likely to be fixed (X. Chen and Kwan, 2012; Kitamura et al., 2000; L. Nijland et al., 2014). For example, (C. Chen and Kitamura, 2000) found that 30–45 % of the executed activities were scheduled a day before, and these planned activities are less flexible for adjustment (E. W. L. Nijland et al., 2009). On the other hand, space-time flexibility has also been found to be related to individuals' accessibility to opportunities in the urban space. For example, Schwanen et al. (2008) found that higher density is found to facilitate more flexibility, especially for women, which is explained through access to resources. In the Chinese context, Shen et al. (2015) found that the impact of built environments differs across community types. Also, the flexibility in scheduling can be conditioned by individuals' access to various travel modes (Doherty and Mohammadian, 2011; Small, 1982). Especially, private vehicle tends to found to offer individuals higher flexibility in choosing the time of departure and destination, and to reduce the degree of fixity of at least some activity types (Buliung et al., 2008; Schwanen et al., 2008). Especially for women, having a car at their disposal provides women "more independence in choosing time for undertaking out-of-home activities" (Schwanen et al., 2008). Also, in the Chinese context, household car ownership is found to facilitate more spatial flexibility of daily activities for residents in Beijing (Shen et al., 2015).

With activity flexibility reflecting both the space-time constraints imposed on and opportunities offered to individuals (Hägerstrand, 1970; Schwanen et al., 2008; Shen et al., 2015), hypotheses can be raised with regards to its impact on activity satisfaction from two different approaches. On the one hand, for flexible activities, individuals are more likely to choose the starting time and activity location they prefer. In other words, there is a higher probability for them to find an alternative that complies with their wishes (Botti and Iyengar, 2006; Van Hees, 2004) and consequently show higher satisfaction levels. On the other hand, it is also reasonable to expect high satisfaction with fixed activities. The pre-planned possibility of fixed activities (Chen and Kwan, 2012; Kitamura et al., 2000; Nijland et al., 2014), may provide individuals with more realistic expectations without any alternative choices. Consequently, the individuals are less likely to be unsatisfied because of earlier high expectations (MORI, 2002; Schwartz, 2004). Additionally, fixed activities are likely to be associated with companionship, especially with non-family members. A pre-planned eating-out activity with friends might be both space- and time-fixed, but the experiences could be more satisfactory than an impulsive eating out alone. Furthermore, given the limitation of facilities and especially performers, a concert/exhibition is likely to be fixed in both location and time, but the activity episode can still be highly satisfactory given the respondents' interests.

Furthermore, at the individual level, there have been many studies linking overall life satisfaction and trip satisfaction with individuals' mobility levels and their access to transport resources (Ballas and Tranmer, 2012; Bergstad et al., 2011; Morris and Guerra, 2015). However, it is still not clear how the mobility level affects the momentary-level satisfaction with the activity episodes. In the following analysis, individuals' modality will be indicated by their modality styles, and the impact on activity satisfaction will be investigated. Multimodality is generally defined as the use of at least two travel modes (as main modes for different trips) during a specified period (Block-Schachter, 2009; Nobis, 2007), while monomodality is the exclusive use of one transport mode during that period. The distributions of modality styles vary across different contexts with various measurements implemented in previous studies (e.g., Block-Schachter, 2009; Buehler and Hamre, 2014; Nobis, 2007), but generally, they are likely to be predicted by social demographic attributes such as gender, age, income, the presence of child, full-time employment, etc. (Buehler and Hamre, 2014b; Kuhnimhof et al., 2006; Nobis, 2007; Scheiner et al., 2016); policy-related attributes such as quality of the public transport system and travel demand management measures (e.g., Block-Schachter 2009; Brons et al. 2009; Kuhnimhof et al. 2006); and the built environment (e.g., Block-Schachter, 2009; Kuhnimhof et al. 2006; Klinger, 2017).

Individuals' modality indicators could affect their activity satisfaction through two possible pathways. First, multimodality might facilitate higher activity satisfaction via a larger activity choice set in the urban space, and the ease to reach desired facilities. For example, a study in Toronto showed that the scheduling constraints imposed by the use of public transit can "limit spatial variety seeking behaviour" (Buliung et al., 2008), while a personal car is likely to offer higher flexibility in location choices. Especially, due to quality or symbolic differences with each facility category (i.e., cinemas or recreational facilities), some features other than proximity are also important in activity location decisions (Næss, 2006). In these case, individuals' travel options (e.g., private vehicles) may facilitate them travelling to more attractive locations and consequently having more satisfying activity episodes (Bergstad et al., 2011). While car use has been found to benefit individuals by facilitating their participation in diverse non-work activities in Western studies (Farber et al., 2011; Frei and Axhausen, 2009; Srinivasan and Bhat, 2006), the use of multiple modes (i.e., multimodality) has also been found to encourage more engagement in various non-work activities in the Chinese context (Mao et al., 2017). In a high urban density context such as Beijing, multimodal travellers are likely to employ different travel modes for various situations and benefit from the ease of reaching desired activity locations with various travel modes. Therefore, we can raise the hypothesis that individuals with higher mobility levels (e.g., car use, multimodal) are more likely to become satisfied with the activities they perform. Second, activity satisfaction might differ across different mode users due to the spill-over effect of their trip experiences. It is assumed that the experience of and satisfaction with a trip could affect the execution and perception of the activity at the trip destination (Bergstad et al., 2011; Ettema et al., 2010; Friman et al., 2017). Negatively perceived trips could "worsen the performance of and lower the satisfaction with the upcoming activity," and this spill-over effect is confirmed in the study of leisure trips and upcoming leisure activities (De Vos, 2017). We can assume that users of more satisfying modes (e.g., cars and active modes rather than public transport) are more likely to be satisfied.

6.3 Research Design

6.3.1 Dataset

The data used in this study are from the "Daily Activity and Travel Survey of Beijing, 2012," which was collected from October to December 2012 in the Shangdi-Qinghe area of Beijing. This survey includes socio-demographic characteristics of commuters, a weekly activity-travel diary and data from GPS loggers carried by the respondents. As the study defines modality style at the weekly level, only those commuters with complete travel and activity diaries for a whole week are included in the study. The dataset for the current analysis includes 410 commuters, with 2870 days and 2063 out-of-base, non-work activity episodes. Their personal/household attributes are presented in Table 6.1.

There are more female commuters involved in the survey, the average age is 33.41, and the majority are married (72.4%). Car ownership in the sample is lower than the average recorded in Beijing (63 cars for every 100 households) at the end of 2012. Commuters are only included in the analysis when they commute at least once during the week.

Table 6.1 Personal attributes of the commuters

Socio-economic attributes		**No.**	**Pct. (%)**
Gender	Female	225	54.9
	Male	185	45.1
Age	Age < 30	184	44.9
	Age 30–49	205	50.0
	Age ≥ 50	21	5.1
Marriage	Unmarried (single, divorced, widowed)	113	27.6
	Married	297	72.4
Personal Income	low income (<4000 RMB /Month)	212	51.7
	Middle income (4000 -10,000 RMB/Month)	169	41.2
	High income (≥10,000 RMB/Month)	29	7.1
Education	Under college	41	10.0
	College and university	305	74.4
	Above college	64	15.6
Household structure	0 = Other household structure	356	86.8
	1 = extended household	54	13.2
Household car ownership	No car	188	45.9
	At least one car	192	46.8
	Missing values	30	7.3
Work- and commute-related factors		**Avg.**	**Std.**
Work Duration	Weekly work duration (min)	2338.90	632.00
H-W distance	Straight-line distance between home and work place(km)	7.73	6.58
Commute duration	Average duration for direct commute tours	84.42	43.32

Regarding the non-work activity episodes, the activity attributes are shown in Table 6.2. The most frequently visited location type is restaurants, while people spent more time on activities at leisure/ recreational facilities and others' residential places. Although more non-work activities are performed during the weekdays, the duration for each activity episode is longer during the weekends. Additionally, more than 50% of the non-work activities are conducted with companions.

Table 6.2 Description of the activity episodes

Activity attributes		No. of episodes	Pct. (%)	Avg. Dur (min)
Activity locations	Restaurants	583	28.3	64.9
	Stores	232	11.2	63.8
	Leisure/recreation facilities	247	12.0	120.9
	Service facilities (e.g., school, hospital)	402	19.5	88.0
	Others' residences (e.g., relatives/friends' homes)	274	13.3	135.7
	Other	298	14.4	79.0
	Missing value	26	1.3	87.8
Day type	Weekday	1301	63.1	72.6
	Weekend	762	36.9	113.3
Start Time	10 p.m. – 6 a.m.	148	7.2	116.6
	6 a.m. – 11 a.m.	424	20.6	95.0
	11 a.m. – 3 p.m.	786	38.1	85.7
	3 p.m. – 6 p.m.	319	15.5	78.1
	6 p.m. -10 p.m.	386	18.7	80.2
Companion	Solo activity	655	31.7	76.6
	With companion	1147	55.6	89.0
	Missing value	261	12.7	109.5
Sum		2063	100	87.6

6.3.2 Measurements

(1) Activity satisfaction

In this study, activity satisfaction is regarded as a cognitive evaluation of the activity. Commuters were asked to rate their satisfaction with each activity episode on a 5-point scale ranging from "very unsatisfied" to "very satisfied."

(2) Activity flexibility

Temporal flexibility: Commuters were asked "how hard/easy is it to adjust the start time for this activity" for each specific activity episode in the survey, according to the categories "very hard," "hard,"" neutral", "easy" and "very easy." Hence, temporary flexibility assessments are based on commuters' subjective perceptions of their ability to change the start time for each activity episode.

Spatial flexibility: Commuters were asked "how hard/easy is it to adjust the location for this activity" for each specific activity episode in the survey, according to the categories "very hard," "hard,"" neutral", "easy" and "very easy". Hence, spatial flexibility assessments are based on commuters' subjective perceptions of their ability to change location for each activity episode.

(3) Accumulated satisfaction with previous activities

To examine the spill-over effects of previous activities, for each activity episode, an accumulated satisfaction indicator is calculated by averaging the satisfaction with all the former activity episodes during the day. For example, if the activity is the sixth activity episode during the day, the accumulated satisfaction variable is calculated by averaging the satisfaction level with the earlier five activity episodes during that day. Because we focus on out-of-home activity episodes in the analysis, a few (122 of 2063 activity episodes) are reported as the first activity of the day, and the accumulated satisfaction would be addressed as missing values.

(4) Modality groups

Modality styles are measured by observing individuals' use of different transport modes during a whole week, as multimodality is defined as the mixing of modes across trips (rather than within trips, which can be termed intermodality). Predominantly using a single mode for multiple trips is defined as monomodality. The threshold value used for monomodality differs across different studies. In the following analysis, the threshold of 90% is adopted, which indicates that monomodal travellers show a high tendency of relying on one single mode in daily practice, but on average, they use an alternative mode for less than one tour during one week.

Three types of transport modes are identified in our analysis as follows: car, public transport (bus and subway), and active travel modes (bike and walking). For each commuter, the most frequently used travel mode is defined as the habitual travel mode.

3.3 Model specification

The dependent variable is measured at an ordinal scale in our analysis, and there are also multiple observations at the activity level (2063 episodes) and for each individual level (410 commuters). Therefore, a multilevel ordered logit model is adopted to explore the determinants of activity satisfaction. First, this model is a multinomial response model, where the responses are irrelevant and ordered (Wooldridge, 2010). Second, compared to a standard ordered logistic model, it considers individual specific heterogeneity during the modelling process (Wang et al., 2017). A two-level ordered logistic model will be estimated, with explanatory variables at two levels, as shown below. Specific descriptions of activity satisfaction and flexibility and the distribution of modality styles will be provided in the next section.

(1) Activity level variables

Based on previous empirical studies and the explanatory variables in our dataset, trip characteristics include activity location type, temporary and spatial flexibility of the activity episodes, start time and duration of the activity, companion type and day type (weekend or weekday). Additionally, the accumulated satisfaction with previous activities in the day is added.

(2) Individual level variables

At this level, commuters' socio-demographic attributes include gender, income, marriage and their modality style. Other variables such as age and household structure (child, extended household) have been tested and removed due to insignificant results. The spatial factors around commuters' residences and workplaces are tested, and the densities of facilities are included in the model.

6.4 Results

6.4.1 Descriptive analysis

(1) Activity flexibility and activity satisfaction

Although only non-work activities are included in our analysis, there is still a large share of activities reported as inflexible in temporal and spatial dimensions (Table 6.3). Comparatively, location choices are more fixed (40.1%) than the start time decisions (32.5%). For activity satisfaction, most non-work activities are quite satisfying, which confirms the finding of previous studies (Schwanen and Wang, 2014; Raveau et al., 2016) that the majority of people are satisfied with or feel neutral about their activities. In our dataset, less than 2% of the activity episodes are reported as unsatisfying, while more than 70% are reported as satisfying. Additionally, the average value for accumulated satisfaction with previous studies also reached 4.08

Table 6.3 Activity flexibility and activity satisfaction

Flexibility	Temporal			Spatial				Satisfaction		
	No.	Pct. (%)		No.	Pct. (%)			No.	Pct. (%)	
Very inflexible	366	17.73	32.51	575	27.86	40.07	**Very unsatisfied**	5	0.24	24.08
Inflexible	305	14.78		252	12.21		**Very satisfied**	20	0.97	
Neutral	434	21.03	21.03	372	18.02	18.02	**Neutral**	472	22.87	
Flexible	499	24.18	34.16	407	19.72	29.36	**Satisfied**	994	48.16	48.16
Very flexible	206	9.98		199	9.64		**Very satisfied**	503	24.37	24.37
Missing value	254	12.31		259	12.55		**Missing value**	70	3.39	
Total	2063 activity episodes									

The binary variable tests show the satisfaction level of different flexibility levels (Table 6.4). Instead of a linear trend, a U-shaped line is found to describe the relationship between temporal/spatial flexibility and activity satisfaction assessment. On the one hand, the fact that flexible activities are more satisfying can be explained through the higher utility derived from a larger choice set. With higher flexibility in timing and location choices, it is possible for commuters to conduct the activity complying with their preferences. On the other hand, very inflexible activities are found to be most satisfying, which is probably because they are pre-planned, and individuals have more realistic expectations with no alternative choices. Additionally, the U-shaped line is also identified in a previous study that examined the relation between modal flexibility and trip satisfaction (Mao et al., 2016).

Table 6.4 Activity satisfaction of different flexibility levels

Temporal	Activity satisfaction			Spatial	Activity satisfaction		
	Avg.	No.	Sig.		Avg.	No.	Sig.
Very inflexible	4.33	365		**Very inflexible**	4.23	574	
Inflexible	3.91	305		**Inflexible**	3.91	252	
Neutral	3.62	434	0.000	**Neutral**	3.55	372	0.000
Flexible	4.07	499		**Flexible**	4.05	407	
Very flexible	4.10	206		**Very flexible**	4.07	199	
Total	3.99	1809		**Total**	3.99	1804	

(2) Distribution of modality groups

One week is a typical societal and cultural time unit to capture individuals' habitual travel behaviour (Kuhnimhof et al. 2006). Based on weekly observations, the distribution of different modality groups is shown in Table 6.5. Almost 40% of individuals use one primary travel mode for more than 90% of their trips in a week and are assigned to the monomodality group. The other 60% are comparatively more diverse in their mode usage and are identified as the multimodality group. For the most frequently used travel modes during the week, three types of main modes have been identified: car, public transport (PT) and active travel modes (Act). Almost one-half of the respondents use public transport more often, followed by the car and active modes. This is consistent with our research context, as Beijing is a public transport-dominant city where trips by public transport accounted for 44.0% of all trips (trips on foot excluded) in 2012 (Beijing Transport Research Center, 2013).

Table 6.5 Description of individuals (modality groups)

Modality groups		No.	Pct. (%)
Modality	**Monomodal**	163	39.8%
	Multimodal	247	60.2%
Habitual Mode	**Car**	112	27.3%
	PT	196	47.8%
	Act	102	24.9%

The average flexibility and satisfaction of activity episodes for each individual was computed, and the associations with the modality indicators are presented in Table 6.6. Generally, there is no significant relation found between multimodality, habitual modes and the flexibility level with activity episodes. In other words, the use of different modes does not provide more flexibility for non-work activities in general. However, habitual car users seem slightly more satisfied with their non-work activities, while there is no difference between multimodal and monomodal traveller. The relation is further explored in multivariate analysis, with the activity and personal attributes controlled.

Table 6.6 Activity flexibility and satisfaction of different modality groups[1]

Modality groups		Temporal flexibility Avg.	No.	Sig.	Spatial flexibility Avg.	No.	Sig.	Activity satisfaction Avg.	No.	Sig.
Modality	**Mono**	2.98	133	0.917	2.79	131	0.388	3.89	140	0.138
	Multi	2.97	218		2.69	218		3.99	235	
Habitual Mode	**Car**	2.85	91	0.396	2.62	91	0.327	4.07	98	0.061
	PT	3.02	172		2.81	171		3.90	181	
	Act	3.02	88		2.67	87		3.93	96	

6.4.2 Model results

To further investigate the influence of the explanatory variables, a multi-level ordered logit model was constructed, and Table 6.7 shows the regression results of activity satisfaction.

(1) Activity characteristics, temporal/spatial flexibility, and the accumulated satisfaction

Among all the non-work activities, activities at leisure/recreational facilities are more satisfying than others, which is consistent with previous studies focusing on effect assessments. Comparatively, activities during the morning are likely to be more unsatisfying than those during other time periods, which is different from the findings by Schwanen and Wang (2014). This is probably because they take all the activities (in-home and out-of-home) into consideration. Non-work activities out of the home between 6 a.m. and 11. a.m. are probably constrained by work/commute schedules and the congestion during peak morning hours. The estimation result also confirms the positive effect of companionship. In particular, time spent with friends and family members is significantly more satisfying than time spent alone.

Furthermore, there is a significantly positive effect found for the accumulated satisfaction variable. In other words, if the individual is satisfied with the previous schedules during the day, he or she is also likely to be satisfied with the current activity performed. However, the average satisfaction may also reflect the individual's personality and their overall satisfaction with life (Diener et al., 1985; Kahneman et al., 2006; Lyubomirsky et al., 2005), as a happy person is more likely to feel more satisfied with the activities performed (Schwanen and Wang, 2014). As shown in the descriptive analysis, the "U-shaped" association is also confirmed in this multivariate analysis. Compared to the neutral level flexibility, both being more flexible and being more inflexible (in space and time) are more satisfying, although the positive effect is not significant for those activities that are temporally "flexible" and spatially "very inflexible." This confirms our hypothesis that activity flexibility could be associated with activity satisfaction in two directions: first, those that are highly constrained (in time and space) are more likely to be pre-planned (rather than impulsive) and with companions (Charluex, 2015; Schwanen et al., 2008;

1 To describe the relation between modality (individual level) and flexibility/ satisfaction (activity level), two approaches were tested as follows: 1. compare means at the episode level; 2. average the episode flexibility and satisfaction for each individual, and compare means at the individual level. The relation revealed are similar, and the result of the latter approach is presented in Table 6.

Shen et al., 2015), and the individuals could possibly have a more realistic expectation of the activities; second, for activities that are highly flexible, individuals can choose from a continuum of times and a set of alternative locations, and they are more likely to choose those that comply with their preferences.

(2) Socioeconomic attributes and modality style at the individual level

For personal attributes, there is no significant gender difference found. Although income has been found to contribute to life satisfaction in general (Csikszentmihalyi and Hunter, 2003; Raveau et al., 2016; Schimmack et al., 2008), there is no significant effect shown on activity episode satisfaction. However, being married is negatively associated with activity satisfaction, although previous studies have found that being married is positively associated with higher life satisfaction in both the Western and Chinese contexts (Morris, 2015; Wang and Wang, 2016; Ram et al., 2017). For cognitive assessment of out-of-home activity episodes, married people are less satisfied. Other socio-economic variables (e.g., age, education level, child, work duration and household structure) were also tested but were found to be insignificant. Furthermore, the density of facilities around a residence is found to have a positive effect on activity satisfaction. This is probably because the greater density provides “more opportunities for satisfaction of an individual’s needs for social interaction, mental stimulation, and confirmation of status and taste” (Kennedy and Adolphs, 2011; Schwanen and Wang, 2014), and individuals are also more likely to reach the desired destination within a shorter distance.

As for the modality indicators, there is no difference between multi- and monomodality groups, but habitual PT users are significantly less satisfied compared to habitual car users. According to findings in our previous study (Mao et al., 2017), multimodality benefits individuals by facilitating more non-work activities during the week compared to monomodality, but it also requires longer travel time for these non-work activities. According to the model results, being multimodal does not necessarily provide more satisfying activities. On the other hand, habitual car users show no advantage in the duration of activity participation, but they save more travel time for non-work activities during the week. Furthermore, car trips are found to be more satisfying than public transport in previous studies (Eriksson et al. 2013; Friman et al. 2013; Turcotte 2006) and in our research context (Mao et al. 2016). Therefore, there could be two reasons for the more satisfied level reported by habitual car users. On the one hand, car users compared to other mode users, can benefit from higher flexibility in activity location choices in the urban space and the ease of reaching the desired location (e.g., shorter travel time) (Bergstad et al., 2011; Buliung et al., 2008). On the other hand, they are more likely to have a better experience in reaching the activity locations (e.g., higher trip satisfaction).

Table 6.7. Regression on activity satisfaction

Non-work activity satisfaction	Coef.	Std. Err.	P-value.
Location type (ref.=Restaurants)			
Stores	0.10	0.22	0.64
Leisure/recreational facilities	0.41**	0.22	0.05
Service facilities	-0.07	0.20	0.72
Residence of others	0.37	0.25	0.15
Other location type	0.19	0.21	0.37
Timing flexibility (ref.=neutral)			
Very inflexible	0.84***	0.25	0.00
Inflexible	0.20	0.22	0.37
Flexible	0.39*	0.22	0.08
Very flexible	0.64**	0.30	0.04
Location flexibility (ref.=neutral)			
Very inflexible	0.98***	0.24	0.00
Inflexible	0.64***	0.25	0.01
Flexible	0.57**	0.24	0.02
Very flexible	0.47	0.31	0.13
Timing (ref.= 10 p.m. -6 a.m.)			
6 a.m. - 11 a.m.	-0.53*	0.30	0.08
11 a.m. - 3 p.m.	-0.38	0.28	0.18
3 p.m. -6 p.m.	0.07	0.30	0.82
6 p.m. - 10 p.m.	0.26	0.29	0.36
Other activity attributes			
Log (Activity duration)	0.15	0.16	0.35
Company: Family members (ref.=solo)	0.34**	0.17	0.04
Company: Friends	0.38**	0.19	0.04
Company: Colleague and others	0.28*	0.17	0.09
Accumulated satisfaction in the day	2.43**	0.14	0.00
Weekend (ref. =weekday)	0.12	0.15	0.42
Personal attributes			
Male	-0.13	0.17	0.47
Married	-0.40*	0.21	0.06
Middle income (ref.= low income)	-0.20	0.18	0.26
High income	0.13	0.35	0.71
Log (Density around residence)	0.56**	0.23	0.02
Log (Density around workplace)	0.12	0.25	0.62
Modality indicators			
Multimodal (ref. =mono)	-0.12	0.18	0.50
Habitual PT user (ref.= Car)	-0.46**	0.21	0.03
Habitual ACT user	-0.42*	0.24	0.08

Thresholds			
cut1	4.22***	1.09	0.00
cut2	5.67***	1.02	0.00
cut3	10.15***	1.02	0.00
cut4	14.10***	1.05	0.00
Individual level variance	0.89	0.20	
Model summary			
Wald chi2(32)		***472.86***	
P-Value		***0.00***	
LR test vs. ologit model		***0.00***	
Number of obs.		***1663***	
Number of groups		***335***	

Note: * sig.<0.10; ** sig. <0.05; *** sig.<0.01

6.5 Conclusion and Discussion

This paper presented an investigation of the non-work activity satisfaction of urban residents in Beijing. Consistent with previous studies (Kahneman and Krueger, 2006; Schwanen and Wang, 2014; White and Dolan, 2009), our results show that activities at leisure/recreational facilities are generally more satisfying than other non-work activities. Time spent with companions, especially friends and family members, is more satisfying than time spent alone, and non-work activities in the morning are less satisfying. Furthermore, the spill-over effect of satisfaction with previous activities is confirmed in our analysis. For personal and environmental attributes, married individuals are less satisfied with their non-work activity episodes out-of-base, while living in a place with higher density is associated with more satisfying activities.

A significant contribution of this study is that we investigate the effects of activity flexibility (temporal and spatial) and individuals' modality styles on activity satisfaction. We found that for out-of-base, non-work activities, location is more fixed (40.1% inflexible) than timing (32.5% inflexible). A "U-shaped" relation between activity flexibility (both temporal and spatial) and satisfaction is revealed. More specifically, activities that are more fixed/flexible are also more satisfying, compared to those with neutral flexibility levels. This could be explained by the fact that highly constrained activities are likely to be pre-planned or routinized with more realistic expectations, while more flexible activities offer the individuals a chance to choose from a larger choice set. For modality indicators, although multimodality has been found to encourage participation in more non-work activities in previous studies, it does not a show significant effect of providing more satisfying activities. While car users are found to report higher satisfaction levels on average in our descriptive analysis, the model results confirm that public transport users are significantly less satisfied with their non-work activities. This is probably because of the spill-over effect of the travellers' travel experiences, that public transport trips are reported as the least satisfying in our research context (Mao et al., 2016); on the other hand, habitual car users probably benefit from the ease of reaching desired activities, such as spending less travel time (Mao et al., 2017) or travel further to attractive activity locations.

To conclude, from a theoretical perspective, as a reflection of momentary changes, activity satisfaction is not only related to objectively observed activity attributes but also to salient factors such as flexibility for activity decisions, and the mobility attributes at the individual level (e.g., habitual modes). However, due to the survey design, there is a lack of emotional assessment of momentary well-being in our study (Csikszentmihalyi and Hunter, 2003; Kahneman et al., 2004; Raveau et al., 2016; Schwanen and Wang, 2014). It would be valuable to adopt the examined emotional indicators in previous studies and to further explore if emotional responses differ across flexibility levels. Additionally, personality attributes of individuals (Diener et al., 1985; Kahneman et al., 2006; Lyubomirsky et al., 2005) and their the overall life satisfaction information were not collected and are not included in our analysis of momentary satisfaction. The measurement of activity flexibility in our study follows previous empirical studies and adopts the use of activity diaries. However, the interpretations of space-time flexibility of individuals are based on memories, and as a consequence, the response may differ with real-time collection of data. In particular, distinguishing between pre-planned activities and impulsive activities might provide more insight into the understanding of activity flexibility. For example, an eating-out activity could be fixed in both time and space when it was pre-planned, but an impulsive one could be more flexible in location choices. More detailed measurements of scheduling attributes and flexibility of activities could be considered and discussed in further research.

From the perspective of policy making, it has been proposed that higher density and better accessibility can encourage more activity participation, while it is also important to understand how individuals experience these activities. The determinants of high activity satisfaction could be complicated, related to both low and high activity flexibility perceived by the individuals. However, the built environment attributes still contribute, especially facility density around residential places. Possible policy implications can be proposed to inform individuals of possible timing and location choices in practice. The provision of opportunities, such as the number of/accessibility to location choices (spatial flexibility and the opening times of facilities (temporal flexibility)) and informing individuals of the possible choices (e.g., through ICT), may result in higher flexibility levels and consequently higher satisfaction. Furthermore, the significant relation between habitual travel modes and activity satisfaction reveals that a possible effect of travel experience on activity experience exists. This suggests that improvements in travel options, such as better public transport services and shorter travel times, will not only positively affect the travel experience but will also have positive effects on activities performed after the trip. Although this relation is not directly investigated in our study, it could be examined in further research and considered in agendas that aim to improve quality of life.

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7. Discussion and Conclusions

7.1 Introduction

The urban transformation in China, sharply increased car ownership and massive public transport investment in the past decades have changed the daily mobility and mode choices of urban residents in China, resulting in longer travel distances, increasing car use and dramatically decreased trips by physically active travel modes (Shen, 1997; Wang and Zhou, 2017; Zhao, 2013). Like Western cities, Chinese cities are experiencing environmental externalities associated with car use (e.g., traffic congestion and air pollution) (Cervero, 2013; Darido et al., 2014; Zhao et al., 2017). The spatial imbalance between residences and jobs in megacities, such as Beijing, results in longer and more motorized commutes for its residents (Ta et al., 2017; Wang, E. et al., 2011; Zhao et al., 2010). As commuters make up the largest group (54.6%) in the city, the massive amount of trips by commuters inevitably contribute to the congestion of the city's transport systems. Multimodality, regarded as an alternative towards sustainable travel in Western studies, has not been investigated in Chinese cities to date. It is not clear how urban residents' modality styles are shaped in a dramatically changing but also constrained context, such as Chinese cities. Furthermore, the policy aim of sustainable travel includes both the environmental and social aspects (Handy, 2014; Nawijn and Peeters, 2014; Rubin and Bertolini, 2016; Stanley et al., 2011). However, to date, the understanding of the social impacts of transport is limited in the context of Chinese cities, with the majority of studies to date focusing on direct travel behaviour (Feng et al., 2014; Wang, D. et al., 2011; Wang and Zhou, 2017). Therefore, the first aim of this thesis is to explore the share and determinants of individuals' modality styles in Beijing. The other aim is to contribute to the existing literature on the social impacts of transport in China, by exploring how modality styles affect activity participation, social interaction, travel time and well-being.

This thesis consists of a collection of five research articles, addressing the presence of modality styles and its impacts in the Chinese context. This concluding chapter presents an overview of the main findings in response to the research questions raised in Chapter 1, followed by a discussion of their theoretical and policy implications.

7.2 Answers to research questions

As formulated in Chapter 1, five research questions have been put forward in this dissertation to better understand the share and determinants of modality styles in Beijing, and to investigate its impacts on individuals' activity participation, social interaction, travel time and well-being in Beijing. Chapter 2 (research question 1) constructs a conceptual model exploring the interaction between car ownership, car use and modality styles, and estimates their impacts on individuals' non-work activity participation simultaneously. Chapter 3 (research question 2) investigates the influence of modality styles on commuters' social interaction with different companions, in commute days and non-commute days respectively. Chapter 4 (research question 3) examines the extra travel time for multi-purpose commute, and also how the extra time is affected by personal/household attributes, spatial factors and travel modes. Chapter 5 (research question 4) focuses on the satisfaction with direct commute trips by various modes, and especially how commuters' experience with alternative modes (multimodality) and self-reported modal flexibility can affect commuting satisfaction. Chapter 6 (research question 5) examines the satisfaction with non-work activity episodes, and also how they are affected by the space-time flexibility of activities and individuals' modality styles. The answers to each research question are discussed below.

1. *What are the shares and determinants of commuters' modality styles, and what is the impact of these modality styles on commuters' non-work activity participation?*

Building on the literature analysis, we proposed a conceptual model, estimating how car ownership and car use influence modality styles and investigate their eventual effects on individuals' non-work activity participation. Among the sampled commuters (380 individuals) in this analysis, around 50% have at least one private car in the household, around 27% actually use their car more often than other modes, and around 60% tend to be multimodal in their daily life practices. One contribution of this study to existing knowledge, is exploring the interaction between car ownership, car use and also modality styles. With the estimation of a structural equations model, we found that car ownership encourages more car use, while car users are less likely to be multimodal. Nevertheless, car ownership also encourages multimodality by offering an extra choice to travellers, although this effect is impeded indirectly due to increased car use. Overall, car ownership is found, in the context of Beijing, to lead to a diverse mixture of travel modes rather than to car dependence. This finding is different from the "monopolizing" effect of car ownership in previous studies (Buehler and Hamre, 2014; Chatterjee et al., 2016; Kuhnimhof et al., 2012). These differences can be related to both the geographical and institutional backgrounds in Beijing: the impact of higher facilities densities which is found to help reducing car use, and relatively low-car ownership in Chinese households and car-use restriction policies implemented in the current stage. Furthermore, we estimated the influence of car ownership, car use and multimodality simultaneously in the model structure. Car ownership itself does not affect individuals' non-work activity participation but only matters via car use and multimodality. Different from studies in Western contexts, our study found that at the weekly level, car users mainly benefit from saving travel time for non-work activities but do not show higher non-work activity participation. In contrast, with the use of multiple travel modes, multimodal travellers are more likely to engage in various non-work activities but also spend more time travelling.

2. *What is the impact of commuters' modality styles on their social interactions with different companions?*

We measured commuters' social interaction through their out-of-home, face-to-face interactions with their family members, friends and colleagues on both commute and non-commute days. Generally, commuters spend more time on solo activities or with colleagues on commute days, while they spend more time with family members and friends on the non-commute days. While previous studies mostly focus on the interaction with one certain type of contact (e.g., intra-household heads, family members, friends, local ties), the estimations in our analysis of multivariate Tobit regression models show that the interactions between different types of contacts are correlated. More specifically, the interactions with friends are positively correlated with the interactions with family members and with colleagues on the commute days, while no significant relationship is found among the interactions on non-commute days. To expand upon existing transport and social interaction studies, we identified differences between different days, as opportunities and constraints are found to vary from day to day. Generally, the influence of modality differs across companion types and between commute and non-commute days. During commute days, with more time constraints imposed by work and commute durations, the use of the car facilitates interactions with family member and friends. This facilitation is probably related to the flexibility of the car, which makes it easier to add non-work stops to their commuting, as well as the capacity to chauffeur companions for the joint activities. Additionally, car use shows no advantage in participating in solo activities with less coupling constraints or in interactions with colleagues that are more likely to be work-related. During non-commute days with fewer time constraints, car use also shows no advantage in interactions with any companion type. Conversely, multimodal travellers participate more in out-of-home activities on non-commute days. Mono public transport travellers appear to be more constrained in social interactions on both commute and non-commute days.

3. *What is the impact of socio-demographics, spatial attributes and alternative mode use on the trade-off between extra travel time and non-work activity duration in multipurpose commute trips?*

Based on the multi-day observations and the comparison between direct commute and multi-purpose commute trips, this study shows that chaining a stop to commuting trips reduces the travel time expenditure for non-work activities for commuters, which can benefit urban residents with tight time-budgets. The extra travel time for non-work stops and the trade-off between travel and activity time for non-work stops has been examined, and it varies among the different types of non-work stops. The impact of socio-demographics and spatial attributes has been investigated. Regardless of the activity type, longer work duration reduces the extra travel time. Furthermore, the model results show that the impacts of personal and spatial factors differ across the activity types. For example, gender difference is observed only for eating out, which suggests that male commuters travel longer for the same amount of activity time. Concerning spatial factors, a greater mix of facilities near workplaces helps to reduce the extra travel time invested for a time unit of shopping and family/personal/other activities. While our analysis confirms the findings in previous studies that multi-purpose trips tend to be more motorized, we further extended previous studies by exploring how different travel modes can affect the extra travel time due to detours. The results show that compared with public transit users, active mode users have shorter extra travel time for dining-out activities, while car users have shorter travel time for social/leisure activities. Additionally, travel modes are assumed to be fixed in previous studies of commuting trips; however, among our sampled commuters, we found that almost 20% of the multi-purpose commuting trips include a change toward a more motorized transport mode than their direct counterparts. However, contrary to our hypothesis, mode shift does not show any significant impact. Instead of saving extra travel time with more motorized travel modes, commuters may relocate the activity and travel farther, probably to reach more attractive locations.

4. *What differences exist between travel modes in commuting satisfaction and how can this be explained by modal flexibility and modality styles?*

Based on the direct commute trips made by commuters in the week, we first present a consistent finding with previous studies. Although differences exist in social norms, transport conditions and the built environment between Beijing and cities in Western contexts, such as Denmark, the Netherlands or the U.S., it seems that physically active commuters always have the highest levels of travel satisfaction. In our study, the active travelers are followed by the car commuters, and public transport users are the least satisfied. We have examined the influence of personal and trip attributes on trip satisfaction. Additionally, there are several findings that are unique to this study. We found a significant portion (33.2% in our dataset) of commuters showing multimodal behaviour in commuting. We also find that multimodal commuters tend to feel less satisfied with trips by alternative modes compared with monomodal commuters who exclusively use that mode, which is probably related to multimodal travellers' experiences with multiple modes or their undesirable deviation from habitual transport modes. Moreover, the relationship between modal flexibility and trip satisfaction is not linear, but U-shaped. Commuters with high flexibility are generally most satisfied because there is a higher possibility for them to choose their mode of transport out of preference. Very inflexible commuters can also reach a relatively high satisfaction level, however, which is probably caused by their lower expectations beforehand and the fact that they did not have an alternative to regret in trip satisfaction assessments. These two findings with regard to multimodality and modal flexibility add to the existing knowledge about trip satisfaction by indicating the relevance of the presence of choice options to trip satisfaction.

5. *What is the impact of activity flexibility and commuters' modality styles on momentary subjective well-being with non-work activity episodes?*

Based on the observations of all out-of-home non-work activity episodes, we first reveal a finding that is consistent with previous studies. Regardless of the social and geographic context differences, it seems that leisure/recreational facilities are generally more satisfying than other non-work activities in all research contexts. We observe that for out-of-base non-work activities, location is more fixed (40.1% inflexible) than timing (32.5% inflexible). Furthermore, a unique finding in our activity satisfaction studies is that there is a "U-shaped" relation between activity flexibility (both temporal and spatial) and satisfaction. More specifically, activities that are more fixed/flexible are also more satisfying compared with those with neutral flexibility levels. This finding could be explained by the fact that highly constrained or inflexible activities are likely to be pre-planned or routinized with more realistic expectations, while the more flexible activities offer the individuals the chance to choose from a larger choice set. For the modality indicators, although multimodality has been found to encourage the participation in more non-work activities in previous studies, it does not show a significant effect of providing more satisfying activities. While car users are found to report a higher satisfaction level on average in our descriptive analysis, the model results confirm that public transport users are significantly less satisfied with the non-work activities. Although not directly investigated, this decreased level of satisfaction could be associated with the "spill-over" effect of travel experience identified in other studies; in other words, it is probably because car use provides more benefits in reaching the destinations, such as saving travel time, higher comfort and higher trip satisfaction.

7.3 Theoretical implications

This thesis has made three major theoretical implications. First, this thesis contributes to the understanding of modality styles in the Chinese context. Second, it explores the impacts of transport and modality styles on activity participation in Beijing, as affected by its specific geographical context, social-economic setting and individuals' time constraints on various days. Third, this thesis contributes to the transport-related well-being studies by including not only trip attributes but also the context for choices (the subjectively assessed flexibility indicators). These contributions are further elaborated below.

7.3.1 Determinants of modality styles in Chinese cities: The geographical and institutional factors matter

One of the major theoretical contributions of this research to the existing knowledge is exploring the determinants of modality styles in the Chinese context. To date, modality styles were primarily discussed and elaborated within the context of Western and developed societies, such as Germany, the U.S. and the Netherlands. However, due to various socio-economic, institutional and geographic differences, we have shown different shares of modality styles as well as differences in meaning of determinants (e.g., car ownership, built environment attributes) of modality styles in the Chinese context compared to the Western context.

In Chapter 2, we constructed a conceptual framework to explore the interaction between car ownership, car use and modality styles and the determinants. To a certain extent, our research confirmed several previous findings that built environment attributes play an important role in shaping individuals' travel behaviour (Cao et al., 2008; Ewing and Cervero, 2010; Handy et al., 2005; Wang and Zhou, 2017). For example, we found that higher density can discourage habitual car use but encourage the use of multiple modes, which is probably because a higher density of facilities is associated with a more walkable/bicycle-friendly environment and better accessibility to public transport facilities. However, a different finding is that car ownership does not necessarily lead to car dependency in the Chinese context but rather provides an extra choice and increases multimodality at the current stage. The interpretation of this result should be closely associated with both the geographical and institutional background in our research context. The urbanization and suburbanization in Chinese cities are processing at the same time (Feng and Zhou, 2004; Yao and Wang, 2014). Although the planning ideology in Beijing is targeted to decentralize concentration or clustered suburban development, the reality was that urban expansion had taken the form of "a continuous expansion of the central built-up area through encroachment on greenbelts and absorption of satellite communities and towns" and resulted in a more evenly distributed population density in different parts of the city (Wang and Zhou, 2017; Yang et al., 2012). This high-density expansion of urban space in China is usually accompanied with the construction of expansive public transport infrastructure (Yao and Wang, 2014), and together they may facilitate more sustainable travel modes and decrease the possible dependence on car use. On the other hand, the Chinese local governments have undertaken a series of car control policies to reduce the growth of private vehicles and car use (Chen and Zhao, 2013; Hao et al., 2011; Yang et al., 2014). The low household car ownership and the intervention by local governments in daily car use in urban areas could constrain individuals' car dependence and lead them to be (probably involuntary) multimodal car users in the short term. However, driving is becoming a lifestyle choice for Chinese residents now, and the share of drivers among females and elderly is increasing (Zhao, 2014; Zhao et al., 2017), which may indicate a preference for more car use. In practice, this development can be observed in some households buying more cars to counter car travel control policies (Eskeland and Feyzioglu, 1997), and car management policy alone cannot encourage those with car preferences to forsake the convenience and comfort of cars (Vlek, 1995). In other words, with increasing car ownership, the multimodal-orientation of car owners caused solely by the car management policies may not be sufficiently viable in the long term.

To conclude, not only the share of the modality styles but also the determinants and the interpretation of determinant values can vary across different contexts at different developing stages. The lessons learned from developed economies are unlikely generalizable to China given its unique characteristics (Feng et al., 2014; Wang and Lin, 2014). Although explicit determinants are still debated, the phenomenon of multimodality in Western countries is primarily discussed in the context of "a pluralization of life orientations and mobility styles" and new urban mobility services provided by sharing economies (e.g., car- and bike- sharing, ridesharing) (Diana, 2010; Klinger, 2017). However, our case study reveals that the local context characteristics in China can largely affect the mechanism in shaping individuals' modality styles. Especially, the institutional setting (i.e., the car management policies) may play a significant role in the development of modality styles. In other words, for travellers, especially car owners in Beijing, being multimodal can be encouraged by the urban features but might also be an outcome of constraints set by policies. Hence, the behavioural response to urban transport policies rather than individuals' life style choices (Vij et al., 2011; Vij et al., 2013) may be underlying modality styles. This implication can be examined in further studies, by investigating both individuals' attitudes to different travel modes and the implementation of policies (e.g., waiting for the monthly car-plate lottery draw, traveling in a rational day or not) in the analysis of modality styles.

7.3.2 Transport and activity participation in Chinese cities: The influence of modality, geographic context and personal constraints

The exploration of the impact of transport on activity participation in Beijing is another major theoretical contribution made by this research to previous studies that mainly focus on mode choices in the Chinese context. Many studies in the Western contexts have highlighted the positive influence of car use on non-work activity participation (Frei and Axhausen, 2009; Merlin, 2015; Rubin, 2015) with several exceptions, such as that car use is associated with "sedentary" life styles and may cost more travel time for non-work activities (Farber and Páez, 2009; Schwanen and Dijst, 2002).

In our research context, the investigation at the weekly level (Chapter 2) indicates that multimodal travellers benefit from more participation in non-work activities, while car users do not have much advantage compared to other travel mode users in this respect. To a certain extent, we show that currently, the functionality of car use can be substituted by the use of multiple travel modes in our research context of Chinese cities. This comparative advantage of multiple mode users rather than car users is facilitated by Beijing's urban form transition since the mid-1980s (Feng et al., 2009), which is accompanied with the high density, mixed land-use pattern in Beijing (Li and Wu, 2008) and public service facilities relatively balanced distributed at the city scale (Li and Feng, 2017). The provision of facilities and public transport infrastructure and the existing distribution of land use offers more activity opportunities accessible by non-car travel modes in the urban space and lays the foundation for transport's influence on activity participation in Beijing. Furthermore, this influence may differ when the commuters have different activity agendas between commute and non-commute days and differ between the companionship of different social contacts. More specifically, monomodal car users have more advantage in interaction with social contacts on commute days, while this advantage disappears and is overtaken by multimodality on the non-commute days. In other words, the flexibility and capacity of car use does show its benefits for commuters on commuting days, given the time constraints imposed by work and commuting as well as the capacity to chauffeur companions for the joint activities. Moreover, at the trip level (Chapter 4), we found multi-purpose trips are more motorized, confirming the assumption in Chapter 3 that it might be easier for car users to chain non-work stops with the commute trip. Additionally, the car could help commuters reduce their travel time for leisure/social activities, which contributes to the travel time-saving effect of car use at the weekly level (Chapter 2). With respect to culture norms, previous studies have highlighted the importance of collectivism in shaping individuals' travel behaviour (Dijst, 2014; Feng et al., 2014), activity location and companion choices (Zhao et al., 2016). Their assumptions are confirmed in our results. For example, while the interaction with other companions are likely to be affected by individuals' modality styles, time spent with colleagues out of the workplace are rarely affected (Chapter 3). Interactions with colleagues are likely to cost more activity time (Chapter 3) and travel time (Chapter 4) for male commuters. The insignificant effect of transport but significant gender difference is possibility due to the cultural background. More specifically, social and eating-out activities with colleagues are likely to be required by the work environment or the collectivism orientation for the development of workplace relationships (“Guanxi” in Chinese) (Han and Altman, 2009). Women are less likely to be involved in these activities in a Chinese context as they are considered male activities or intruding on home and family responsibilities (Bedford, 2016).

Therefore, a conclusion regarding the facilitating/impeding effect of car on activity participation cannot generally be achieved without considering the context for observations, including both the geographic context and social-cultural settings. Furthermore, even for the same individuals, their time constraints or “timeframes” differ across days (Habib and Miller, 2008; Kitamura et al., 2006; Susilo and Avineri, 2011). Together with the temporal variation of facilities/transport services (e.g., opening hours between weekday and weekends) (Weber and Kwan, 2002), the role different travel modes play in activity participation may differ due to the observed time period. One limitation of our study is that we only included the commuters with a clear distinction between commute and non-commute days. For the non-worker groups, they are likely to have more free time, and the types and number of constraints imposed on them are generally different (Manoj and Verma, 2015). Previous studies have shown that they are less sensitive to travel time (Azari et al., 2013) and engage more in trip chaining (Bricka, 2008). However, there is not a clear picture of their modality styles and how the modality styles affect their daily life in the Chinese contexts, which can be addressed in future studies.

7.3.3 Transport and well-being/satisfaction: The context of choices matter

Subjective well-being (SWB) and travel attributes/behaviour have been related in many previous studies (Abou-Zeid and Ben-Akiva, 2014). Studies of trip satisfaction have identified which trip attributes contribute to a higher or lower trip satisfaction (Ettema et al., 2013; Novaco and Gonzalez, 2009; Novaco and Gonzalez, 2009). Studies of activity satisfaction have identified factors influencing the attractiveness of activities, including spatial characteristics (Deutsch-Burgner et al., 2014; Ettema and Schekkerman, 2016). The main theoretical contribution of our study is to extend the discussion of revealed trip attributes and activity attributes by including the context of travel choices as an explanatory factor. More specifically, trip satisfaction is not only affected by travel modes but also individual’ experiences with other modes (due to multimodality) and their freedom in decision making (with different modal flexibility levels). For activity satisfaction, it is not only related to the objectively observed activity attributes but also the factors related to the freedom in choosing the timing and location for these activities (temporal and spatial flexibility).

From a theoretical point of view, utility-maximization theory (McFadden, 2001) assumes that choices people make maximize utility and the maximized utility results in satisfaction with the outcomes of their choices (Bergstad et al., 2011b). When the distinction between experienced utility and decision utility (Kahneman, 2000) was introduced to the transport research area, researchers argued that in addition to deriving utility from the discrete choice models based on (random) utility theory, measuring experienced utility of travel/activity provides important added insight into the outcomes of travel choices (Abou-Zeid and Ben-Akiva, 2014; Abou-Zeid and Ben-Akiva, 2012; Bergstad et al., 2011a; Ettema et al., 2010).

However, the "U-shaped" relationship between flexibility and satisfaction found in this thesis indicates that the decision context can further impact individuals' experienced utilities. For those with higher flexibility in their choice context, their decisions are likely to be made out of preferences, as having more options offers a higher probability of finding an alternative that complies with one's wishes (Botti and Iyengar, 2006; Van Hees, 2004). For those with rather fixed choice contexts, there is no existence of "forgone" alternatives (Inman et al., 1997) or lower expectations (Schwartz, 2004) associated with their decisions, and they are therefore less likely to be dissatisfied. The choice context can result from various factors such as constraints (e.g., car availability/ car restriction), preferences (e.g., psychological motivation for car use), social norm (e.g., female more temporally constrained than male) or geographic background (e.g., spatially flexible due to more available facilities) (Schwanen et al., 2008; Shen et al., 2015). Understanding the factors shaping choice contexts may help us better interpret its influence on their satisfaction with decisions, and this can be explored in future studies.

A limitation of our analysis is that we only measured satisfaction at the episodic level without the observations at higher levels, e.g., overall life satisfaction. Although the "bottom-up theory" hypothesized that satisfaction with certain episodes contributes to the overall satisfaction with life (De Vos, 2017; Feist et al., 1995; Schwanen and Wang, 2014), this has not been examined in the Chinese context and it is not clear how modality styles can actually influence the overall life satisfaction of residents of Beijing. For example, although there is no significant influence found for multimodality on activity satisfaction, it can be hypothesized that multimodality may contribute to overall life satisfaction through facilitating activity participation (as we found in Chapter 2).

7.4 Policy implications

In recent years, the Chinese government has implemented various policies, such as a high vehicle purchase tax, a plate lottery or auction, vehicle restrictions and large investments in public transport, all with the goal of reducing automobile dependence, promoting public transit use, and reducing air pollution associated with transport emissions. The effectiveness of policies has mainly been evaluated from the perspective of the alleviation of air pollution and mitigation of traffic congestion (Chen and Zhao, 2013; Guo et al., 2015; Yang et al., 2014). However, understanding the social influences of transport policies at the individual level can also contribute to policy making, as it is important not to diminish urban residents' quality-of-life when trying to influence their transport mode choices. Therefore, the policy implications derived from our study concern the possibility of encouraging more environmentally sustainable travel with less car use, while achieving social goals of travel such as facilitating urban residents' daily life and promoting their life quality.

Generally, our research results support the recognition that spatial attributes can influence travel behaviour significantly. Chapter 2 concluded that the development of neighbourhoods and work places with high densities can reduce habitual car use and promote the use of multiple modes in practice. Moreover, Chapter 5 reconfirmed that the workplace merits particular attention, because it is observed that the supply of mixed functions around workplaces plays an important role in reducing extra travel time for multi-purpose commute trips. In Chinese cities, the government has a strong influence on the land use strategies due to the state ownership of land (Pan et al., 2009). Decision-makers and planners, when aiming to influence or change individuals' mode choice through the planning of built environments, need to comprehensively consider the entire city and efforts should be made to improve facilities located in both residential and workplace areas. These efforts not only can reduce the pressure on urban transport system associated with car use but can also be a way to increase commuters' satisfaction with travel and activities.

Moreover, our analyses revealed the importance of providing and combining different travel modes in urban life for both car and non-car users. Specifically, for habitual car users, the goal is to encourage them to use sustainable travel modes more often. Current restriction policies may have impacts in the short term, such as the use of alternative modes for commute trips (Chapter 4). However, the benefits of a more satisfying trip experience while driving (Chapter 5), activity satisfaction (Chapter 6) and travel time saving (Chapter 2 and Chapter 4) may reduce their willingness of using alternative modes, especially when more households get access to cars. Our analysis shows that, multimodality can deliver similar advantages as car use in certain aspects, such as activity participation at the weekly level and on the weekends (Chapter 2 and Chapter 3). Policies to reduce car use could therefore be improving the attractiveness of alternative modes to attract car users towards multimodal travel, providing various economic incentives or developing appealing infrastructure and urban landscapes to encourage use of public transport, walking and cycling (Pucher and Buehler, 2008). Improvements in alternative travel modes may be guided by observations of current travel satisfaction. Currently public transport users have the most unsatisfying trip experience (Chapter 5) and are more constrained in mode choice and less satisfied with their non-work activities (Chapter 6). Monomodal public transport users are the most constrained group in activity participation and social interaction (Chapter 2 and Chapter 4). For them, it would be helpful to provide multiple choices by enlarging their modal choice “basket”. This may require providing more satisfying public transit services but also encouraging private transit, such as car-sharing programs and shared bikes. With respect to mitigating crowdedness and improving public transport users’ trip experiences, urban and transport management from a temporal dimension may provide more choices. For example, flexible working schedules may help people to avoid rush-hour traffic congestion and reduce the travel time for public transport users, which significantly affects public transport users’ trip satisfaction assessments (Chapter 5). Moreover, as there is a potential positive effect of travel experience on activity experience, improving public transport services may also play a role in improving satisfaction with activities performed at the destination (Chapter 6).

Active mode users’ trip experiences are ranked as most satisfying among all the mode users (Chapter 5), which indicates the attractiveness of active modes to potential users/ other mode users. This positive may have contributed to the “bike revival” in Beijing (Yang et al., 2015; Yang and Zacharias, 2016), which could have been further facilitated by the “dock less app-based” sharing bikes (e.g, Ofo, Mobike) in the past two years. These shared bikes offer great availability and flexibility of active modes to the urban residents. Although there is no official estimation of their influence, “there’s no escaping them on the streets of China’s big cities” now (Mead, 2017). As we found that travellers do compare their trips with different modes (Chapter 5), providing more satisfying cycling experience may attract motorized modes users to occasionally cycle in the short term, and also this could be a chance to encourage them to adopt a more sustainable modality style with more active travel in the longer term (e.g., multimodal active traveller). However, the motorized transport development in Beijing has “marginalized bicycle users”, and the major main concerns for cyclists could be traffic safety and air quality (Yang and Zacharias, 2017). For transport planners and decision makers, efforts need to be made by providing bicycle/walking facilities (e.g., safety with cycling lanes, pedestrian lanes) in the short run and improving the atmospheric cycling conditions (e.g., better air quality, less smog) in the long term.

It should be noticed that the above policy implications are primarily based on our findings from Beijing. Other Chinese cities might exhibit certain differences from Beijing regarding the size and structure of the city, the level of motorization, the provision of public transport, the implemented policies and other contextual characteristics. Our implications with regard to enlarging individuals’ choice basket and promoting sustainable travel modes can however also be valuable to transport planners in the small- or middle-sized cities (Yang et al., 2017). However, there is thus far a lack of travel behaviour studies in small- or medium-sized cities in China, where the provision of public transport is relatively limited and where traffic congestion problems are associated with fast motorization (Hu et al., 2017). Consequently, the role different transport modes play in their residents’ daily life can be different from our findings in Beijing. These differences should be taken into account, and policies concerning both environmental and social sustainability should be explored within these specific contexts.

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Summary

In the recent decades, daily mobility and mode choice in Chinese cities have developed in the presence of fundamental transformations in the built environment and soaring car ownership. Similar to their Western counterparts, metropolitan areas in China are currently also experiencing extreme transport problems. Encouraging sustainable travel become a goal for planners and also transport policy makers in China. Many Chinese cities adopt radical policies to reduce car use by limiting individuals' private car availability and lead to car owners' daily use of alternative modes through financial penalties. In recent Western studies, the use by travellers of multiple transport modes in a specified period (i.e., multimodality) is promoted as an alternative to car dependent travel behaviour. Considering the significant differences of Chinese cities with North American and European cities, the distribution of modality styles and its interaction with car ownership, individuals' availability of travel modes are likely to be shaped differently. Exploring urban residents' modality styles and its determinants in a developing economy context, can be crucial for developing a sustainable transport system in Chinese cities. Also, the sustainability of transport systems must be discussed not only from an environmental perspective but also from a social perspective. The social benefits/costs of different transport modes can also be affected by certain unique Chinese institutional barriers or facilitators, individual barrier or facilitators and external impacts. A further investigation of how modality styles affect urban residents' daily lives can contribute to the understanding of social sustainability of transport in the Chinese context.

In this research, empirical analyses are carried out to understand the share and determinants of individuals' modality styles in Beijing, and to explore how their modality styles affect activity participation, social interaction, travel time and well-being. Using the dataset of "Daily Activity and Travel Survey of Beijing, 2012", this search examines how multimodality interacts with car ownership and car use, and further estimates its social impacts from the perspective of commuters' non-work activity participation, social interaction with different social contacts, and satisfaction with commute trip/ non-work activity episodes.

Our study finds that not only the share of the modality styles but also the determinants and the interpretation of determinant values can vary across different contexts at different developing stages. Car ownership does not necessarily lead to car dependency in the Chinese context but rather provides an extra choice and increases multimodality at the current stage. The interpretation of this result can be closely associated with both the geographical and institutional background in Beijing. This high-density expansion of urban space and the construction of expansive public transport infrastructure facilitate more sustainable travel modes and decrease the possible dependence on car use, while the relatively low-car ownership in Chinese households and car-use restriction policies implemented may constrain individuals' car dependence and lead them to be (probably involuntary) multimodal car users in the short term. The local context characteristics in China largely affect the mechanism in shaping individuals' modality styles. For travellers, especially car owners in Beijing, being multimodal can be encouraged by the urban features but might also be an outcome of constraints set by policies.

As for the influence of modality styles, this research shows that to a certain extent, the functionality of car use can be substituted by the use of multiple travel modes in the research context of Chinese cities. At the weekly level, multimodal travellers benefit from more participation in non-work activities, while car users do not show much advantage. However, this influence may differ when the commuters have different activity agendas between commute and non-commute days and differ between the companionship of different social contacts. Specifically, the flexibility and capacity of car use may benefit commuters on commuting days, given the time constraints imposed by work and commuting as well as the capacity to chauffeur companions for the joint activities. At the trip level, multi-purpose trips are more motorized, and the car could help commuters reduce their travel time for leisure/social activities. Also, culture norms may also play an important role. For example, the insignificant effect of transport but significant gender difference in time spent with colleagues is possibility due to the cultural background. Our findings reveal that a conclusion regarding the facilitating/impeding effect of car on activity participation cannot generally be achieved without considering the context for observations, including geographic context, social-cultural settings, and also the observed time period.

In addition to the participation in travel/activities, this study also investigates individuals' experience of their daily travel and activities in the context of Chinese cities. Consistent with previous studies in Western contexts, it is found that active commuters always have the highest levels of travel satisfaction, and activities at leisure/recreational facilities are generally more satisfying than other non-work activities. This research extends the current literature of trip/activity satisfaction, by including the context of travel choices as an explanatory factor. Specifically, trip satisfaction is not only affected by travel modes but also individual' experiences with other modes (due to multimodality) and their freedom in decision making (with different modal flexibility levels). For activity satisfaction, it is not only related to the objectively observed activity attributes but also the factors related to the freedom in choosing the timing and location for these activities (temporal and spatial flexibility).

The research also delivers some implications for transport policies. Generally, the results support the recognition that spatial attributes can influence travel behaviour significantly. Decision-makers and planners, when aiming to influence or change individuals' mode choice through the planning of built environments, need to comprehensively consider the entire city and efforts should be made to improve facilities located in both residential and workplace areas. Moreover, this research reveals the importance of providing and combining different travel modes in urban life for both car and non-car users. Policies to reduce car use should be improving the attractiveness of alternative modes to attract car users towards multimodal travel, providing various economic incentives or developing appealing infrastructure and urban landscapes to encourage use of public transport, walking and cycling. While for public transport dependent users, it would be helpful to provide multiple choices by enlarging their modal choice "basket". This may require providing more satisfying public transit services but also encouraging private transit, such as car-sharing programs and shared bikes. Active mode users' trip experiences are ranked as most satisfying among all the mode users, which indicates the attractiveness of active modes to potential users/ other mode users. As travellers are found to compare their trips with different modes, providing more satisfying cycling experience may attract motorized modes users to occasionally cycle in the short term, and also this could be a chance to encourage them to adopt a more sustainable modality style with more active travel in the longer term.

Samenvatting

In de afgelopen decennia hebben de mogelijkheden voor de dagelijkse vervoersmobiliteit en -wijze in de Chinese steden zich ontwikkeld als gevolg van fundamentele transformaties in de bebouwde kom alsmede door het toegenomen autobezit. Net als hun westerse tegenhangers, hebben stedelijke gebieden in China momenteel ook te maken met extreme transportproblemen. Het stimuleren van duurzaam vervoer is een doel geworden voor planners en de makers van het transportbeleid in China. Een groot aantal Chinese steden voert een radicaal beleid om het autogebruik te verminderen door de beschikbaarheid van privé-auto's voor particulieren te beperken, wat zal leiden tot het dagelijks gebruik van alternatieve vervoersmiddelen van autobezitters middels financiële boetes. Uit recent westers onderzoek is gebleken dat het gebruik door reizigers van meerdere vervoersmiddelen gedurende een bepaalde periode (d.w.z. multimodaliteit) gepromoot wordt als een alternatief voor auto-afhankelijk reisgedrag. Gezien de aanzienlijke verschillen tussen Chinese steden en Noord-Amerikaanse en Europese steden, wordt de distributie van modaliteitsstijlen en de interactie met autobezit, alsmede de beschikbaarheid van vervoersmiddelen voor individuen, waarschijnlijk zeer anders gevormd. Het verkennen van de modaliteitsstijlen van stadsbewoners en de bepalende factoren ervan binnen de context van een ontwikkelingseconomie, kan cruciaal zijn voor het ontwikkelen van een duurzaam vervoerssysteem in Chinese steden. Tevens moet de duurzaamheid van vervoerssystemen besproken worden en niet alleen vanuit een milieuperspectief, maar ook vanuit een sociaal perspectief. De sociale voordelen/kosten van verschillende vervoersmiddelen kunnen ook beïnvloed worden door bepaalde unieke Chinese institutionele belemmeringen of facilitatoren, individuele barrières of facilitatoren, alsmede externe invloeden. Verder onderzoek over de manier waarop modaliteitstijlen van invloed zijn op het dagelijks leven van stadsbewoners kan bijdragen aan een beter begrip van de sociale duurzaamheid van vervoer in een Chinese context.

In dit onderzoek worden empirische analyses uitgevoerd om een beter inzicht te krijgen in het aandeel en de bepalende factoren van de modaliteitstijlen van individuen in Beijing, en om te onderzoeken hoe hun modaliteitsstijlen van invloed zijn op de actieve participatie in activiteiten, sociale interactie, reistijden en welzijn. Deze opdracht onderzoekt, met behulp van de dataset van "Daily Activity and Travel Survey of Beijing, 2012" ("Dagelijkse Activiteiten- en Reisenquête in Beijing, 2012"), hoe multimodaliteit interageert met autobezit en autogebruik, en het schat de sociale gevolgen ervan in vanuit het perspectief van deelname aan activiteiten van forenzen, sociale interactie met verschillende sociale contacten, en de tevredenheid over het reizen naar niet werkgerelateerde activiteiten.

Ons onderzoek komt tot de bevinding dat niet alleen het aandeel van de modaliteitsstijlen maar ook de bepalende factoren en de interpretatie van de bepalende waarden in verschillende ontwikkelingsstadia in verschillende contexten kan variëren. Autobezit leidt niet noodzakelijkerwijs tot autoafhankelijkheid in een Chinese context, maar biedt eerder een extra keuze en het verhoogt, in het huidige stadium, de multimodaliteit. De interpretatie van dit resultaat kan nauw geassocieerd worden met zowel de geografische als institutionele achtergrond in Beijing. Deze dichtbebouwde uitbreiding

van de stedelijke ruimte en de bouw van een uitgebreide infrastructuur voor het openbaar vervoer zorgen voor een vergemakkelijking van meer duurzame vervoersmiddelen en vermindert de mogelijke afhankelijkheid van de auto, en het relatief lage percentage aan autobezit in Chinese huishoudens, alsmede het geïmplementeerd beperkingsbeleid inzake autogebruik dat ertoe kan leiden dat de auto-afhankelijkheid van personen beperkt wordt en dat zij op korte termijn (waarschijnlijk onvrijwillig) multimodale autogebruikers worden. De plaatselijke context karakteristieken in China hebben in hoge mate een invloed op het mechanisme dat vormgeeft aan de modaliteitsstijlen van individuen. Onder reizigers, en met name autobezitters in Beijing, kan multimodaliteit worden aangemoedigd door middel van de stedelijke karakteristieken, maar ook door beperkingen die beleidsmatig zijn vastgelegd.

Wat betreft de invloed van modaliteitsstijlen, toont dit onderzoek aan dat, tot op zekere hoogte, de functionaliteit van het autogebruik vervangen kan worden door het gebruik van meerdere vervoersmiddelen binnen de onderzoekscontext van Chinese steden. Op het wekelijkse niveau, profiteren multimodale reizigers van meer participatie in activiteiten buiten de werktijd om, terwijl autobestuurders dit voordeel niet zo zeer ervaren. Deze invloed kan echter verschillen wanneer de forenzen verschillende activiteitenagenda's hebben op pendel- en niet-pendeldagen en wanneer zij verschillen vertonen op het gebied van sociale contacten. Met name de flexibiliteit en capaciteit van een auto kan voor forenzen op pendeldagen voordelig zijn, gezien de tijdsbeperkingen die opgelegd worden door het werk en het woon-werkverkeer en het biedt de mogelijkheid om metgezellen te vervoeren voor gezamenlijke activiteiten. Op vervoersniveau zijn multifunctionele trips vaker gemotoriseerd, en de auto stelt forenzen in staat om hun reistijd voor vrije tijd/sociale activiteiten te verkorten. Culturele normen kunnen ook een belangrijke rol spelen. De onbeduidende gevolgen van vervoer maar beduidende sekseverschillen qua tijd doorgebracht met collega's is bijvoorbeeld mogelijk het gevolg van de culturele achtergrond. Onze bevindingen onthullen dat het trekken van een conclusie over de faciliterende/belemmerende gevolgen van het hebben van een auto op de participatie aan activiteiten over het algemeen niet kan worden gerealiseerd, zonder dat daarbij rekening gehouden moet worden met de context voor observaties, met inbegrip van de geografische context, de sociaal-culturele situatie, alsmede de waargenomen tijdsperiode.

Naast de deelname aan vervoer/activiteiten, onderzoekt deze studie ook de individuele beleving van hun dagelijks vervoerspatroon en de activiteiten in de context van Chinese steden. In overeenstemming met eerder onderzoek in Westerse contexten, is gebleken dat actieve forenzen altijd de hoogste mate van vervoertevredenheid hebben, en dat activiteiten in vrije tijd/recreatieve faciliteiten over het algemeen meer voldoening geven dan andere niet-werk gerelateerde activiteiten. Dit onderzoek breidt de huidige literatuur naar de tevredenheid over vervoer/activiteiten uit, door de context van vervoerskeuzes op te nemen als een verklarende factor. Vervoerstevredenheid wordt niet alleen beïnvloed door de vervoersmiddelen maar ook door de individuele ervaringen met betrekking tot andere vervoersmiddelen (als gevolg van multimodaliteit) en hun vrijheid in het nemen van beslissingen (met verschillende modale flexibiliteitsniveaus). Voor activiteitstevredenheid, is het niet alleen gerelateerd aan de objectief waargenomen activiteitsattributen maar ook aan de factoren die verband houden met de vrijheid om het tijdstip en de locatie voor deze activiteiten te kiezen (temporele en ruimtelijke flexibiliteit).

Het onderzoek levert ook enkele implicaties op voor het vervoersbeleid. Over het algemeen ondersteunen de resultaten de erkenning dat ruimtelijke karakteristieken het reisgedrag aanzienlijk kunnen beïnvloeden. Besluitvormers en planners, wanneer zij ernaar streven om de keuze van vervoersmiddelen voor individuen te beïnvloeden of te veranderen door middel van de planning van bebouwde omgeving, moeten rekening houden met de hele stad en zij moeten proberen om de faciliteiten in zowel de woon- als werkomgevingen te verbeteren. Bovendien toont dit onderzoek het belang van het aanbieden en combineren van verschillende vervoersmiddelen in het stadsleven aan, voor zowel auto- als niet-autogebruikers. Beleidsregels om het autogebruik te verminderen zouden de aantrekkelijkheid van alternatieve vervoersmiddelen moeten verbeteren zodat multimodaal vervoer aantrekkelijker wordt voor autogebruikers, door verschillende economische prikkels te verstrekken of door aantrekkelijke infrastructuur en stedelijke landschappen te ontwikkelen waardoor het gebruik van openbaar vervoer, wandelen en fietsen aangemoedigd wordt. Voor gebruikers die afhankelijk zijn van het openbaar vervoer, zou het echter nuttig zijn om meerdere keuzes aan te bieden door hun modale “keuzemandje” te vergroten. Dit kan vereisen dat er meer bevredigende openbaar vervoerdiensten moeten worden aangeboden maar dat ook het privévervoer aangemoedigd moet worden, zoals door middel van carpooling en het gezamenlijke gebruik van fietsen. De ervaringen van actieve gebruikers van vervoersmiddelen worden gekenmerkt als de meest bevredigende onder alle gebruikers, wat duidt op de aantrekkelijkheid van actieve vervoersmiddelen voor potentiële gebruikers van andere vervoersmiddelen. Aangezien reizigers hun vervoersmiddelen met verschillende modi kunnen vergelijken, kan het bieden van een meer bevredigende fietservaring ervoor zorgen dat meer gebruikers van gemotoriseerd vervoer zich aangetrokken voelen om, op de korte termijn, af en toe wat te fietsen, en dit zou ook een mogelijkheid kunnen zijn om hen aan te moedigen om een duurzamere modaliteitsstijl aan te nemen met een actievere vorm van vervoer op de langere termijn.

Curriculum Vitae

Zidan Mao was born on 28 February 1990 in Anhui Province, China. She got his bachelor degree in Urban Management in 2010 from Renmin University of China. After that, she started her master' study in Human Geography in Peking University and graduated in 2013. In 2013, she started her PhD student at the Department of Human Geography and Planning, Faculty of Geosciences, Utrecht University. Her research interests focus on travel behaviour and society, travel-related well-being.