Impact of Individuals' Commuting Trips on Subjective Well-being: Evidence from Xi'an

by

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Declaration

I , Runing Ye, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signature:

Date: 25/06/2017

Abstract

Transportation as an important component for urban sustainability has been well recognized. Although the lay understanding of sustainability generally focuses on environmental stewardship, more broadly sustainability is comprised of three aspects: environmental, economic and social sustainability. Individual and societal well-being are critical indicators of social sustainability, however, little attention from research and policy has been paid to the impacts of transportation on well-being.

With extensive urban expansion resulting from rapid urbanization, commuting has become a physical and mental burden for many residents in the megacities of China because of the increasing travel distances and worsening travel experiences, significantly influencing their well-being. Relying on the data from a survey conducted in Xi-an, a mega-city of western China, this study quantitatively investigated the relationship between commuting and subjective wellbeing in the Chinese context.

Based on the evidence from Xi-an, China, this study found that (1) commute characteristics, including travel mode choice and level of services, significantly influence commuting satisfaction, which in turn significantly affects overall satisfaction with life; (2) the built environment has no direct effect on commuting satisfaction, however it could indirectly affect commuting satisfaction through the path of commuting characteristics; most of travel-related attitudes have both direct and indirect effects on travel satisfaction; (3) the lower income population are more likely to live in pedestrian and transit unfriendly places, are more captive to their travel modes, and have lower levels of life satisfaction; all of which contribute to the lower level of commuting satisfaction among the lower income population.

This study contributes to the literature by framing and quantitatively exploring the complicated relationships between the built environment, attitudes, travel characteristics, travel satisfaction and subjective wellbeing. This study also informs policies that help to improve satisfaction with commuting and wellbeing.

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Chapter 1. Introduction

Research Background

The relationship between well-being, and in particular subjective well-being, and transportation has recently attracted attention from both scholars and policy makers. Well-being is defined as “the state of being happy, healthy, or successful” (Merriam-Webster, n.d.) and subjective well-being (SWB) is broadly defined as a person’s perception of their wellness, including their moods and emotions in reaction to the events happening to them (affective component), as well as their broad judgments about their life as a whole (cognitive component) (Diener, 1984). Even though the relationship between SWB and transportation is largely indirect and often goes unnoticed by travelers, several studies (Bergstad et al., 2011; Cao, 2013; Ettema et al., 2010; Smith, 2013; Stutzer and Frey, 2008) have shown that the relationship is significant; as a result some policy makers (Stiglitz et al., 2009) have proposed that transportation related strategies could be an effective and far-reaching solution to well-being related problems. Several recent studies have called for an investigation as to whether, how, and to what extent SWB can be influenced by changes of travel context, such as changes of travel mode and changes of level-of-service of public transit (Bergstad et al., 2011; Ettema et al., 2010). Better understanding the key travel-related determinants on SWB will help to design transport and urban planning policies and interventions that improve social wellbeing. Further, SWB would be a powerful tool for transportation policy evaluation if a relationship between transportation and SWB can be found (Ettema et al., 2011; Ettema et al., 2010). For example, the changes of travel wellbeing following the implementation of a transport policy could be an important outcome indicator to assess the success of the policy. Finally, SWB has been intensively studied in economics, psychology and social sciences, the discipline of transportation has only recently started to investigate the link between transportation and SWB. We have little knowledge about how and to what extent transport contributes to SWB, and this limits our ability to make effective transport policies that aim to improve SWB.

Subjective wellbeing (SWB), as an alternative and enrichment to utility, offers a direct measurement of individuals' mood, emotion and cognitive judgment (Kahneman and Krueger, 2006; Kahneman et al., 1997), and therefore could be a better tool to capture individual "true" preferences on travel choice. Previous studies have generally not used SWB partially because of the argument that subjective hedonic experience cannot be observed and measured (Kahneman et al., 1997). The development of psychological research has enabled the measurement of SWB, and various measures have been proposed and validated. As a specific domain of SWB, travel satisfaction has also recently been measured (Ettema et al., 2011; Stradling et al., 2007b).

Travel and the characteristics of the journey could influence well-being positively and negatively, directly and indirectly. Long-duration commuting, for example, can reduce the amount of time an individual has for other activities which contribute to (subjective) well-being, such as physical exercise, time with family, social activities, etc. (Ettema et al., 2010). Travel also potentially increases exposure to nuisances and hazards, such as traffic noise, crowds, congestion, pollution and poor thermal conditions (Stutzer and Frey, 2008). These can cause physical or emotional distress and can have a direct influence on one's physical and mental health (De Nazelle et al., 2009; McNabola et al., 2008; Wener et al., 2003). Furthermore, change from active travel (e.g. walking and bicycling) to vehicle-dependent travel reduces the possible walking- and bicycling- related physical activities, which are important to prevent obesity and other related chronic diseases (Wareham et al., 2005).

Travel for the purposes of commuting is of particular interest with regards to well-being. Commuting is often associated with particularly poor travel conditions created by serious congestion; it may make up the greatest proportion of travel time in a daily travel, and has been a major target of travel management policies (Redmond and Mokhtarian, 2001; Shiftan and Barlach, 2002). Therefore, commuting has not only a monetary cost, but also an environmental cost to society and can be a physical and mental burden for individuals, significantly influencing their well-being.

Although a growing number of studies have investigated the connections between travel characteristics (e.g. travel mode choice, travel time, level of service, etc.) and subjective wellbeing (Abou-Zeid, 2009; Cao, 2013; Ettema et al., 2012; Friman and Fellesson, 2009; Gatersleben and Uzzell, 2007; Hine and Mitchell, 2001; Mokhtarian et al., 2014; Olsson et al., 2013; Paez and Whalen, 2010; Susilo and Cats, 2014), the empirical work in this area is still limited and most of these studies are conducted in North America and Europe.

Several recent studies further explored the role of the built environment (Cao and Ettema, 2014; De Vos et al., 2015; Friman et al., 2013) or travel attitudes (Manaugh and El-Geneidy, 2013; St-Louis et al., 2014) in influencing travel satisfaction; both are important factors for transport policies. However, these studies have several limitations. First, only one study (Cao and Ettema, 2014) measures the built environment at a disaggregate (household) level using different dimensional measures (e.g. density, diversity, design). The others only use very simple built environment indicators at an aggregate level (e.g. urban vs. suburban neighborhood). Second, all of these studies treat the built environment, travel attitudes and other travel characteristics as separate determinants of travel satisfaction; few of them explore the potential interactions between various types of factors and the structural relationships between these factors. Finally, few of these studies focus on commuting trips and commuting satisfaction.

Finally, little previous research has focused on low-income populations. Due to economic constraints, lower income populations tend to have relatively fewer travel options, and are more likely to experience transport poverty, which may further prevent them from participating in social activities, work or education opportunities and healthcare etc., thereby reducing their life chances and wellbeing (Currie et al., 2009). Understanding the factors contributing to the lower levels of travel and life satisfaction of lower income populations is important for improving societal wellbeing overall.

Research Context

Unhappiness is currently a growing social problem in China as a consequence of the dramatic social transformation occurring in recent decades (Easterlin et al., 2012), and despite China's high rate of economic growth and rising levels of prosperity. China has been undergoing a period of rapid urbanization and its cities have been changed radically (Ding, 2007; Ma, 2002). Alongside increasing urban expansion, China has seen worsening transportation conditions and increasing travel distances, particularly for the daily commute (Guan and Cui, 2003). For many residents in the big cities of China, commuting may have become a physical and mental burden, significantly influencing their wellbeing. These may in part be contributing to the growing levels of unhappiness.

Those members of the population that are on low-incomes may especially suffer during the daily commute. They are more likely to live in the outskirts of the city for more affordable accommodation, and thus may have longer commuting distances, spend a higher share of their income on commuting costs, have less choice of travel modes (Choi et al., 2013; Morris and Guerra, 2014). They are also more likely to have a poorer quality living environment and are less likely to have flexible working times (Olsson et al., 2013). This highlights the importance of exploring the impact of the daily commute on the wellbeing of low-income populations. However, little research on the connections between commuting and wellbeing has focused on low-income populations, particularly in the Chinese context.

As an economic hub in western China (Figure 1), Xi'an has, like many Chinese cites, undergone massive urban development in the past 30 years. The population increased from 5 million in 1980 to about 8.5 million in 2010 (Xi'an Bureau of Statistics, 2011). Over the same period the urban built up area has increased threefold, from approximately 120 square kilometers in 1980 to 370 square kilometers in 2010 (Xi'an Bureau of Statistics, 2011). This large expansion of the urban space has had two significant consequences on travel activities, especially commuting. First, commuting distance and time have increased significantly due in part to the increasing spatial separation of jobs and housing. The average commuting distance and time in Xi'an is 10 kilometers and 38 minutes (one-way) respectively, and this number is likely to increase due to continuing urban expansion and rising congestion (Ye and Titheridge, 2015). Second, the traditional travel modes, bicycling and walking, are gradually becoming impossible due to these longer- trip distances. Instead, more and more people are relying on either the private car or public transit for their daily commuting.

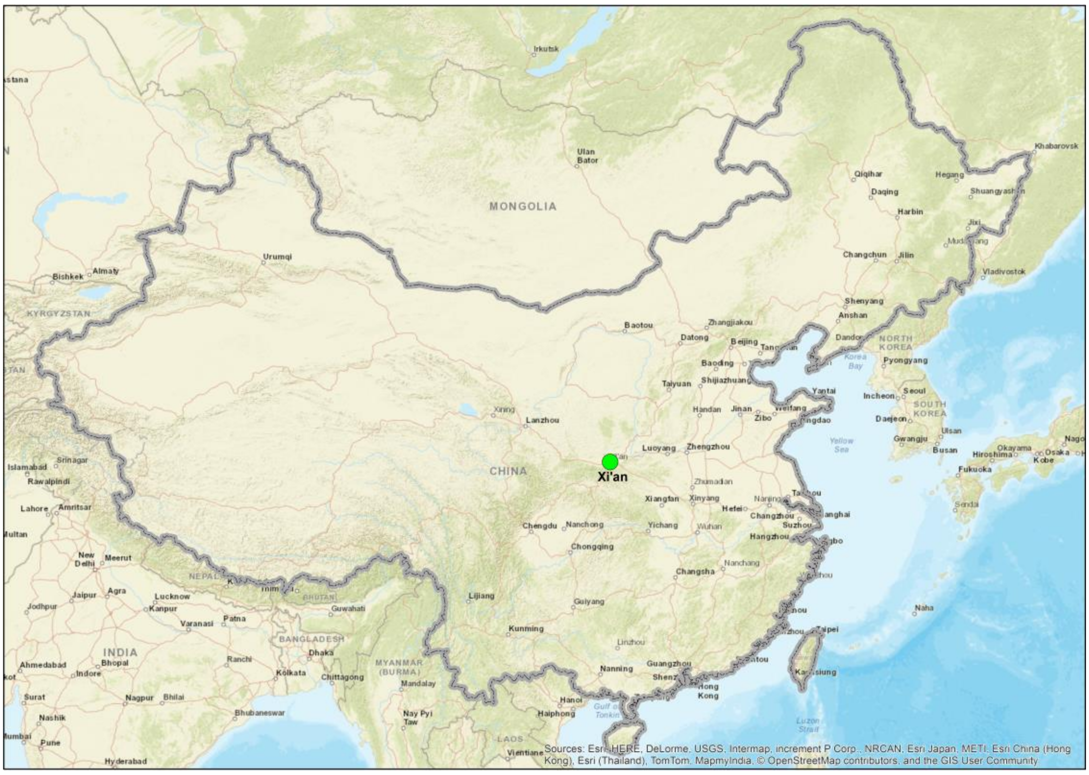

Figure 1 Location of Xi’an in China

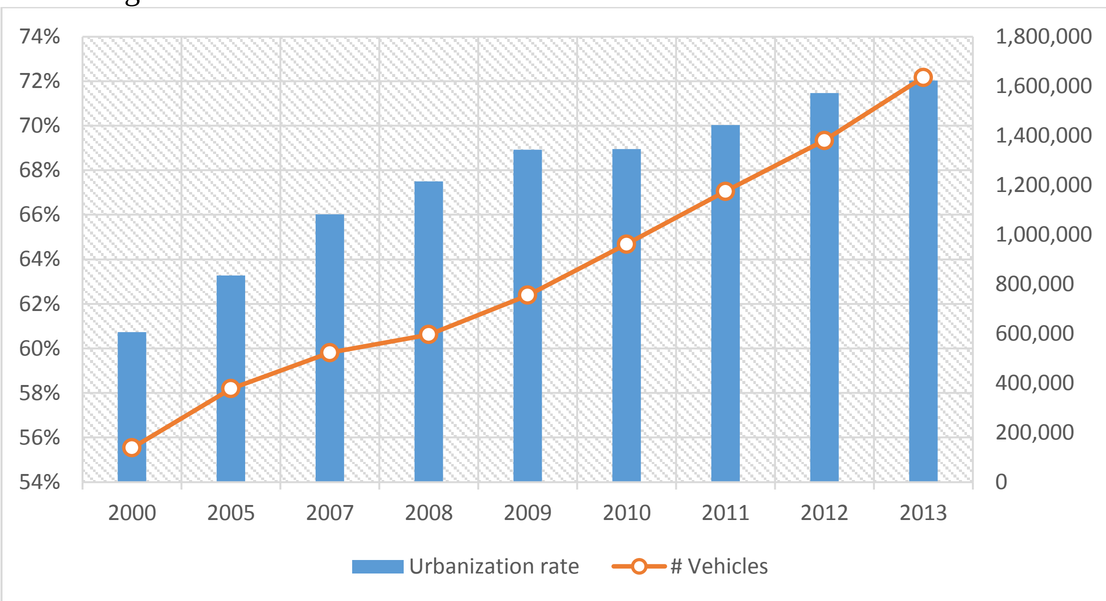

Figure 2 Urbanization rate and amount of vehicles in Xi’an over years

Rapid economic development, fast urbanization and accumulation of population bring a swift rise in car ownership which causes congestion problems in many Chinese cities. Traffic congestion has become a constraint on economic development, affecting the quality of life of urban residents (Cai, 2002; Li, 2009; Xu and Wang, 2008). As a predominant city in western of China, Xi’an has experienced a rapid development which leads to a booming increase in number of vehicles (over a million) (Figure 2). Traffic congestion in Xi'an has been exacerbated due to the lack of transport infrastructure and management (Li, 2009; Liu, 2012).

Previous research on Chinese cities has primarily focused on Beijing, Shanghai, and Guangzhou, the mega cities of China, with a population over 10 million. However, the policy implications derived from studying those cities may not be transferrable to other Chinese cities because of their very unique characteristics. Few previous researches have explored these urban issues for cities at the second level of scale. According to 2010 Census data (China City Statistical Yearbook, 2010), there are 47 cities in China, including Xi'an, that have a population of 2-10 million. By focusing on Xi'an, therefore, the study will have a broader impact on urban policies that address travel problems and social wellbeing in China.

Research Objectives

This study aims to contribute to the growing literature on the relationship between transportation and subjective well-being and also to quantitatively test this relationship in the Chinese context using data from a survey conducted in Xi-an. This study also aims to quantitatively explore the structural relationships between the built environment, travel attitudes, and travel characteristics and travel satisfaction, focusing on commuting trips. Exploring this question helps to not only build a comprehensive framework linking the built environment, travel behavior and satisfaction with travel, but will also help identify potential interventions to improve individual satisfaction with travel and levels of wellbeing. The unique context of this study also contributes to the literature by providing empirical evidence from a developing country and fast growing city. Further, this study also aims to investigate the relationships between the built environment, commuting characteristics, and subjective wellbeing amongst the lower income working population, thereby informing policies that help to improve the wellbeing of the urban lower income population in China from a transportation planning perspective.

Research Questions

This study starts from asking whether the experience of journey significantly contribute to the overall life satisfaction, alongside other issues, such as personal relationship, social involvement, family life etc. After confirming the significant relationship between travel satisfaction and SWB, the second question further asks what travel characteristics matter for travel satisfaction. The third question extends the first two questions by further asking what specific built-environment characteristics and travel attitudes might influence travel satisfaction, as theoretically they could influence travel satisfaction through affecting travel characteristics. After establishing the general relationships between the built environment, travel attitudes, travel satisfaction and SWB, the last question aims to explore whether these relationships are different for different groups of population. In particular, this study aims to answer the following four questions:

(1) Does travel satisfaction influence overall life satisfaction? (Chapter 4)? While there are theoretical discussions on how travel satisfaction might influence life satisfaction, little empirical research has tested this hypothesis. This study will provide the first empirical evidence from China on this research question. Further, comparing with previous studies, this study particularly focuses on commuting trips, which are more likely to influence life satisfaction because it may take up a significant portion of one's daily time. Third, this study accounts for the satisfaction with other important domains of life, and this will

help to evaluate the relative effects of travel satisfaction on life satisfaction more accurately than previous studies.

(2) What commute characteristics affect travel satisfaction (Chapter 4)? This question has been examined by several previous studies, but none of them has focused on Chinese cities and conclusions of these studies are sometimes mixed. Investigating this question in Chinese context will provide new evidence on the relationship between commuting characteristics and commuting satisfaction. Further, previous studies has focused on one or two dimensions of travel characteristics and their associations with travel satisfaction, while this study provides a whole picture regarding the effects of various commuting characteristics and commuting satisfaction. This will allow comparing the importance of different commute characteristics in improving or deterring satisfaction during the commute.

(3) What built-environment and attitudinal characteristics affect travel satisfaction and life satisfaction (Chapter 5)? Despite the role of the built environment on public health has long been recognized in urban planning discipline, previous empirical studies have much focused on the effects of the built environment on physical health, little research has investigated the role of the built environment on mental health and subjective wellbeing. The built environment shapes the pattern of our daily life. It determines when, where and how we go for daily activities, such as work, school, shopping, meal, social and recreational activities, which are the important domains of life. The built environment, therefore, potentially influences our quality of life and wellbeing. Urban planners have proposed the idea of "happy city" or "happy neighborhood". However, we have little knowledge about how to create a

happy city or neighborhood. Several recent studies have called for an investigation as to whether, and how, SWB can be influenced by urban planning (Pfeiffer and Cloutier, 2016). This study will help to better understand how the urban planning can contribute to higher level of satisfaction with commuting and greater level of happiness in life. Travel attitudes are well known to influence travel behavior, while its effects on travel satisfaction and SWB are largely unknown. The travel attitudes may influence the moods and emotions during the travel as well as the cognitive evaluations of the travel, thereby potentially affecting travel satisfaction. As travel satisfaction is an important domain of life satisfaction, therefore, travel attitudes may also influence SWB. This study will explore the direct and indirect effects of travel attitudes on travel satisfaction and SWB after accounting for the socio-demographics and the built environment. This study will contribute to better understand the mechanism on the relationships between travel attitudes, travel characteristics, and travel satisfaction.

(4) What factors contribute to the lower level of travel satisfaction of lower income group relative to higher income group (Chapter 6)? Due to the socio-economic disadvantage, the life of low-income population might be disproportionally affected by their daily commuting. Few previous studies on travel and SWB have focused on this specific population group. Through comparing such factors as travel characteristics, the built environment and travel preferences contributing to travel satisfaction and SWB between the lower and higher income group, this study aims to inform policies that address the lower levels of commuting satisfaction and SWB for the low-income population.

Research Focus

This study contributes to the literature in three ways. First, this research contributes to existing theories of links between travel and subjective wellbeing, through a more robust consideration of the impact of the built environment and attitudes. This helped to build a comprehensive framework that integrates studies on travel mode choice, travel attitudes and travel satisfaction. Second, this research specifically focused on China, a booming economy and transforming society, providing a unique context to study the relationships between travel and subjective wellbeing. By comparing relative studies from Western countries, this study shows similar as well as different findings, helping to complement current theories established primarily based on empirical studies from Western countries. Third, this research particularly investigates the factors associated with lower level of travel satisfaction among lower income population, who are more likely to be suffered from the commuting. Studying the travel satisfaction of lower income population helps to promote social equity and design specific interventions to improve the wellbeing of the lower income population.

Thesis Overview

The thesis is divided into Seven Chapters. This first chapter gives a general introduction about the background and aims of the research, and then raises the research questions. Chapter Two focuses on the literature review and Chapter Three explains the methodology used in this project. Chapters Four, Five and Six provide key findings of the research. Chapter Seven summarizes the key findings of this research, acknowledges its limitations and proposes directions for future research.

Chapter 2. Literature Review

This chapter aims to build a comprehensive conceptual framework that links travel and subjective wellbeing. The framework helps to uncover the mechanism between travel and subjective wellbeing by exploring the complicated relationships between the important factors that determine travel characteristics and important components of subjective wellbeing. The review includes four sections. The first section briefly reviews the definition of subjective wellbeing, and its distinction from utility which is often used in travel behavior studies. The second section summarizes how travel could directly and indirectly affect subjective wellbeing through influencing moods, emotions, stress, physical health, social inclusion or exclusion, etc., and how the built environment and travel attitudes could integrate into the framework that link travel and subjective wellbeing. The third section reviews the recent empirical studies that link travel and travel satisfaction and subjective wellbeing. Finally literature gaps are summarized in the fourth section.

Definition of Well-Being

The relationship between Well-being/wellness/health and transportation is an emerging field in transportation studies, even though the relationship is indirect and unnoticed, several studies have shown that their relationship is much more significant than expected, and some policy makers have proposed that transportation-related strategies should be an effective and far-reaching solution to well-being related problems. More empirical studies on this topic need to be conducted in order to fully understand the policy implications. This chapter will review various definitions of health and wellness from different disciplines, and build a framework to define health and wellness that can be used in the following empirical analysis on the connections between transportation and health.

Many individuals and organizations have defined well-being from various perspectives. Webster dictionary defines well-being as "*the state of being happy, healthy, or successful*" (Merriam-Webster, n.d.). These is no consensus on how to define well-being, but there is general agreement that well-being at least includes the presence of positive emotions and moods (positive affect) and the absence of negative emotions (negative affect), satisfaction with life (cognitive wellbeing), fulfillment and positive functioning (eudaimonic wellbeing) (Andrews and Withey, 2012; Diener, 2000; Frey and Stutzer, 2010; Ryff and Keyes, 1995). Even though the definition of well-being emphasizes the personal experiences and emotions, well-being is historically measured in objective ways and at the aggregate level.

In general, two types of well-being measure are used: objective measures and subjective measures. Traditionally, well-being is measured by economists using objective economic indicators such as income or GDP. A single economic indicator, however, cannot capture all aspects of human life. Well-being measurement then has been expanded to incorporate social and environmental indicators with an effort to capture the multidimensional aspects of well-being (Conceição and Bandura, 2008). One example is the *Human Development Index*, which includes income per capita, life expectancy at birth, adult literacy and education enrollment ratios (Anand, 1994). The objective account of well-being is based on the assumption that there is significant correlation between these objective indicators and the well-being of individuals. For example, high income or GDP allows us to satisfy more of our preferences and so, increase our well-being. However, this assumption cannot always hold. Some studies have found there are some significant discrepancies between objective indicators and actual well-being. For example, increase of GDP was found to be associated with increasing pollution and rising obesity (Dolan et al., 2011). In addition, social indicators alone do not define quality of life. People react differently to the same environment, and they evaluate conditions based on their unique values, lifestyles, preferences and previous experiences (Diener et al., 1999).

In addition to well-being based on objective measures, there is growing interest in definition and measurement of subjective well-being (SWB), and use of SWB for policy purposes. Compared with objective indicators, subjective well-being is designed to take into account people's feelings or real experience in a more direct way. Subjective well-being has been well recognized as an important measure of economic development and social progress. Stiglitz Commission (Stiglitz et al., 2009), for example, states that "*Research has shown that it is possible to collect meaningful and reliable data on subjective as well as objective well-being. Subjective well-being encompasses different aspects (cognitive evaluations of one's life, happiness, satisfaction, positive emotions such as joy and pride, and negative emotions such as pain and worry): each of them should be measured separately to derive a more comprehensive appreciation of people's lives... [SWB] should be included in larger-scale surveys undertaken by official statistical offices*".

By reviewing the previous literature on subjective wellbeing, two main schools are identified - the hedonic and eudaimonic approach. The hedonic approach (Kahneman et al., 1999) deems that wellbeing consists of pleasure and happiness. Diener et al. (1984, 2000; 2003; 1999) defined SWB as people's moods and emotions to the events happening to them, and their broad judgments about their life as a whole, as well as about important domains such as work and marriage. They argue that SWB is composed of a number of separable components: life satisfaction (global judgments of one's life), satisfaction with important domains (e.g., work satisfaction), positive affect (experiencing many pleasant emotions and moods), and low levels of negative affect (experiencing few unpleasant emotions and moods). Cognitive well-being refers to an individual's cognitive assessment of his or her life in general, while the affective well-being refers to an individual's emotions and moods (Diener et al., 1985). The eudaimonic approach (Waterman, 1993), on the other hand, contends that wellbeing consists of more than just pleasure and happiness, emphasizing the realization of self-worth and achievement of goals.

Empirically, the eudaimonic wellbeing could be strongly correlated with hedonic wellbeing, but nonetheless they represent two types of philosophical thinking. The hedonic approach developed based on the thoughts from early philosopher like Aristippus, who stated that the goal of life is to experience the maximum of pleasure (Ryan and Deci, 2001). The utilitarianism by Bentham (1789), who argues that a good society is built through individuals desire to maximize pleasure and self-interest, was based on Aristippus's philosophical thought on hedonism. On the other hand, the philosopher, Aristotle, criticized happiness per se as a principal criterion of wellbeing, and argued that true happiness derives from the expression of virtue and excellence, and self-realization. Ryff and Singer (1998), drawing from Aristotle, argued that wellbeing is not just gaining pleasure and happiness, but is "the striving for perfection that represents the realization of one's true potential". Ryff and Keyes (1995) proposed a multidimensional construct for subjective wellbeing that include six aspects of human actualization: "autonomy, personal growth, self-acceptance, life purpose, mastery, and positive relatedness".

This study adopts a hedonic approach, concentrating on subjective well-being based on moods, emotions and life satisfaction as per Diener et al. (1985), since the hedonic approach is the mainstream in previous and current wellbeing and transportation research.

Utility and Subjective Well-being

Previous transportation studies have primarily relied on random utility theory (McFadden, 1986), which assumes that people make travel decisions to minimize travel cost and maximize utility. In practice, utility is often derived from observed choices. However, utility inferred from this way, referred as decision utility, has been criticized for its inadequate representation of travelers' satisfaction, since choices are frequently made under constraints and lack of complete information (Ettema et al., 2010). Kahneman and his colleagues (Kahneman et al., 1997) have made important distinctions between decision utility, which is often employed in travel choice modelling, and experiences utility, which represents the consequences of the choice and is closer to the Bentham's definition of utility as the experience of pleasure and pain (Bentham, 1789). As mentioned above, due to lack of information and cognitive distortions, decision utility might diverge from anticipated utility and experienced utility (Ettema et al., 2010). Therefore, it is questionable to evaluate the benefits of travel choices and policies just based on decision utility models.

Subjective well-being (SWB), as an alternative and enrichment to utility, has recently attracted attention from transportation researchers. SWB offers a direct measurement of individuals' mood, emotion and cognitive judgment on travel experiences, and thus better captures the experienced utilities of travel. Several recent research has called for the investigation on whether and how SWB can be influenced by the changes of travel context, such as changes of travel mode, changes of level-of-service of public transit (Bergstad et al., 2011; Ettema et al., 2010). SWB would be a powerful tool for transportation policy evaluation if a relationship between transport and SWB could be found (Ettema et al., 2011; Ettema et al., 2010).

Framework of Transport and Subjective Well-being

Several recent studies have constructed frameworks linking subjective well-being with travel in general (Abou-Zeid, 2009; Ettema et al., 2010) and commuting in particular (Novaco and Gonzalez, 2009). Ettema et al. (2011) deem that the utility of travel could influence overall well-being for two reasons. First, overall well-being has been shown to be related to well-being in specific domains (e.g. family, work, health). Therefore, it is plausible to assume that well-being (or satisfaction) in the travel domain has implications for overall well-being. For example, people may experience pleasure and enjoyment just going for a walk or a bicycle ride. Second, improvement in travel conditions may increase options to participate in meaningful or enjoyable activities and may reduce stress associated with these activities, with both increasing well-being (Pychyl and Little, 1998).

Travel and Mental Stress

Transport can affect subjective well-being directly. Travel itself may invoke positive and negative moods and emotions (affective well-being) as well as cognitive assessments of quality of travel (Ettema et al., 2010). The link between commuting and mental stress has been well established in the literature (Abou-Zeid, 2009). Studies have found that commuting-related stress results from various commuting attributes including long commute distances, traffic congestion, long travel or waiting time, the unpredictability of travel time and conditions, over-crowding, and other travel conditions (Evans et al., 2002; Novaco et al., 1990; Wener et al., 2003). Gatersleben and Uzzell (2007) found that active commuting by walking and bicycling is perceived as more “relaxing and exciting” than commuting by car and public transit, which are perceived as being more “stressful and boring”. They also found that the affective appraisals of the daily commute are not only related to instrumental aspects, such as journey time, but also to general attitudes toward various travel modes. In addition to the traffic condition per se, there are other factors which can worsen or alleviate commuting stress. Lucas and Heady (2002) found that commuters with flextime employment contracts reported less driver stress and fewer feelings of time urgency than those without flextime, but there was no significant difference in terms of commute satisfaction. Lyons and Urry (2005) hypothesized that undertaking activities, such as working, during the journey, might help individuals to cope with travel stress.

Travel and Happiness

Travel is traditionally considered as a derived demand, and travel itself is often judged as wasted time, only yielding negative utility. However, a number of studies have recognized that an individual can also gain positive value during the travel (Mokhtarian and Salomon, 2001; Mokhtarian et al., 2001; Steg, 2005), for example from working, playing, socializing, sleeping, etc. (Lyons and Urry, 2005). Furthermore, people may enjoy traveling for a number of other reasons including the sensation of speed, feelings of freedom, exposure to the environment and movement through the environment, the ability to control movement, enjoyment of scenic beauty or the attractions of a route (Mokhtarian and Salomon, 2001). In particular, Steg (2005) found that commuter car use was most strongly related to symbolic and affective motives, and not to instrumental motives, such as speed, flexibility, and convenience. Based on data from a web-based survey of university students in Hamilton, Canada, Paez and Whalen (2010) found that active travelers tend to feel more satisfied with their commute than those traveling by other modes, followed by those who travel in personal vehicles and transit users. They also found that there are a number of attitudinal responses that may impact the desire to travel more or less, including the social environment, availability of local activities, quality of facilities, productive use of the commute, and the intrinsic value of commute travel.

Travel and Health

In addition to the direct effects on SWB, the transport system also affects SWB indirectly by influencing important domains of SWB, such as health. Exposure to the traffic environment can affect our physical and mental health (De Nazelle et al., 2009; McNabola et al., 2008; Wener et al., 2003). Commuting stress can further spillover into domains such as work performance and family relationships (Novaco et al., 1990; Wener et al., 2005). Transportation can also affect our work-life balance and our ability to access activities, goods and services, essential for our well-being (Delbosc, 2012; Ettema et al., 2010).

The significant role of transportation with respect to public health has been widely recognized. There is a mushrooming literature on the topic, with most finding that characteristics of transportation can have direct and indirect influences on public health. The link between transportation and public health can be broadly summarized into the following five aspects. First, travel behavior is associated with level of physical activities (Handy et al., 2002), which in turn influence one's physical health. Second, commuting time (Stutzer and Frey, 2008) and mode choice (Wener et al., 2003), which are in part determined by the built environment, are correlated with people's mental health (e.g. stress). Transport also enables "contact with nature", which can provide an effective strategy in prevention of mental illness (Maller et al., 2006). Third, the risk of injury from road traffic and pedestrian collisions is influenced by not only traffic management factors, such as traffic speed, signage and volume, but also by the design of the built environment, factors such as the street network design, road layout, road width, and land use patterns (Ewing and Dumbaugh, 2009). Further, fear of being injured may also affect mental health. Fourth, traffic-related emissions affect ambient air quality on a wide range of spatial scales, from local roadsides and urban scales to broadly regional background scales. Exposure to traffic pollutants is associated with a variety of respiratory and cardiovascular symptoms and illnesses (Buckeridge et al., 2002; Riediker et al., 2004). Finally, transportation planning influences the accessibility of food shopping destinations (Clifton, 2004). Lack of access to affordable, healthy food is potentially associated with obesity and other health problems (Walker et al., 2010).

Physical Activity

It is well known that walking and bicycling for daily transportation are important sources of physical activity, which is the important source to reduce the risk for obesity and chronic diseases. Transportation investments can either support or impede walking and bicycling in people's daily trips, and thus benefit to the people's health or increase the risk for obesity and related diseases. People living in a community with good quality of pedestrian and bicycling paths, and good street connectivity are more likely to walk and bike for trips than ones in the community without such infrastructures. Besides, residents of compact neighborhoods walk, bike and use transit more than residents of spread-out communities, and they have lower rates of obesity and chronic diseases. These relationships have been confirmed by many empirical studies.

Sallis et al. (2009) conducted surveys in 11 countries using the same self-report environmental variables and the International Physical Activity Questionnaire, and found that five environmental variables were significantly related to meeting physical activity guidelines, ranging from access to low-cost recreation facilities to sidewalks on most streets. The results suggest neighborhoods built to support physical activity have a strong potential to contribute to increased physical activity. Designing neighborhoods to support physical activity can now be defined as an international public health issue. Rodríguez et al. (2006) also found that residents of the new urbanism neighborhood were more likely to be physically active in their neighborhood than were residents of conventional suburbs. They explained this difference was due to the more walking for utilitarian purposes in new urbanism neighborhood.

Through a comprehensive literature review, Shephard (2008) found that empirical studies to date have yielded mixed results: a reduced all-cause and cardiovascular mortality has been observed more frequently in cyclists than in walkers, and more frequently in women and older men than in young active commuters. Abu-Omar and Rutten (2008) found leisure time physical activity was positively associated with self-rated health and inversely with obesity, and physical activity for commuting is associated with a decreased risk of being obese. Hamer and Chida (2008) found that active commuting that incorporates walking and cycling was associated with an overall 11% reduction in cardiovascular risk, which was more robust among women. Hansson et al. (2011) found that the health outcomes most clearly associated with commuting were perceived poor sleep quality, exhaustion (low vitality) and low self-rated health, whereas low mental health was not significantly associated with commuting. Based on a cross-sectional study of 4297 adults who had a comprehensive medical examination between 2000 and 2007in 12 Texas metropolitan counties, Hoehner et al. (2012) found that commuting distance was negatively associated with physical activity and cardiorespiratory fitness (CRF) and positively associated with BMI, waist circumference, systolic and diastolic blood pressure, and continuous metabolic score in fully adjusted linear regression models.

Exposure to Unsafe Traffic Condition

Ewing and Dumbaugh (2009) reviewed studies on relationship between built environment and traffic safety, and they found that, overall, the dense urban areas appears to create safer traffic environment than the lower dense environments of the suburbs. They argued that people tend to drive less miles and slower speed in dense urban settings and thus lower fatal crashes. Besides, the safer traffic designs, such as traffic-calming, narrow lanes, and street tress close to the roadway, enhance safety performance of drivers.

Dumbaugh (2008) addressed the safety and mobility needs for aging population, which is vulnerable population group to unsafe traffic conditions due to age-related disabilities. Different from current policy solutions on increasing safety and mobility for aging population, he proposed four strategies, which focus on designing the communities and transportation systems, to better meet the needs of aging population. These strategies include adding lower-speed, two-lane through-routes into arterial roads, enhancing the street connectivity, protecting left turns and pedestrian crossings by balancing system capacity, and encouraging more retail and services within the community.

Elvik (2006) pointed out four “laws” for accident causation based on previous empirical studies. The first law states that accident rate per unit of exposure declines as the amount of exposure increase; the second law states that the more rarely a certain risk factor the larger the effects on accident rate; the third law states that the more elements of information the traffic environment contains the higher the accident rate; the fourth law states that the more cognitive capacity approaches its limits, the higher the accident rate.

Dumbaugh and Li (2011) empirically explored whether urban crash incidence is the product of random error, or whether it may be influenced by built environment characteristics, and they found that associations between vehicle miles of travel and crashes involving motorists and pedestrians is weak, while associations between crashes and built environment characteristics is strong. In particular, they found that miles of arterial roadways and numbers of four-leg intersections, strip commercial uses and big box stores to be major crash risk factors, while pedestrian-scaled retail uses were associated with lower crash incidences. This study implies that improvements to urban traffic safety require that designers balance the inherent tension between safety and traffic conflicts.

Exposure to Traffic-Related Air Pollution

Active living design is encouraged to promote people's active travel behavior, such as biking and walking, so as to reduce the risk of obesity or other chronic diseases associated with insufficient physical activities in population. Unintended consequences may emerge, however, especially due to potential increases in the inhalation of pollutants as the population walking or cycling in polluted environments increases. De Nazelle et al. (2009) assessed the exposure risk and benefits of active travel associated with changes of built environment. They found that participants engaged in more than the recommended levels of physical activity or in which ozone and PM10 thresholds were exceeded show that no chronic individual physical activity benefits are demonstrated, and that chronic ozone inhalation doses are decreased by a switch to a pedestrian-friendly built environment. However, the low activity-variability scenario showed that these benefits may in part be off-set by increased chronic inhalation doses of PM10. The result of this study implies that decreases in particulate matter and ozone will mitigate any negative impacts of increased outdoor activity resulting from incremental changes to the built environment. Community changes towards pedestrian-friendly designs appear to generate risk-benefit tradeoffs, and therefore additional policies must be applied to minimize the increased risks.

Health Effects Institute (2010) summarizes and synthesizes studies linking emissions from, exposures to, and health effects of traffic sources (i.e., motor vehicles), and they concluded that traffic-related emissions affect ambient air quality on a wide range of spatial scales, from local roadsides and urban scales to broadly regional background scales. They further identified that the most highly affected area by traffic emissions is the exposure zone within 300 to 500 meters from a major road, and in light of the large population residing within this area, they concluded that exposure to traffic-related pollution are likely to be of public health concern and deserve public attention.

McNabola et al. (2008) investigated relative exposure to and uptake of air pollutants between modes of commuter transport based on 468 samples in Dublin, Ireland, and they found that the car commuters have the highest exposure to VOCs, while the bus commuter was found to have the highest exposure to PM2.5, and the pedestrian was consistently found to have the lowest exposure. Moreover, they also estimated total uptake of pollutants, and the results indicated that the cyclist had the highest deposition of PM2.5 in the lungs followed by the bus, pedestrian and car. The car passenger had the highest absorption of VOCs followed by the cyclist, pedestrian and bus.

Morabia et al. (2009) assessed the magnitude and variance of personal exposure to particulate matter 2.5 microns or smaller (PM2.5) and concomitant physical activity energy expenditure (PAEE) for transportation by car, subway, or walking, and they found no statistically difference in PM2.5 exposure among car, subway, and walking arms, this result implies that driving cars was associated with less physical activity but not necessarily less exposure to PM2.5 than riding subways or walking in an urban environment.

Traffic-Related Mental Health

Many studies linking transportation to mental health focuses on the relationship between commuting and stress. Long-time commuting is not only a monetary cost, but also a physical and mental burden for individuals. Long-time commuting on the one hand reduces one's share of time for other activities, such as physical exercises, time with family, social activities, etc., and on the other hand increases the exposure to the commuting related nuisances, such as noise, crowds, pollution and thermal conditions, which cause negative physical and emotional reactions. Recent research has found that people with long commuting time suffer from disproportionate pain, stress, obesity, and dissatisfaction.

Stutzer and Frey (2008) explored the relationship between commuting time and stress level of commuters using panel data in Germany, and they found that, contrary to prediction of equilibrium location theory, people with longer commuting time reported systematically lower subjective well-being.

Ohta et al. (2007) assessed mental health of 670 men and women in three municipal offices in Japan by a 28-item General Health Questionnaire (GHQ), and they found that GHQ scores decrease according to increasing duration of time on commuting to work by either walking or cycling in men, but not in women.

Wener et al. (2003) used a pre-post design to study the changes of stress level of commuters after the operation of a major mass transit improvement, which provided a "one-seat ride" into New York for commuters who previously had to transfer in Hoboken, they found that riders on this new line had lower levels of stress than they had earlier, and the reduced trip time of the new, direct service is a primary factor in reduced stress to riders.

Travel and Social Activities

Apart from the direct link between travel and SWB, travel also influences SWB by facilitating participation in activities that are important for life, such as working, education, leisure, social and family activities (Ettema et al., 2010). Even though that approximately 50% of the variance in happiness was determined by genetic and personality factors (Lyubomirsky et al., 2005), there are several other influences that have significant impacts on life satisfaction. Three of the most important influences are employment/poverty, social relationships and health (Delbosc, 2012).

Jones and Lucas (2012) emphasized the importance of understanding the social impacts and consequences of transport, and they argued that consideration of the social impacts of transport planning can significantly increase the quality, effectiveness and efficiency of a number of other important areas of economic and social policy, including employment, health, education and economic development. They also identified two types of social consequences of transport; one is the short-term or 'immediate' categories of social impact, namely accessibility, movement and activities, health-related, financial related and community-related impacts; the other one is the longer-term social consequences, including health, individual and community well-being and social equity and justice.

Using data from existing household surveys in the London and Paris regions, Jones et al. (2008) examined the differences in the overall numbers and kinds of trips and activities carried out on weekdays and at weekends by “short” duration (30 minutes or less one way) and “long” duration (60 minutes and over one way) commuters. They found that short duration commuters make more non-home trips, spend more time at home, and make more trips and more stops than long duration commuters. Urry (2012) argued that the importance of travel stems from how it enables people to be connected with each other, to meet and to re-meet over time and across space. These connections form patterns or networks, which many commentators see as the critical feature of contemporary life.

Travel and Social Exclusion

Previous studies that link transport and subjective wellbeing in the lower income population have focused on transport poverty and social exclusion (Church et al., 2000; Currie et al., 2009; Currie and Stanley, 2007; Delbosc and Currie, 2011a; Lucas, 2012; Stanley et al., 2011). Transport can influence wellbeing by facilitating participation in activities that are important for life, such as working, education, leisure, social and family activities (Ettema et al., 2010). Lack of transport contributes to social disadvantage and exclusion by restricting access to such activities that enhance people’s life chances (Lucas, 2012; Mackett and Thoreau, 2015). There is evidence shows that those on lower incomes, living in deprived neighborhoods, are affected more adversely by the impacts of transport than those with greater affluence (Mackett and Thoreau, 2015; Titheridge et al., 2014). Due to the economic constraints, many lower income population lived in rural or remote communities, where there are higher levels of car dependence coupled with a lower availability of transit. Lack of other affordable transport options, the lower income households are forced to own and operate cars and spent a greater share of income on transport, experiencing transport poverty. Delbosc and Currie (2011b) explored the spatial differences in measures of transport disadvantage, social exclusion and well-being in a survey of inner metropolitan, outer suburban, urban fringe and regional areas of Victoria, Australia, and they found that transport disadvantage had greater impact on social exclusion and wellbeing in remote areas than in accessible urban areas. The deprived communities also suffer disproportionately from pedestrian deaths, pollution and the isolation which can result from living near busy roads. Fear of injury from traffic, fear of falling on poorly maintained footways, pollution and difficulty crossing busy traffic further deter the lower income residents from leaving their homes and thus reduce levels of social interaction (Social Exclusion Unit, 2003). This highlights the importance of living environment in addressing the transport poverty and social exclusion and improve wellbeing for the low-income population.

Previous studies addressing transport poverty and social exclusion have focused on the role of accessibility to cars and transit. The importance of accessibility to affordable cars and reliable transit on employment and participation in activities for lower income population have been consistently reported in many studies conducted in North America and Australia, where cities are spread out in lower density. For example, using a rich panel of data on welfare recipients in Alameda County, California, Cervero et al. (2002) found that car ownership significantly increased the odds that someone switched from welfare to work, while public-transport service quality variables were largely insignificant. Grengs (2010) also found that inner-city residents in Detroit are disadvantaged by a lack of cars and poor transit service. He concluded that policies aimed at helping carless people gain access to automobiles may be an effective means of improving the employment outcomes of inner-city residents. Ong and Miller (2005) compared the impacts of spatial mismatch (the geographic separation of workers and jobs) and transportation mismatch (the lack of access to a private automobile) on neighborhood employment-population ratio and unemployment rates using tract-level data for the Los Angeles metropolitan area, and found that transportation mismatch is the more important factor in generating poor labor-market outcomes, particularly for disadvantaged neighborhoods. Similar findings were also reported in Australia. Currie et al. (2009) assessed the transport disadvantage and social exclusion in Melbourne, Australia, and they identified two types of transport disadvantage groups in fringe urban Melbourne – those who are forced to own a car and those without a car. They found that households forced to own cars are primarily those on low incomes, highly car dependent, lack of alternative transport options, high transport cost, and make less trips than the average outer area households with cars, while the households without a car are primarily relied on walking for daily needs and therefore they have to live near the local activity centers.

Role of Built Environment in Travel and Subjective Wellbeing

The associations between the built environment and travel mode choice have been well established. A recent meta-analysis found that there are over 200 studies on this topic, most of which were completed since 2001 (Ewing and Cervero, 2010). The built environment affects travel behavior by affecting the generalized cost of travel to various destinations (Boarnet and Sarmiento, 1998). The generalized cost of travel not only includes the actual money and time cost, but also the perceived time cost, which could be affected by the quality of the journey (e.g. reliability, crowding, congestion, number of interchanges. Etc.). For example, ten minutes on a comfortable train impose less cost than the same amount of time on a crowded bus.

Crane (1996) constructed a travel-demand model integrating land-use factors. Based on Crane (1996), travel demand was determined by three factors: generalized travel cost, income, and the social-demographic characteristics of the traveler. Generalized cost can be influenced by densities, street connectivity, and land-use diversity, and thus land use is added as a vector in the travel-demand model. The rationale for this model depends on the conventional theory of consumer demand, assuming that households choose the number of trips by each mode to maximize the well-behaved utility function, subject to their time and money budget. This study is the first to provide a theoretical framework to model the relationship between land use and travel behavior.

Variables measuring the built environment can be classified into five dimensions: density, diversity, design, destinations and distances to transit/job/park (Ewing and Cervero, 2010). In addition to the 5Ds, Alfonzo (2005) categorized the built environment elements based an application of Maslow's hierarchy of needs to walking. Both objective (e.g. GIS) and subjective (e.g. self-reported) measures have been used in the literature to measure the built environment (Handy et al., 2006). Either way, most of the previous studies have found that the built environment features of high density, mixed land uses, well-connected streets, and high transit and job accessibility at both home (Cervero and Kockelman, 1997; Ewing and Cervero, 2010; Handy et al., 2005) and job locations (Chatman, 2003; Chen et al., 2008; Ding et al., 2014; Zhang, 2004), are associated with less car use and more active travel and transit use. The built environment, therefore, could indirectly influence travel satisfaction by affecting travel behavior. In addition to the travel behavior, the built environment may also affect other travel characteristics, such as congestion, transit level of service (LOS), actual and perceived travel cost, all of which could in turn influence travel satisfaction.

In addition to the link from the built environment to travel characteristics, the reverse link is also possible. For example, those who have adopted a lifestyle of riding a bicycle for their daily commute may consider whether a neighborhood environment is friendly for bicycling when relocating to a new home. People may also change their neighborhood environment by relocating as a result of changes of transport services (e.g. increase of bus/train fare) in their current home location.

The built environment, therefore, could indirectly influence travel satisfaction through affecting travel behavior and other travel characteristics. In addition to the indirect effects, the built environment may also have direct effects on travel satisfaction. The amenities and landscape along the travel route, for example, may have direct impact on one's mood and feeling, which in turn influence the subjective evaluation of the trip. This study (Kim et al., 2014) found that pedestrians are more satisfied in higher density environment that provides greater opportunities of activities and events and streets with crossings that make it easier for walkers to cross roads. Another study (Li et al., 2012) found that physical environment, such as width of path, presence of slope and surrounding land use, significantly influence bicyclists' perception of comfort.

As one important dimension of physical environment, the role of green environment or open space on health and wellbeing has been well studied. The landscape and aesthetics of the neighborhood have direct effects on the affect component of wellbeing, such as moods and emotions. For example, studies have found that exposure to green and open spaces within the neighborhood help the residents to reduce stress and improve mood (Abraham et al., 2010; Fan et al., 2011). Further, there is abundant evidence (Lee and Maheswaran, 2011; Maas et al., 2006; Matsuoka and Kaplan, 2008) that the natural environment and green space within the neighborhood and aesthetically appealing environment promote good health by creating opportunities for physical and social activities. The associations between the neighborhood social environment and health and wellbeing are also well studied. For example, neighborhood safety and neighborhood social connections with neighbors, and neighborhood trust are consistently found to be positively associated with neighborhood residents' physical and mental health (Yen and Syme, 1999). By contrast, social exclusion, which could be a result of transport disadvantage and poor neighborhood environment, significantly and negatively affect SWB (Currie et al., 2010).

However, the empirical studies that directly look at the impacts of the built environment on wellbeing is limited (Pfeiffer and Cloutier, 2016). Numerous studies have contended that people living in walkable, mixed-use neighborhoods may have higher wellbeing through greater connection to community, better access to healthy food, and opportunities for recreational and incidental physical activity, as compared to those living in homogenous areas designed to be navigated by car rather than on foot (Frank and Engelke, 2001), however, little research has formally explored this hypothesis. Only one empirical study was found before 2016. Leyden et al. (2011) explored the associations between the built environment and happiness using the survey data collected in 10 major international metropolitan cities. They find that happiness of residents is associated with important aspects of the built environments, including (self-reported) accessibility to cultural amenities and public transport, which provide the opportunities to connect with people and society that are critical for happiness. They also find that the maintenance or quality of these built environments is important for happiness, for example, those who felt their cities were beautiful were happier than others. Their work is one of the first to quantitatively examine the relationship between the built environment and happiness, however, the built environment variables used in this study was only measured in a subjective way and at an aggregate level.

With the popularity of using subjective wellbeing as an outcome measure in travel behavior and urban planning studies recently, and in response to the above research gap, the Journal of Travel Behavior and Society organized a special issue on "Built environment, mobility and quality of life" (Cao and Zhang, 2016). In this special issue, five papers empirically explored the impact of the built environment on wellbeing using the data from different cities and countries.

Wang and Wang (2016) investigated the spatial variations of life satisfaction within the city of Beijing using a household survey data collected in Beijing, China. This study finds that there are significant differences in life satisfaction between different administrative districts in Beijing, even after controlling for the socio-demographic characteristics of the respondents. This study also finds that those living in outer suburban areas have lower level of life satisfaction than those living in central and inner suburban areas. However, this study does not further explore what specific built-environment characteristics within each district that contribute to the differences in life satisfaction.

Xiong and Zhang (2016) explored the direct and indirect effects of land use and travel behavior on satisfaction with different dimensions of life and quality of life in general using structural equation modelling and data collected from young adults in Japanese cities. This study finds that Japanese young adults living in metropolitan areas are more satisfied with their life than those living in non-metropolitan areas, as there are more employment opportunities, housing choices, social and recreational activities in metropolitan areas.

Relied on the data from the Minneapolis-St. Paul metropolitan area, Cao (2016) quantitatively explored the relationships between the built environment, perceptions, residential satisfaction and life satisfaction by using the Campbell's conceptual model (Campbell et al., 1976). This study finds that street connectivity has positive effects on life satisfaction, while the density has negative effects on life satisfaction, although the negative effects of density is much smaller comparing with the positive effects of street connectivity.

Relied on a survey data from Utrecht province in Netherlands, Ettema and Schekkerman (2016) evaluated the different impacts of objective and subjective built-environment attributes on different subjective wellbeing measures, including the cognitive evaluation of life (life satisfaction), affective wellbeing and mental health. This study finds that life satisfaction and affective wellbeing is more influenced by subjective environment attributes, while the mental health more by objective environment attributes.

van den Berg et al. (2016) explored the impact of mobility and built environmental characteristics on feelings of loneliness using the data collected in the southeast of the Netherlands. This study finds that built environment plays a critical role in explaining loneliness. Specifically, satisfaction with neighborhood environment and accessibility are less likely to feel lonely, while urban density does not affect feelings of loneliness.

In summary, among these five empirical studies, only one study explored the effects of the built environment on both cognitive and affective component of SWB, three studies only focused on life satisfaction and one only focused on negative affect. Regarding the measurement of the built environment, two studies measured the built environment at aggregate level (e.g. districts, metropolitan areas) without specific environmental characteristics, and only two studies includes both objective and subjective measures. My study aims to partially fill these gaps by exploring the effects of the built environment on three components of SWB: life satisfaction, positive affect and negative affect.

Role of Attitudes in Travel and Subjective Wellbeing

Similar with the built environment, travel attitudes may also influence subjective wellbeing both directly and indirectly. Though there is little consistency among transportation researchers on measuring attitudes, travel behavior theory has long recognized the role of attitudes and preferences in influencing travel behavior (Boarnet and Crane, 2001). Among the studies linking the built environment and travel behavior, a growing number of these have incorporated attitudes into their models. Even though attitudes often worked as control variables for self-selection (Cao et al., 2009; Handy et al., 2005, 2006; Kitamura et al., 1997; Naess, 2005), almost all of these studies have concluded that attitudes play a significant role in influencing travel behavior. As discussed above, travel behavior may influence travel satisfaction and subjective wellbeing. The travel attitudes, therefore, may indirectly affect travel satisfaction and subjective wellbeing through influencing people's daily travel.

In addition to the indirect effects, the attitudes may also directly influence the subjective evaluations of the travel experience and subjective wellbeing. For example, pro-bike bicycling commuters are more likely to be happy and satisfied with their commuting trip than those who use the bike for their daily commute through lack of suitable alternatives. In addition, daily travel is an important part of life, people's attitudes towards travel are, therefore, logically associated with their attitudes towards life, which is subjective wellbeing.

Also the attitudes towards travel may directly influence the subjective evaluations of the travel experience. Studies have found that a priori attitude towards a certain travel mode influence the level of satisfaction of using that mode for travel (Cao and Ettema, 2014). The inverse causality between the built environment, travel attitudes, travel mode, and travel satisfaction is also plausible. For example, people may consider relocation of home when they are dissatisfied with the daily travel experiences at current home locations. Further, travelers' real experience of daily travel may reinforce or even change their previous travel attitudes.

Finally, travel attitudes and the built environment influence each other, and they have interactive effects on travel. First, self-selection hypothesis (Mokhtarian and Cao, 2008; Van Wee, 2009) contends that people choose home locations with the built-environment characteristics at least to some extent confirm to their travel-related attitudes. People might also self-select with respect to work locations (Van Wee, 2009). A person with a strong preference for traveling by bicycling might prefer a job in a city with much bicycle-friendly infrastructure. The travel attitudes, therefore, affect both residential and job location and hence are associated with built environment characteristics and in turn travel behavior. Schwanen and Mokhtarian (2005) found that a mismatch between travel preferences and the living environment has a significant impact on travel. Second, social cognitive theory (Bandura, 1986) and the social ecological model (Sallis et al., 2002) argue that the built environment may also influence the intrapersonal factors, such as travel attitudes, at least in the long-term. Several studies have explored the interactions between the built environment and travel attitudes and their direct and indirect effects on travel behavior (Alfonzo, 2005; Dill et al., 2014).

Framework

Based on the literature summarized above, a framework that links travel and subjective wellbeing was established (Figure 3). The framework combines the decision utility theory, which is the theoretical basis for most of previous travel behavior studies, and experienced theory, where recent studies linking travel and SWB have relied. As illustrated in the framework, the relationships between the variables are not straightforward, involving direct and indirect effects, interactions, mediations, and recursive effects. Few previous studies linking travel and SWB have explored these effects.

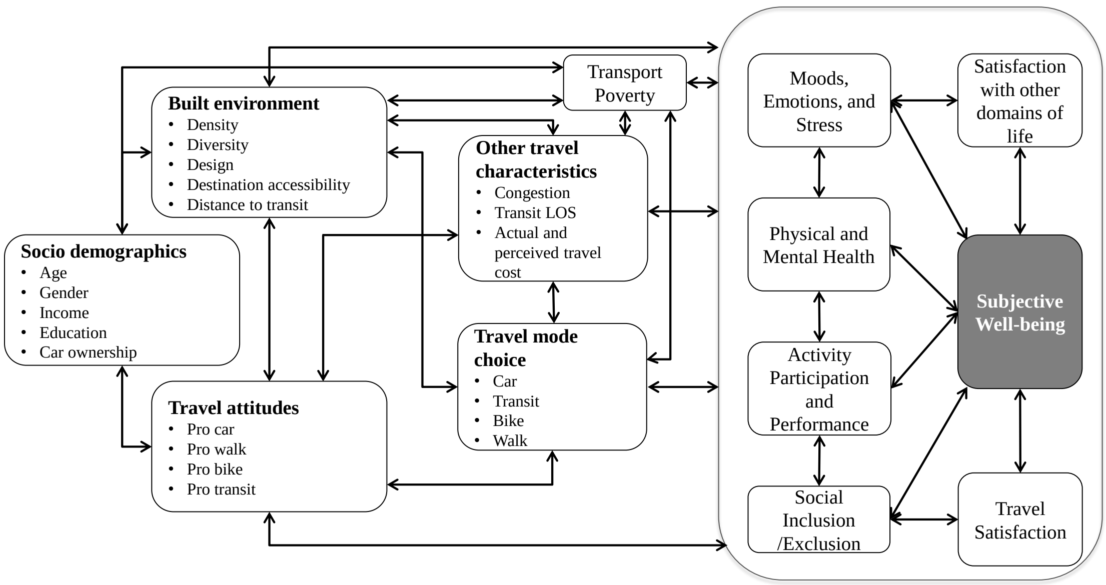

Figure 3 Links between transportation and SWB

Empirical Studies on Transport and Subjective Well-being

Although there is growing interest in the relationship between transportation and subjective well-being, there is relatively little empirical work that has directly studied the impact of transport on subjective well-being. Further, existing studies have reported mixed results.

Several recent studies have found a significant association between transportation and subjective well-being. Anable and Gatersleben (2005) evaluated the relative importance of instrumental (e.g., cost, flexibility, predictability) and affective (e.g., relaxing, restful, stress, excitement) attributes for commuting and leisure trips, and they found that instrumental factors are slightly more important than the affective factors for commuting, while they are equally important for leisure trips. This study is one of the early studies that highlight the importance of affective factors in travel behavior research. Further, this study found that active travel commuters rated high on affective factors such as no stress, relaxation, and freedom, all of which are components of SWB. However, the small sample size (n=235) of this study limits the generalization of its findings. Based on work in customer service literature, Stradling et al. (2007b) developed a six-step method to measure satisfaction with travel modes. This method plots user dissatisfaction against importance for every element that matters for the service delivery. This method is innovative in identifying the gaps between customer expectations and actual service supply. Using the same method, Hickman et al. (2015) explored the experiences of travel through the interchange at several high-speed rail hubs in China, by identifying the gaps between user's expectations and actual service provisions in two dimensions: instrumental factors (time, cost, flexibility etc.) and attitudinal/ affective factors (perceptions of service quality, feeling and emotions while using the services). This study highlighted the importance of attitudinal/affective factors in forming the utility (i.e., subjective experience) of public transport. Based on a survey data collected in the City of Edinburgh, Stradling et al. (2007a) particularly investigated the factors that discourage people from using the bus in Edinburgh. Through factor analysis, they identified eight key dimensions of bus user dislike with the bus travel experience, and they also found that the importance of these factors varied significantly with age and frequency of bus use. Similarly, Carreira et al. (Carreira et al., 2014; 2013) further analyzed the travel experience of bus users and what factors contributes to the travel experience using a qualitative analysis. These two studies highlighted that evaluation of travel experience should not only consider the cognitive assessments but also the emotional and sensorial aspects. They also found that travel experience factors, such as individual space, information provision, staff's skill, social environment, off-board facilities, and ticket service, have significant effects on both cognitive and emotional responses of bus customers. Based on data from the German Socio-economic Panel Study (GSOEP), Stutzer and Frey (2008) found that people with a longer commuting time report systematically lower subjective well-being than those with a shorter commute. A similar finding was reported by Choi et al. (2013), who found that commute time was statistically significant and negatively associated with SWB. Bergstad et al. (2011) investigated the correlation between satisfaction with daily travel and subjective well-being (SWB). Based on a survey of 1330 Swedish citizens, they found that the effect of satisfaction with daily travel on affective and cognitive SWB is both direct and indirect via satisfaction with performance of activities. They also found that weekly car use has a small but significant positive effect on travel satisfaction and affective SWB. Using data from a web-based survey of workers (n=828) in Portland, Oregon, U.S.A., Smith (2013) found those who bike and walk to work have significantly higher satisfaction with their commuting than transit and car commuters. He also found that, along with travel mode, traffic congestion, travel time, income, health, travel attitudes, job and residential satisfaction also play important roles in shaping commute satisfaction, which in turn may affect SWB. Cao (2013) found that the Hiawatha LRT (in Minneapolis, MN, USA) positively influenced satisfaction with life through enhanced access to different activities, and through improved transit service, enhanced accessibility, and their impacts on satisfaction with travel, but the size of the impacts were small. Olsson et al. (2013) found that commute satisfaction has a substantial influence on overall happiness based on the survey data on commuters living in the three largest urban areas of Sweden. Relying on a commuter survey (n=3,377) carried out at McGill University in Montreal, Canada, St-Louis et al. (2014) found that pedestrian, train commuters, and cyclists are significantly more satisfied with their commuting than drivers, metro and bus users, and they also found that the commuting satisfaction was generally low with modes that are more affected by external factors. De Vos et al. (2015) investigated the relationship between travel mode choice and travel satisfaction for leisure trips, using the survey data (n=1,720) collected in twelve neighborhoods in the Belgian city of Ghent, they found that participants using active travel (especially walking) are most satisfied with travel, while public transit users experience the lowest levels of travel satisfaction.

However, not all studies show a significant relationship between transportation and subjective well-being. Abou-Zeid (2009) proposed a framework that uses happiness measures as indicators of utility to model both activity and travel choices using data from a cross-sectional web-based survey. Through structural equation modelling, she found that commute satisfaction is significantly associated with commute enjoyment and commute stress, which can be further caused by longer travel time, higher variability, encountering congestion frequently, and walking or bicycling beside traffic. However, she found that the association between commute satisfaction and overall well-being is not statistically significant. Morris and Guerra (2014) explored the relationship between mood (affective component of SWB) and mode using the data from American Time Use Survey, and found that bicycling had the most positive affect on mood, followed by driving a car, with bus and train riders showing the most negative emotions. However, most of these relationships were weak and not statistically significant in their models. They also concluded that travel has only a small total impact on affective SWB.

The mixed results in the literature may be due to characteristics of the environmental features studied, inconsistent measurement of well-being, and different statistical methods. They also imply that more empirical studies are needed to make sound conclusions and policy implications.

Literature Gap

1. Empirical studies linking the travel and subjective wellbeing are still limited. Previous studies have reported mixed results and have been conducted in limited contexts, primarily in developed regions and countries. More studies are needed to explore the complexity of the relationships between travel and subjective wellbeing.
2. Few previous studies have looked at the role of the built environment, and psychological factors, such as attitudes, perceptions, and social norms in the relationships between travel and subjective wellbeing. Including these factors into the current frame linking travel and subjective wellbeing helps to

integrate the theories from previous travel behavior research (utility theory) and recent studies on subjective wellbeing.

3. The theoretical framework linking travel and subjective wellbeing involves structural relationships between variables, which require a deeper examination of direct and indirect effects, interactions, mediations, and recursive effects. Addressing these relationships requires appropriate modeling methods, such as structural equation model (SEM) and multilevel model (MLM), which have been widely applied in other disciplines.
4. Studies on travel and subjective wellbeing are at early stages. Most of current studies only focused on the general population, more studies are needed to investigate the effects of travel on subjective wellbeing for special population groups, such as low income, whose quality of life might be disproportionally affected their daily travel.
5. Several studies have consistently reported that public transit (especially bus) users reported the lowest levels of travel satisfaction comparing those using other travel modes. More studies are needed to explore the reasons of the low level of transit satisfaction and identify the strategies to improve the subjective experience with transit, thereby increasing the transit patronage.

Overview of Urban and Transportation Planning in Xi'an

Two major policy reforms, namely land and housing reforms in 1980s, drive the fast expansion of Chinese cities over the last three decades (Yeh et al., 2011). Similar with other Chinese cities, Xi'an has experienced a fast urbanization and dramatic transformations in urban spatial structure and travel pattern since 1980s. Since reform and opening-up to the outside world started at 1980s, China has experienced dramatic changes in economics, politics and social aspects, which alters the impetus of Chinese urban development fundamentally (Yeh et al., 2011). Firstly, with the government reform since late 1980s, the management power in tax, finance, investment, and industries transferred from central government to local governments and local enterprises. Decentralization of political power contributed to the local governments' enthusiasm on economic development. On the one hand, local governments needed economic development to increase employment, attract population, and improve overall economic power to compete with other local governments; and on the other hand, local governments tasted the sweetness from development for the large amount of revenue earned from land sales. Land and housing reforms since 1980s in China provided the governments the best engine to start economic growth. In China, land is only owned either by the state or collective organizations. Before the land reform policy stared at 1987, all the lands in the city were managed by the central and provincial level governments, and all the lands in the rural areas were managed by the village collective organizations. Before the reform, land use was planned and allocated by the state or local governments to industrial sectors based on their needs. Modern land reforms began in the late1980s following a successful experiment in Shenzhen city, in which state-owned land was leased to foreign corporations. In 1990, China officially adopted land leasing as the basis for assigning land use rights to land users. After that, the right of land use can be obtained from the governments by the means of paying the user fees, but this is mainly for the private sectors for the land use, and the land-use needs of public sectors are still allocated by the governments without charge. The reform of land use system was closely associated with the changes in overall economic system during that time, since more and more private sectors were appearing in China. Charging a user fee for land use indicates the emergence of land market in China, and this was the fundamental drive for the transformation of urban form (Ma, 2002).

Another important reform in accordance with land use reform was the commercialization of housing system. Before 1980s, there was only public housing, which was provided by the state as a component of social welfare. However, the public housing system had placed heavy financial burdens on the state because of the negligible rents and excessive housing demand. Therefore, the government initiated a reform program with privatization as a major component during 1980s. The core contents of this reform were: privatization of the public housing and development of new private housing sector. Housing reform means the termination of public housing period. For most of residents in the city, the only way to own a property since 1990s was to buy the commercial housing from the market, and this promoted the development and prosperity of China's real estate market. Although housing reform provides residents a greater freedom of housing choice in terms of location and size, comparing with previous public housing system, it leads to the spatial segregation of housing and job, and the loss of traditional community environment (Man, 2011).

These reforms have significant impact on urban form. Before the 1980s, urban central area was filled with many low-density and mixed-use 'work unit yards'. Work unit or Danwei in Chinese, is the place for people to work as well as live, including factory, shops, schools, universities, hospitals, research institutions, cultural organizations, and government organizations. The main defining feature of a work unit (danwei) is its multi-functionality as a place of employment, residence, education and commerce. Each Danwei can be treated as a small society. Danwei was the fundamental unit for social management under the Planned Economy (Bjorklund, 1986). Politically, work unit has different ties of jurisdiction, is part of political system of the nation, and plays as bridge of connection between the individuals and nation. Economically, work unit is an independent economic entity, and central node of operation and allocation of national resources. In the urban life, work unit is a typical social organization form, and basic unit of social structure. In the field of urban planning in China, work unit yard is the basic spatial element of urban design and planning. Before the 1980s, almost all the urban citizen were belong to different work units, which were not only the workplace, but also a small society with multifunctions: social and political control, social welfares, resources allocation. The main feature of work unit is its independence as a social cell, and multi-function as place for people to work and live. Meantime, each work unit plays independent political, economic and social role in the society.

Work unit yard (Figure 4) is the spatial norm of work unit, and it is just a type of spatial form to integrate all the facilities that are necessary for the work unit in the form of yard, which is the typical Chinese spatial unit. In the work unit yard, people can acquire all the resources and facilities they need for work and life, including offices, housing, schools, canteens, daily-use grocery stores, etc. Development based on these compounds, with their characteristic three- to five-storey rectangular buildings, often stretched for miles. The whole city was composed by each work unit yard, and neighborhoods and districts of the city were relatively undifferentiated by function (Gaubatz, 1999). The idea of work unit yard was not purposely created by the urban planners; rather it was a necessary choice under the Planned Economy. Besides, the idea of work unit yard has similar principles with the idea of Neighbourhood Unit proposed by Mr. Clarence Perry in 1923, for example, the work unit yard advocates to minimize the distance from housing and job, thus people lived in yard mainly relied on walking or bicycling for their daily travel, and encourage mixed land use to guarantee people's daily commercial and entertainment needs can be met within the yard (self-sufficient community). The work unit yard is beneficial to shape an amiable, pleasant, and safe environment for residents to communicate and have the sense of belongings and collectives. Work unit yard is an independent and closed social entity, which is the ideal choice for the political control and organization of economic activities under the Planned Economy system, since each work unit could manage and control all the people in that work unit, and large scale riots were impossible to happen. Besides, before the early 1980s, almost all the economy are state owned, each work unit was in charge of the task assigned from the top government, thus this form was easy and effective for the government to organize the economic activities under Planned Economy. The distinctive role of work unit yard has profound impact of the morphology of Chinese cities.

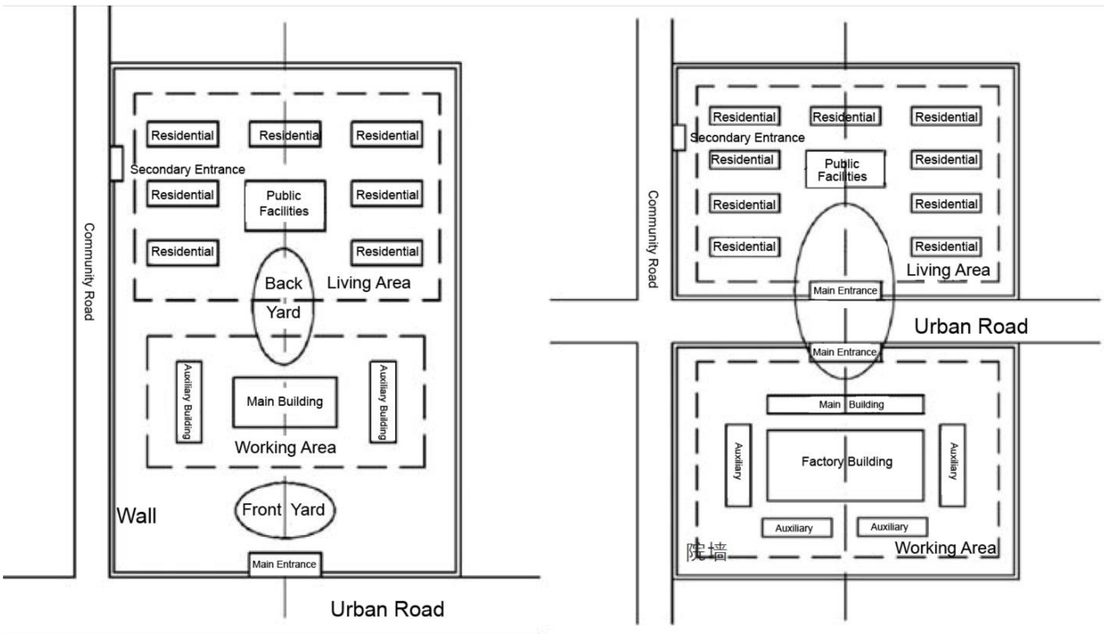

Figure 4 Typical Design for Work Unit (Danwei) Yard
Note: left side was a typical yard for government organizations, and the right one is a yard for factories or corporations.

While serving to promote socialist ideology and minimize popular unrest, the work unit system encountered many limitations and problems when China stepped into

Market Economy system in 1980s. Firstly, marketization of land use system require the more effective and intensive use of land, which leaded to the decomposition of yards in the central areas of the city. Secondly, the reform of public housing made the spatial separation of work unit and housing, since people's housing would not be allocated by their work units and they needed to buy commercial housing developed by the private investors. Thirdly, market economy requires the openness and communication to the outside, while the closed work unit yard discourage outbound contact and relationship. Fourth, the booming service and commercial industries had different spatial requirement with traditional manufacture industries, they need cluster together in space and easily access to the public, while the yard space only afford the small and scattered commercial sites. Fifth, the increasing demand for transportation generated from economic development required to break the large yard, which often blocked the direct traffic flow and generated detour travel.

With the marketization of land and housing system since 1980s, land use density dramatically increased and more and more high-rise buildings were constructed in the city center. Meantime, the previous old and traditional communities were demolished and made way for the commercial and office development. Inner city redevelopment has caused the separation of housing and jobs for many local residents in Xi'an, resulting in the longer commuting distance. Local governments in China over the last several decades behave like a business enterprise, and the economic development was their first priority. Property development is a major source of new tax revenue, so the local city governments have to cooperate with local elites (developers) to realize the economic growth. However, the only interest of developers is profit, which can be achieved by the high density development and development at the best locations in the city, thus the interests of local residents are often ignored by the governments during this process. The real motivation of alliances between local governments and enterprises is for the benefit of the local elites, rather than enhancement of the well-being for local residents (Zhang and Fang, 2004). Urban redevelopment programs in Xi'an could serve as a good example. While these programs were initially aiming to improve the overall image of the city by replacing the outdated infrastructure and dangerously old buildings with modern ones, they often result in massive demolition and ruthless displacement (Zhang and Fang, 2004). As a result, most of local residents have been forced to relocate to the city outskirts that have poor accessibility and transportation services. Another significant phenomenon in urban planning was the functional zoning, which divides the land use by its function. An example of this is the Xi'an Urban Planning 2008-2020 as shown in Figure 5. The whole city was divided into nine functional zones. While the functional zoning helps to maximize the land values, it has negative externalities on transportation, including increase in inter-zone travels and car use and decrease of jobs-housing balance, all of which contribute to congestion. Following the functional zoning, the land use planning in each zone is focused on a specified type that meets the functional purpose (Figure 6). For example, the high-tech industrial zone in the southwest of the city is mainly occupied by the industrial or office land use, while the residential zone in the southeast is clustered with residential land use with little employment function. Further, although mixed land zoning in some areas was considered in current urban planning in Xi'an, the jobs-housing balance is hardly achieved in reality for the following reasons. First, job-housing ratios only indicate the potential for greater balance. The degrees the potential balance can be achieved depend on the percentage of jobs in a community actually filled by its residents, and conversely the share of workers finding a home in that community. Besides, due to the variety of types of jobs and local residents, there need to have a match between the skill levels of local residents and local job opportunities as well as between the earnings of workers and the cost of local housing (Cervero, 1989). Although a varying proportion of residential land use was planned in some industrial zones in Xi'an, the quality and price of those residential properties may not match to needs of the workers in those zones. For example, the workers in high-tech industrial zone in Xi'an are often high-skilled, high-educated and with higher income and high requirement for the residential environment, and they may choose to live in the eco-residential zones which are located in the southeast of the city with better natural environment rather than the properties within the high-tech industrial zone that have very high density. Second, lack of regional cooperation/planning often lead to the difficulty of balance. For example, due to the competition among the jurisdictions for the high-tech projects, the spatial distribution of jobs and housing can be largely mismatched. The winners of the competition have become employment centers, which have high jobs-housing ratios, while the losers have ended up as dormitory communities, which have low jobs-housing ratios. Third, mismatch between worker income and housing cost also contributes to the mismatch. Many retail workers in the city center cannot afford the high priced homes there, and many inner-city companies need to operate special shuttles to transport outskirt residents to workplaces. Class segregation has also been widened by these mismatches. Finally, two wage-earner households, which are very common in Xi'an, also contribute to the imbalance. The trend toward multiple wage-earner households has also contributed to jobs-housing imbalances. In such households, families could be expected to live somewhere in between the workplaces of both wage-earners in order to balance out commuting distances.

The city transport network will be based on a structure that is primarily organized by ring and radial highways and metro lines (Figure 7). All the functional zones will be connected using the metro, which will help to reduce the road traffic and congestion. It is expected that, under the planned transport network, most of the commuting travels within the city will be completed within a half hour. Further, the newest Xi'an Comprehensive Transport Planning (2011-2030) has prioritized the development of transit and active travel, aiming to build a "transit metropolis" with transit and active travel as the primary travel modes. This transport planning also highlights the importance to improve the comfortability, easiness of interchanges, and other level of services of transit. Future bus routes will increase to 730 kilometers, among which 381 (52%) kilometers will be bus designated lanes. It is encouraged that school bus, worker bus, community shuttle bus, ride-sharing, and other on-call bus service to these bus lanes. In addition, by 2030, the metro lines will reach 550-600 kilometers, and the share of metro trips in overall transit trips will be continuously increased.

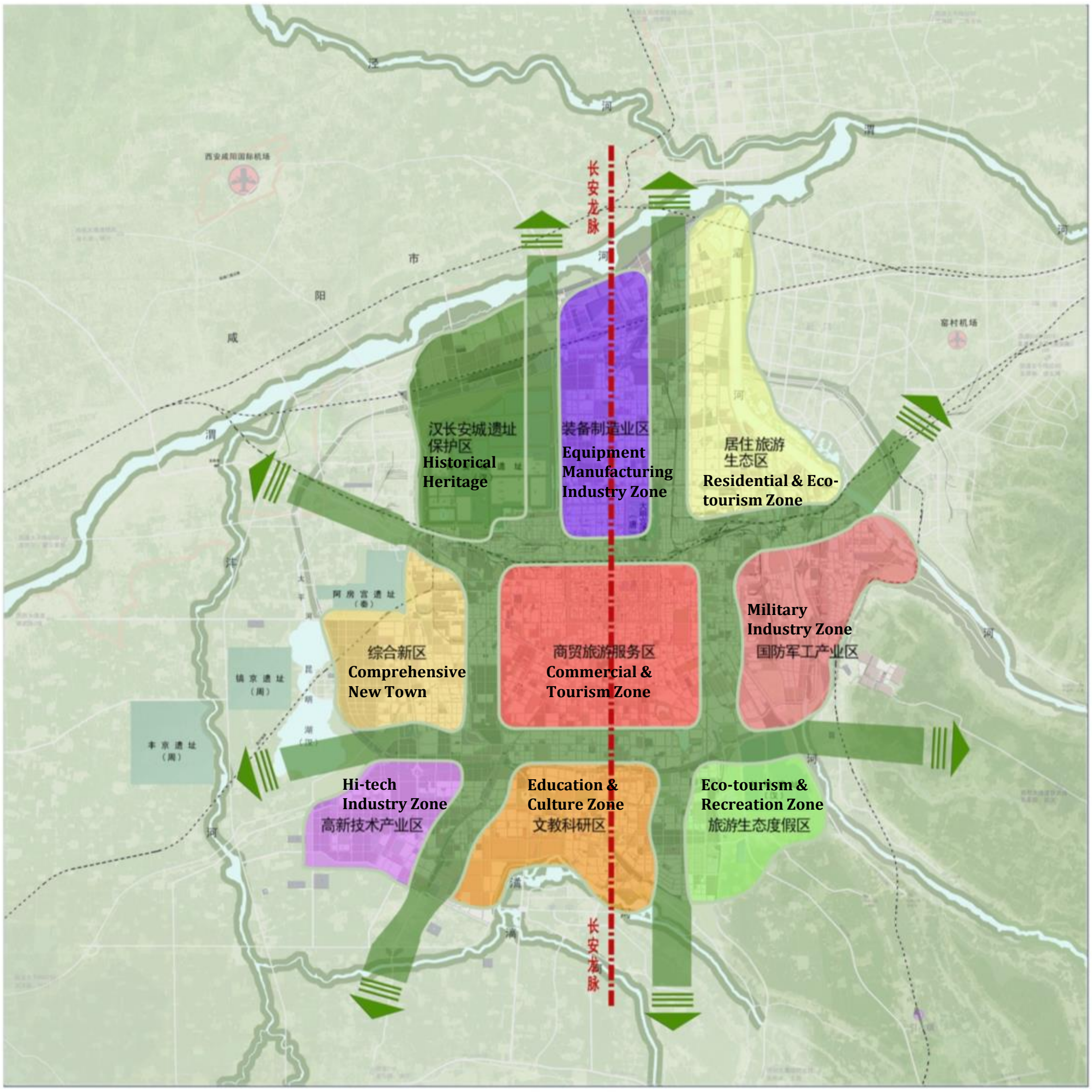

Figure 5 Functional zoning map of Xi’an
Source: Xi’an Urban Planning 2008-2020

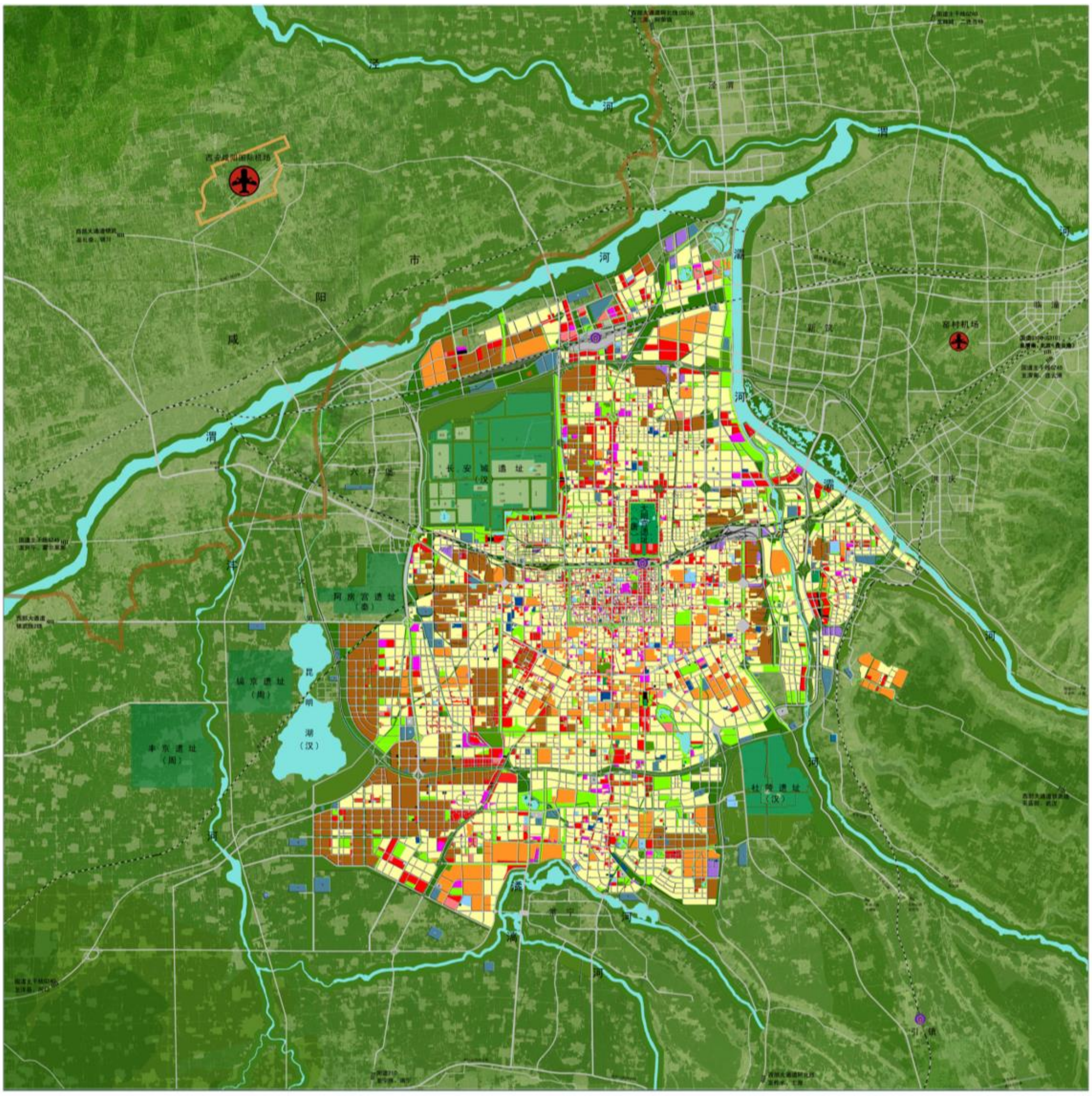

Figure 6 Zoning map of Xi’an
Source: Xi’an Urban Planning 2008-2020

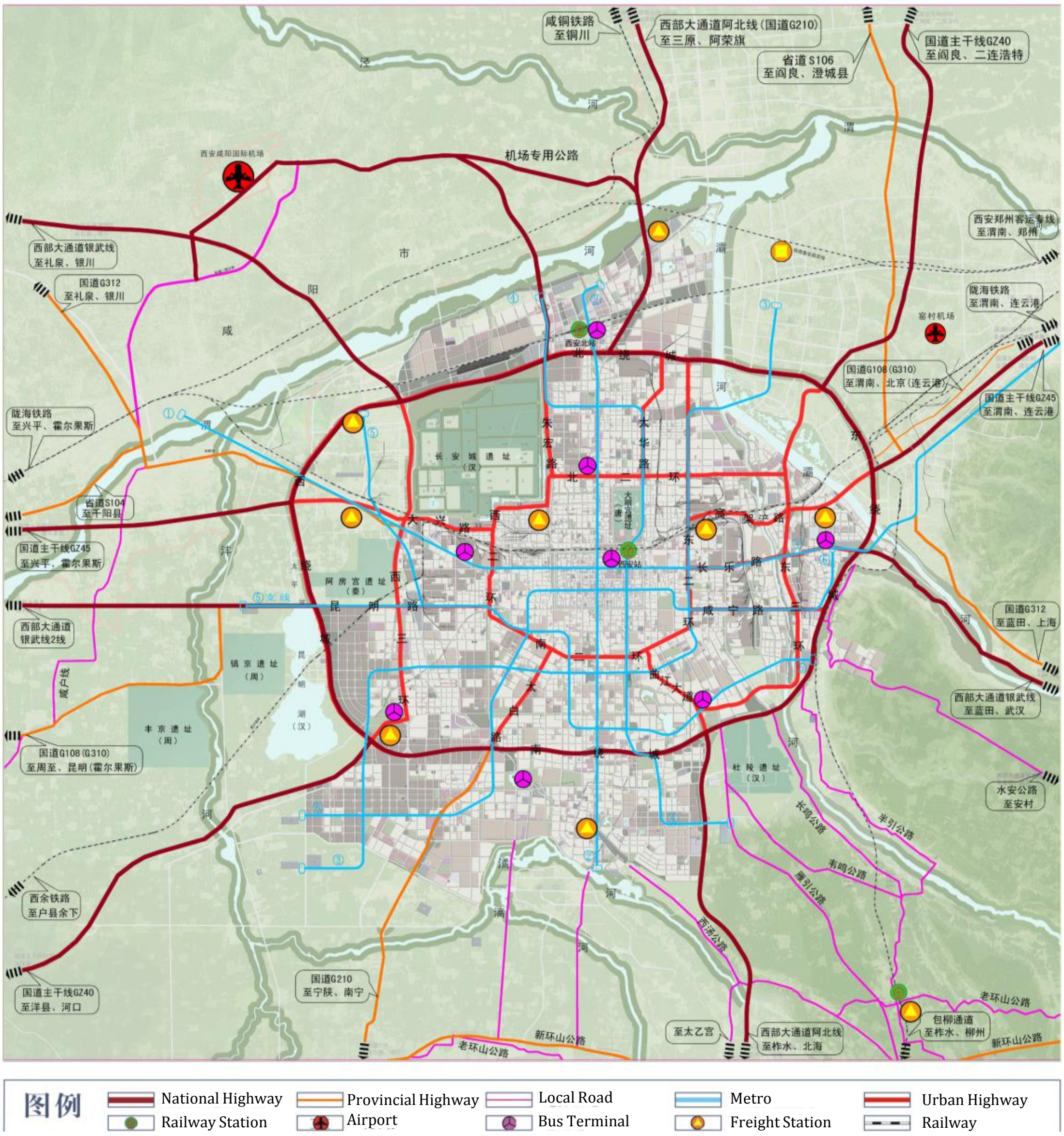

Figure 7 Urban transport system planning of Xi’an
Source: Xi’an Urban Planning 2008-2020

Chapter 3. Data and Methodology

As introduced in Chapter 1, this study aims to answer the following questions:

(1) What commute characteristics, such as journey distance, travel time, travel mode, congestion, level of service etc., influence travel satisfaction, after accounting for socio-demographics? (Chapter 4)

(2) Does travel satisfaction influence overall life satisfaction and well-being, after accounting for socio-demographics and other important domains of life? (Chapter 4)

(3) How do the characteristics of the built environment at people's home and job locations influence their travel satisfaction? (Chapter 5)

(4) How do people's attitudes influence their travel satisfaction? (Chapter 5)

(5) Do people with low income have lower travel satisfaction comparing with those with higher income, and what factors contribute to the differences in travel satisfaction between the two groups? (Chapter 6)

Based on these research questions, the key variables that are used in this study are highlighted in Figure 8.

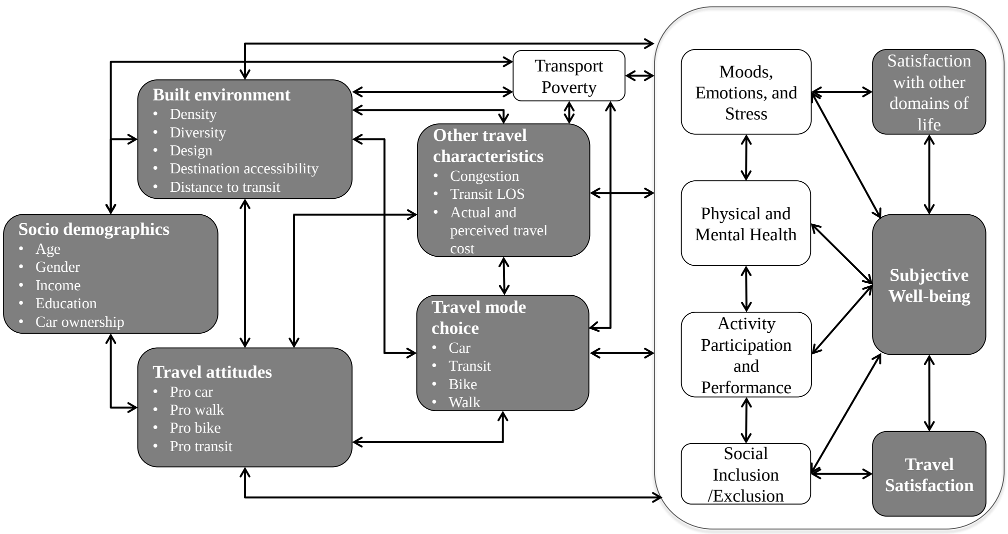

Figure 8 Key variables in this study

This chapter introduces the data collection process and methods of data analysis. Since there are no suitable existing data sets available for this study, a survey was conducted to collect the data. This chapter starts from a detailed introduction of the process of survey design and recruitment of participants. This is followed by a description of the time and methods of distributing the survey. The third section analyzes the characteristics of the sample, including their socio-demographics and travel characteristics. The fourth section provides an overview of all the variables defined in this study. Finally, the statistical methods used for the data analysis are briefly introduced. These are discussed in more detail in Chapters 4 to 6.

Survey Design

The main data used in this study was gathered through a specially designed survey. The study was limited to residents of Xi'an aged over 18 who are in employment within Xi'an and do not work from home. Since no study has been done in terms of the relationship between commuting and subjective wellbeing in a Chinese context, brief and informal interviews with several small groups of local residents with different socio-demographic characteristics were first conducted to capture the basic characteristics and residents' immediate perception of their daily commute and well-being. The participants were recruited through recommendations by my relatives, friends, and previous colleagues in Xi'an. Finally, I was able to interview with eight persons worked in different industries, including two from property consultant firms, two from paint factories, two from government agencies, and two from universities. These interviews helped to design and revise the questionnaire used for the main data collection. For example, the commute modes, e-bike and worker bus, which are rarely used as travel modes in western context, were included in my survey as travel options after the interviews. Before distributing the final survey, a pilot study with 168 participants was conducted between early August and late September in 2012, aiming to test the validity of the survey questions. As a result two questions regarding the measurement of travel satisfaction were dropped because they showed insufficient differences with other items measuring travel satisfaction and deleting them helps to reduce the burden of respondents. Several other questions that are not directly relevant to this study were also deleted to reduce the burden of respondents. The final questionnaire used for this study was attached in the Appendix A.

Participants for the questionnaire survey were recruited through their employers and the survey was conducted at their employers' sites. Employers were sampled by industry type from the current industry listings (catalogues); a quota-based approach was taken to ensure that each industry type was represented in the survey. Once companies were selected, they were contacted to ask their permission to distribute the questionnaire to their employees. For those who accepted, a letter to explain the purpose of the survey, a consent form and a link to the web version of the survey were sent to the person in charge, and then distributed to the employees through their internal mailbox or instant messaging software. For those employees, where it was difficult to obtain internet access, such as those working in factories or banks, the survey and consent form were distributed in paper and/or e-form format. All participants were given a small gift to thank them for their participation.

The survey gathered data on individuals' (1) socio-demographic information, such as age, income, employment status, education, etc.; (2) details of their most recent commuting journey, including travel time and mode choice; (3) current home and job locations; (4) self-reported physical and mental health; (5) travel satisfaction; and (6) satisfaction with life.

Pilot Study

A pilot study was conducted between early August and late September in 2012, aiming to test the validity of the survey questions. The survey was sent to randomly selected staff worked in three types of industries, a paint factory, a property consultancy firm and a construction firm. Finally, I received 168 responses from 200 surveys. Although the sample size is small, the preliminary analysis presented some interesting results. Table 1 summarized some characteristics of the sample. The average age of the respondents is 35, 47% are female, average education level is college degree, and 51% have driver license. On average, every household have 3-4 persons including 1-2 children, 1-2 vehicles, 1-2 bicycles, have lived in current home for over ten years, and have worked in current workplace for about 7 years.

Table 1 Sample characteristics of pilot study

	N	Minimum	Maximum	Mean	Std. Deviation
age	158	18.00	67.00	34.51	10.25
Gender (Female =1)	164	.00	1.00	.47	.50
Education	163	1.00	6.00	3.03	1.22
Household income before taxes	166	1.00	7.00	1.68	1.10
Household Size	168	1.00	7.00	3.52	1.36
# Children	157	1.00	3.00	1.55	.64
Do you have a valid driver license	161	.00	1.00	.51	.50
# Vehicles	167	1.00	4.00	1.43	.67
# bicycles	167	1.00	4.00	1.86	.92
Years lived in your current home?	148	.10	50.00	10.16	10.29
Years worked in your current workplace?	158	.10	33.30	7.33	9.31

Figure 9 illustrates the relative easiness to use each type of travel mode to commute. The score is from 1 (very difficult) to 4 (very easy). Results indicate that walking is the easiest commuting mode, followed by bike and bus, and drive-alone and carpools are the most difficult commuting mode. These results should be interpreted with caution due to the small sample size.

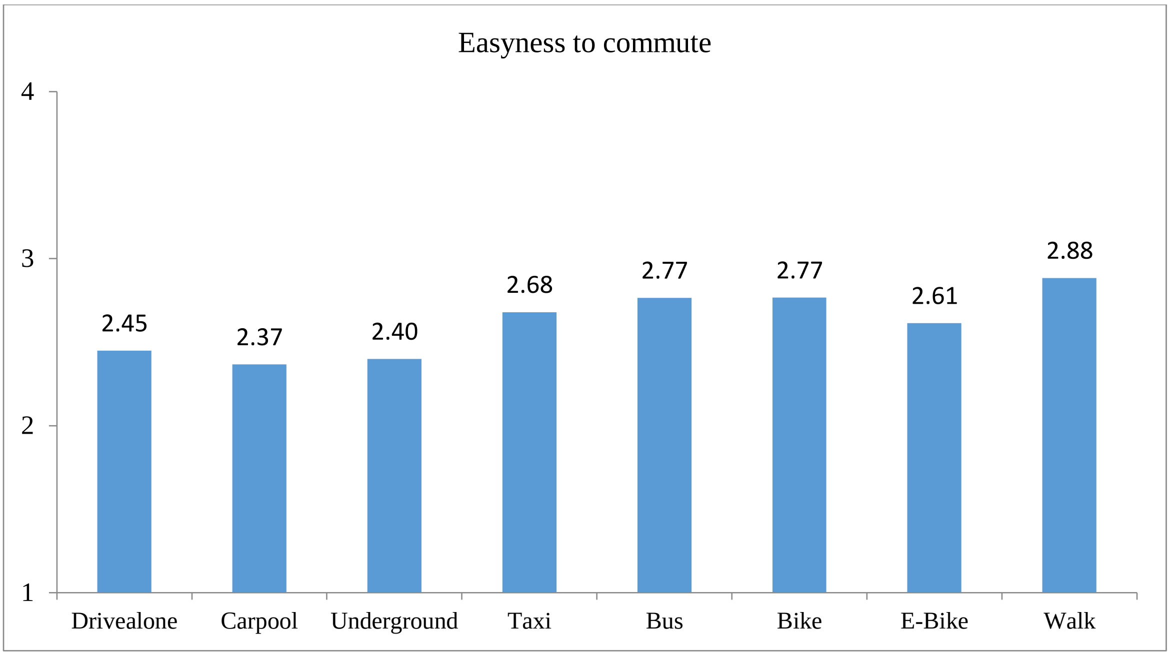

Figure 9 Easiness to commute by different travel mode (pilot study)

The relative importance of different factors on travel mode choice is presented in Figure 10. Each respondent was asked to assess the importance of a list of factors on their travel mode choice using a 5-point scale, from 1 (not at all important) to 5 (very important). The top factors influencing individual travel mode choice are "Provides safety from traffic", "Reduce environmental impact", and "Save time".

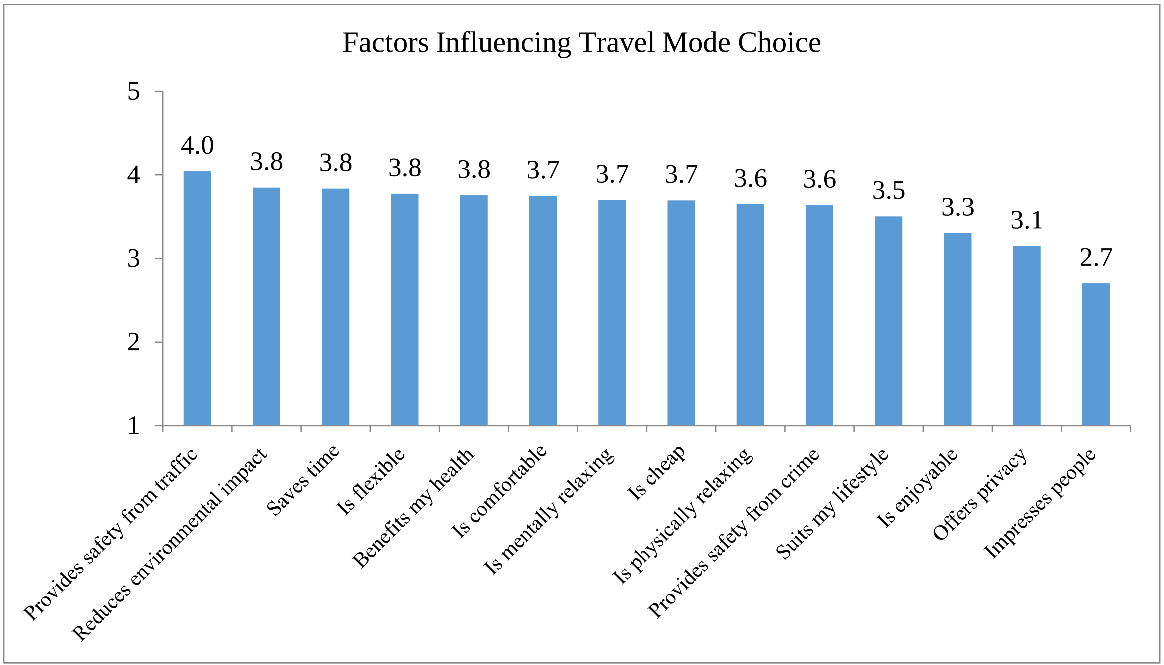

Figure 10 Factors influencing travel mode choice (pilot study)

The travel mode choice for yesterday commuting is summarized in Figure 11, which reflects a diversity of mode choice. About 25% of respondents choose drive alone or carpool, 20% choose walking, 21% choose bike or e-bike, 18% choose public transit (bus and subway), 2% choose worker bus, and 2% choose taxi.

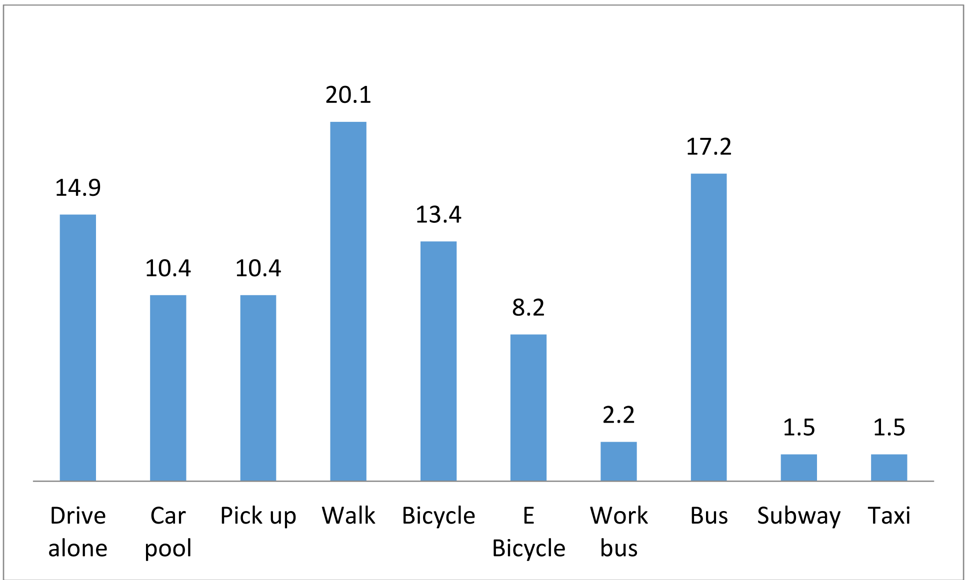

Figure 11 Travel mode choice of yesterday commuting (pilot study)

The measure of travel satisfaction is derived from Satisfaction with Travel Scale (STS) developed by Ettema et al., 2011. The details of STS scale are introduced later in

Measurement section. Nine items are used to capture the affective and cognitive components of the respondents related to daily commute, and each item is scored from -3 to 3. Cronbach's alpha for the nine items is 0.877, indicating the internal consistency among the items is very good. The mean score of the nine items is used to measure the overall satisfaction with the travel.

Figure 12 illustrates the association between travel mode and travel satisfaction. The respondents who walk for their daily commuting have the highest level of satisfaction with commuting. Also, those who drive to work have relatively high level of travel satisfaction, followed by those who ride bicycle and e-bicycle, and those who use bus and carpool. Those who were picked up by other drivers for commuting have the lowest level of satisfaction. However, these results should be interpreted with caution due to the small sample size.

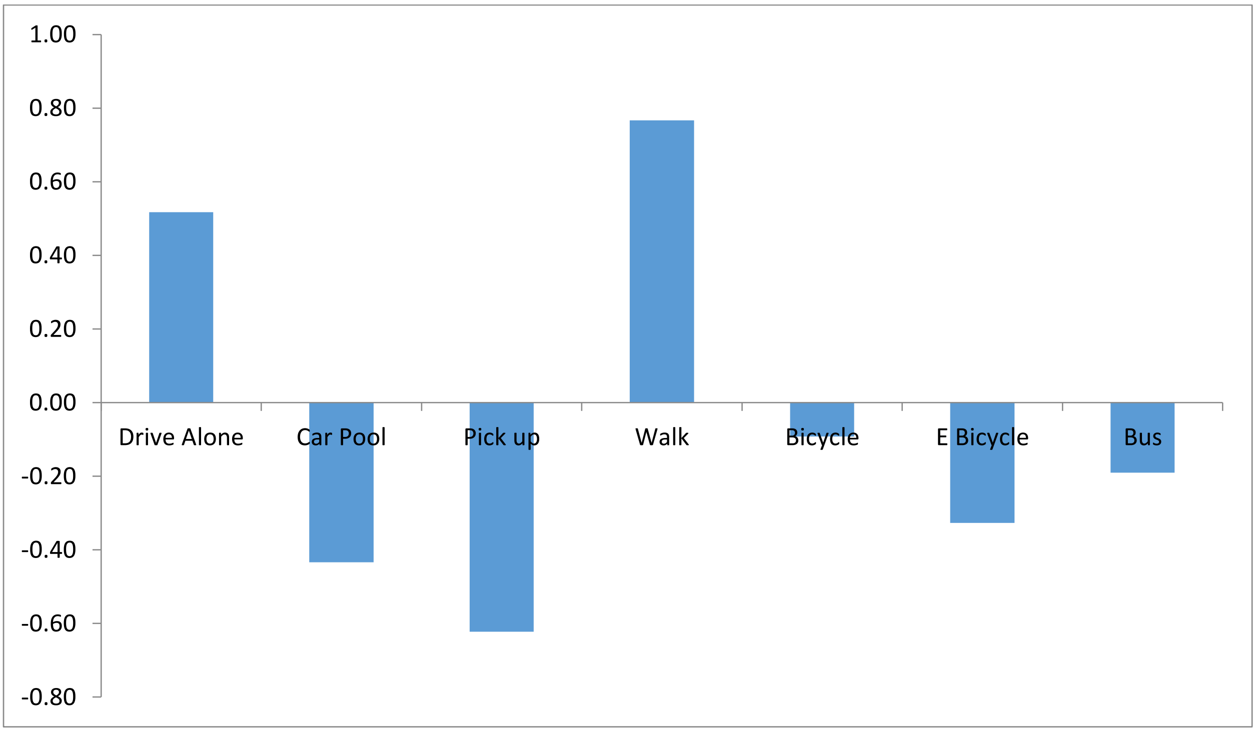

Figure 12 Satisfaction with travel by travel modes (pilot study)

The associations between commuting time, travel satisfaction, and life satisfaction were also tested, the results indicated that commuting time ($r= -.275$, $p<.001$) was negatively associated with travel satisfaction. However, the association between commuting time and life satisfaction was not significant. Further exploration of the interactive effect of commuting time and mode on travel satisfaction is needed.

Figure 13 shows the relationship between travel mode and subjective well-being. Subjective well-being was measured using the Satisfaction with Life Scale (SWLS) developed by Diener et al., 1985. The detailed description of SWLS scale is in the following *Measurement* section. The mean value was calculated based on the scores of the five questions of SWLS scale. Each question was coded from 1 (strongly disagree) to 5 (strongly agree). Results indicates that those choosing drive alone for daily commuting has the highest well-being, this is followed by those who commute by walk, ride regular bicycle and take transit. Those riding E-bike to commute have the lowest well-being.

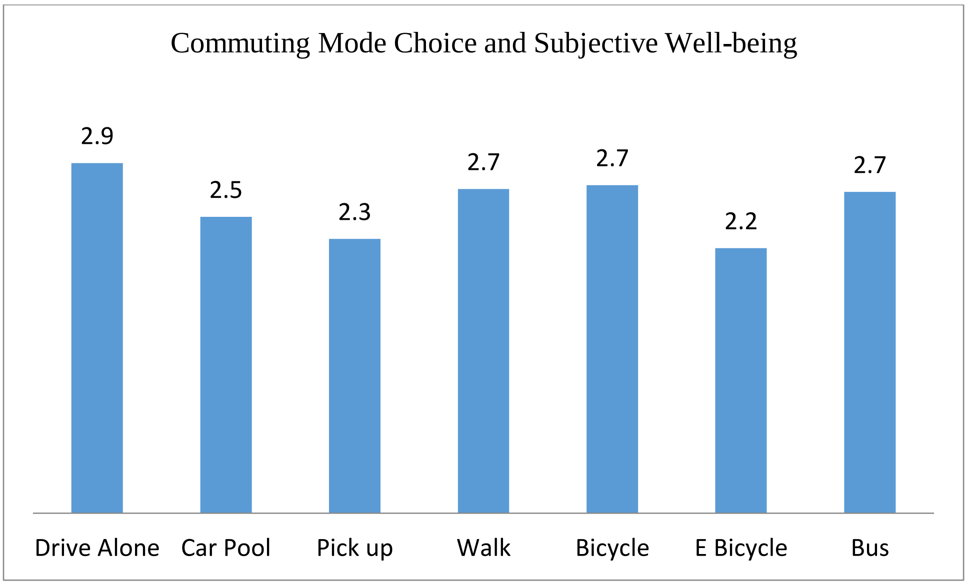

Figure 13 Commuting mode choice and subjective well-being (pilot study)

The correlates of commuting well-being, overall well-being are shown in Table 2. The result shows a significant relationship between commuting well-being and overall well-being. Further, income was positively associated with life satisfaction, indicating that high-income people in Xi'an are happier than low-income people. Those having children are less satisfied with the commuting than those without children. As expected, longer commuting time was negatively associated with commuting satisfaction. Surprisingly, variables related to the transport level of services, such as crowd, transfer, congestion, were not significantly associated with commuting satisfaction. This is probably due to the small sample size.

Table 2 Correlates of Commuting Well-being and Overall Well-being (pilot study)

	Commuting Well-being	**Overall Well-being**
age	-.164	-.060
Income	.078	.184*
Household number	.083	.037
Vehicle number	-.025	.126
Bicycles number	-.010	.090
Children	-.245*	.037
gender	.120	.111
Education	-.021	-.018
Time for living in current location	-.036	-.241*
Time for working in current work place	-.197	-.225*
Time for commuting	-.237*	.021
Crowded about light rail/subway?	-.148	.137
Need Transfers?	-.140	.001
Congested on the streets?	-.028	.283**
Commuting Well-being	1.000	.252*
Overall Well-being	.252*	1.000

**. Correlation is significant at the 0.01 level (2-tailed).*. Correlation is significant at the 0.05 level (2-tailed).

Pilot survey helps to test the questionnaire and provide some hints for the following main data collection. From pilot data, the results proved the hypothesis, which shows the positive and significant, correlates between commuting satisfaction and overall well-being. However, the sample size of pilot data is not enough to cover different catalogues of industry as well as each travel mode to offer persuading results. Thus, more companies that cover each industrial category were targeted in the main data collection. Secondly, companies with computer and internet could answer internet survey, which is more environmental-friendly and economic. Since the survey is time-consuming, incentive gift is a useful way to spur more responses. Thirdly, through the pilot data collection, it shows that the local residents are sensitive to local language and it is easier to get a response by speaking dialect rather than mandarin. The other point worth to pay attention is the local people accept acquaintances culture so that the response rate of a survey that is disseminated by a referee is obvious higher than sending them directly.

Data Collection

Following the pilot study, the main survey was conducted between May 15th and June 30th 2013. 1364 valid surveys were collected, including 794 web-based surveys and 570 paper-based surveys. I compared answers of several survey questions that were conducted by paper and by internet, and I did not find significant differences between them. Further, several previous studies that evaluate the effects of using different modes of survey on results found virtually no differences between paper and web modes of survey in terms of participants' responses (Knapp and Kirk, 2003; Young et al., 2000). After excluding cases with a lot of missing data, 1215 cases were used for the data analysis. The distribution of sample in each industrial category is shown in Figure 14. The sample in other industries occupied 15% of all sample size because survey was send to military units which are not included into any catalogues in Census due to confidential issues. A comparison between the sample and census data on the employment in different industrial categories is shown in Figure 15.

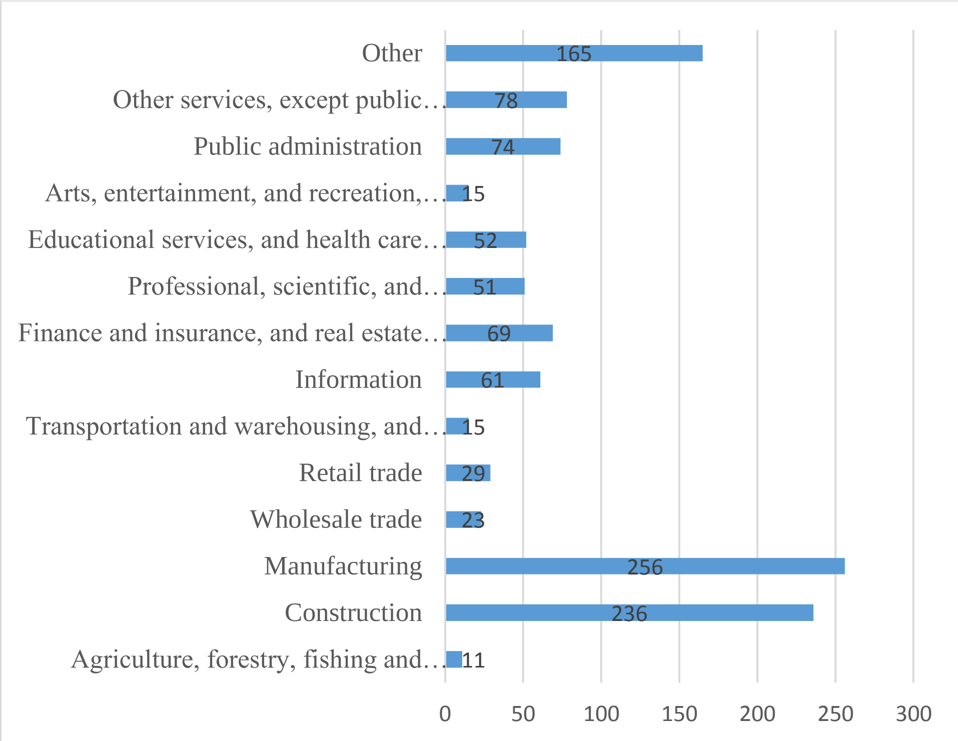

Figure 14 Number of survey samples in different industry categories

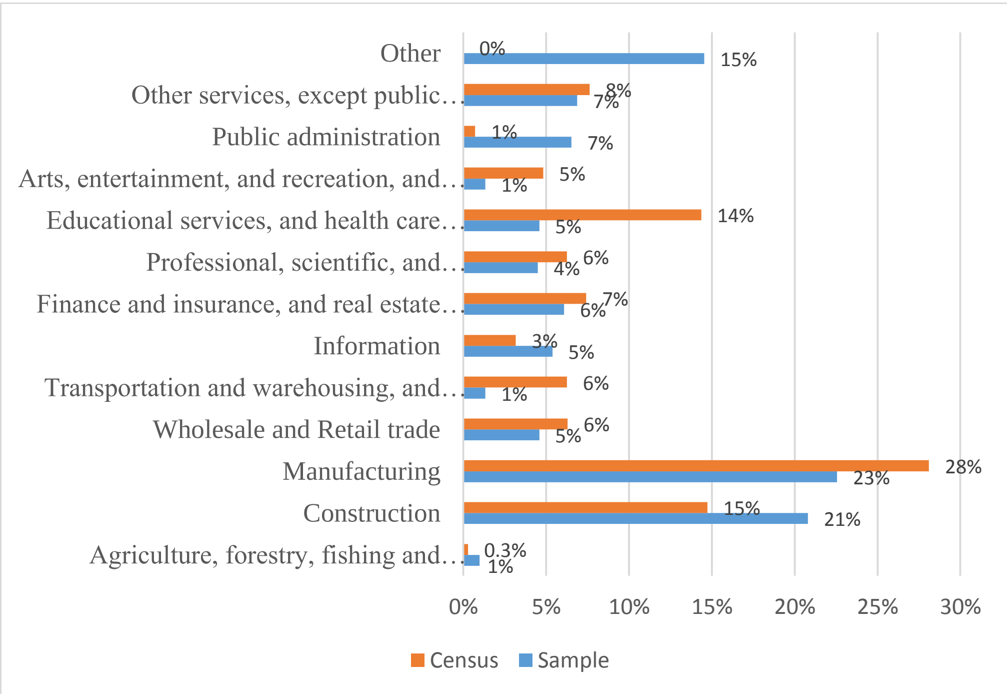

Figure 15 Comparison of sample and census data in different industry categories

Table 3 presents the sample characteristics. In general, the survey captures a variety of population of the Xi'an city. Even with the large sample, the sample is not perfectly representative of the working population. The respondents were more likely to be female (52% vs. 49% in the region), have larger household size (3.5 persons vs.

2.8 persons in the region) and have higher annual income (¥42,000 vs. ¥33,100 in the region[1]). However, this limitation is not expected to materially affect the analysis and results; this is because my focus is on investigating the associations between the commuting and SWB, rather than on describing the patterns and characteristics of commuting and SWB of the city (Babbie, 2007).

Table 3 Sample characteristics

Socio-demographics	Sample Statistics	Census Statistics (2012)
Average household numbers	3.5	2.8
Average number of children in the household	0.6	
Average number of full-time worker	2.0	1.5
% Having a drive license	56%	
% Female	52%	49%
% work in enterprises	84.5%	76.2%
% work in government	2.1%	6.0%
% work in public agencies and organizations	13.4%	17.8%
Average age	33.7	
# Cars in household		
0	49%	
1	41%	
2	8%	
3 and more	2%	
# bike/e-bike in household		
0	45%	
1	35%	
2	16%	
3 and more	4%	
Marriage Status		
single (never been married)	28%	
married	65%	
living with partner	4%	
separated or divorced	2%	
Education Level		
junior high school or less	4%	
high school or technical secondary school	11%	
Some College	36%	
bachelor's degree	40%	
master's degree	8%	

[1] ¥42,000≈US$6,853, ¥33,100≈US$5,401

doctoral or professional degree	2%	
Annual Income		¥33,100
less than ¥10,000	17%	
¥10,000-¥19,999	14%	
¥20,000-¥29,999	18%	
¥30,000-¥49,999	20%	
¥50,000-¥74,999	13%	
¥75,000-¥99,999	8%	
¥100,000-¥149,999	6%	
¥150,000 and over	3%	
Relative Income		
Higher than peers/friends	13%	
Lower than peers/friends	52%	
Almost the same	35%	

Travel Characteristics of the Sample

Table 4 provides the commuting mode choice, commuting distance and time. In terms of commuting mode choice, around 36% of the respondents choose bus for their most recent commuting, followed by car (26%, combined drive alone and carpool), walk (19%), bicycle (10%: combined bicycle and E-bicycle), rail (4%), taxi (3%), and works bus (2%). In addition, transit commuters have the longest commuting distance and time, while the walking commuters have the shortest commuting distance and time.

Table 4 Average commuting distance and time by travel modes

	Mode Share	Job-housing Distance (GIS calculated airline distance, meters)	Self-reported Commuting Time (minutes)
Bus	36%	6,610	51
Car	26%	6,340	35
Walk	19%	1,924	25
Bicycle	4%	2,942	28
E-bicycle	5%	4,082	29
Rail	4%	8,262	45
Taxi	3%	5,313	39
Works bus	2%	2,848	44

Table 5 provides the characteristics of the car commuters, either as the sole occupant or as part of a carpool. Amongst these respondents, around 84% rely on their private car, whereas 16% use a car provided by their employers; 57% reported the road was somewhat congested and 33% reported the road was very congested, whereas only 10% reported the road was not congested at all.

Table 5 Characteristics of the car commute

	%
Car type	
Private car	84.1
Company car	15.9
Parking charge	
Pay to park	56.8
Free for parking	43.2
Traffic congestion levels	
Not at all congested	10.2
Somewhat congested	57.2
Very congested	32.6

Among those respondents who choose transit to commute, around 43% need to transfer during the trip, and 36% of those who did transfer needed to transfer more than once. Almost all of the transit riders reported that the bus or the rail they used was crowded during the commute (Table 6).

Table 6 Characteristics of the transit commute

	%
Need transfers?	
Yes	42.6
No, get there directly	57.4
Number of transfers?	
1	64.0
2	30.6
3+	5.4
How crowded was the bus or rail?	
Not at all crowded	2.6
Somewhat crowded	45.6
Very crowded	51.9

Measurements

This section introduces the measurement of the variables used in this study. Overall, five sets of variables are defined and measured, including subjective wellbeing, the built environment, travel attitudes, travel characteristics, and socio-demographics. A summary of the variables and their measurements, coding and sources are provided at Table 11, Table 12, Table 13, Table 14 and Table 15

Subjective Wellbeing

Early effort of measuring SWB has been emphasized on the measurement of affective components of SWB. For example, mood and emotions can be assessed by the Affect Balance Scale (Bradburn and Noll, 1969), the Affectometer (Kammann and Flett, 1983), the Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988) or the Memorial University of Newfoundland Scale of Happiness (MUNSCH) (Kozma and Stones, 1980). The measurement of general life satisfaction received less attention until the Satisfaction with Life Scale (SWLS), developed by Diener et al. (1985). Subjective well-being in this study was measured using the Satisfaction with Life Scale (SWLS) developed by Diener et al. (1985). Satisfaction with life is a cognitive and judgmental process, where individuals assess the quality of life based on their unique set of criteria (Shin and Johnson, 1978). SWLS has been widely used (Pavot and Diener, 1993) and is a global assessment of one's life rather than only one's satisfaction with specific domains. The SWLS has shown strong internal reliability and moderate temporal stability (Pavot and Diener, 1993). Also, the SWLS has shown sufficient sensitivity to detect the change in life satisfaction during the course of clinical intervention (Pavot and Diener, 1993). The five items for measuring the SWLS are: (1) In most ways my life is close to my ideal; (2) The conditions of my life are excellent; (3) I am satisfied with my life; (4) So far I have gotten the important things I want in life; (5) If I could live my life over, I would change almost nothing. Each item is measured on a 1-7 Likert scale, from strongly disagree to strongly agree.

As a supplement to SWLS, this study also employed the measure developed by Office for National Statistics (ONS) of U.K., which categorizes SWB measures into three types: (1) evaluation (global assessment); (2) experience (feelings over short periods of time); and (3) 'eudemonic' (reports of purpose and meaning, and worthwhile things in life) (Dolan et al., 2011). One question was designed to measure the overall life satisfaction. Two questions were designed to measure the positive and negative affect separately, given to the evidence that positive and negative affect are somewhat independent of one another (Diener et al., 1999). Another question was designed to measure the eudemonic part, which aims to capture the underlying psychological needs of individuals, such as meaning, autonomy, control and connectedness (Ryff, 1989). From 2011 ONS has introduced the above four SWB measures on ONS household surveys, including the Annual Population Survey (APS) and the Opinions Survey (OPN) (ONS, 2012). The four questions are provided as follow:

- Overall, how satisfied are you with your life nowadays

- Overall, how happy did you feel yesterday?
- Overall, how anxious did you feel yesterday?
- Overall, to what extent do you feel that the things you do in your life are worthwhile?

Each question is measured on a 0-10 scale, where 0 is not at all and 10 is completely.

Satisfactions with other important domains of life were measured by asking the respondents to indicate the extent they agree with items adapted from Personal Well-being Index (PWI) (International Wellbeing Group, 2013). PWI has shown relatively high internal consistency (Cronbach's alpha: 0.70-0.85). Comparing with SWLS, PWI focuses on several specific domains that are closely related to well-being, and thus helps to identify which specific domain contributes to the changes of overall well-being. The items include information about respondent's health, personal relationships, community involvement, future security, and spirituality. Each question is measured on a 0-10 scale, where 0 is not at all satisfied and 10 is completely satisfied. In detail, PWI asked the respondents to assess how they satisfied with the following aspects of life:

- Your standard of living?
- Your health?
- What you are achieving in life?
- Your personal relationships?
- How safe you feel?
- Feeling part of your community?
- Your future security?

Though various scales were reviewed and measured in this study, the SWB used in the following analysis is primarily based on SWLS scale. Please also note the term

SWB is used interchangeably with life satisfaction in this study, which only includes the cognitive components of SWB. The affective components of SWB will be referred independently.

Travel Satisfaction

Travel satisfaction was measured using The Satisfaction with Travel (STS) Scale developed by Ettema et al. (2011). This measure includes both affective and cognitive components related to daily travel, and consists of nine items scoring from -3 to 3 to assess each aspect of travel experiences. In this study only seven of the nine items were used because after the pilot study, I found the two items “Fed up- engaged “and “Travel was low-high standard” showed insufficient differences with items “bored-enthusiastic” and “worst-best” respectively after translating into Chinese. Reducing to seven items also helps to reduce the burden of the respondents. The deletion of the two items does not influence the results at all, as indicated by the very high internal consistency among the rest of the seven items. The seven items for measuring commuting satisfaction are: (1) I felt time was pressed - I felt time was relaxed during the commute; (2) I was worried I would not be in time – I was confident I would be in time; (3) I was stressed – I was calm; (4) I was tired – I was alert; (5) I was bored – I was enthusiastic; (6) I think this commute is the worst – I think this commute is the best I can think of; (7) I think this commute worked well – I think this commute worked poorly. Travel satisfaction measured in this study is based on the respondents’ evaluation of the whole commuting journey or the main travel leg of the commute, depending on their interpretation of the question. Individual stages of the trip were not evaluated separately. Other travel characteristics, such as travel mode choice and level of service of transit, were measured by asking the respondents to recall the characteristics of their most recent commuting trip. For example, I asked “for your most recent commute to work, what is your primary mode of transportation to work? By 'primary' I mean the mode you use for the longest duration of your trip" as the measure of travel mode choice, and I asked "for your most recent commute to work, how crowded was the bus?" as a measure of level of service of transit.

Built Environment

All responses with a valid home and work address were geocoded in GIS using ArcGIS 10.2 for Desktop. The spatial distribution of the home and job locations is presented in Figure 16. The street network GIS layer was extracted from OpenStreetMap (OSM, 2014). The land use GIS layer was acquired from the Xi'an Bureau of City Planning. Both ¼-mile and ½-mile (equivalent to 5-minute and 10-minute walking) Euclidean buffers were created around each home and job location. Due to lack of precise GIS data on street network, especially the data of minor streets within the residential neighborhood, I decided not use the network buffer as the unit to calculate the built environment variables. The built environment characteristics around each home and job location were calculated by overlaying the buffers with the land use GIS layer. Researchers have often used the 5Ds to describe the built environment: density, diversity, design, destination accessibility, and distance to transit (Ewing and Cervero, 2010). Following this guideline and the availability of the data, the following built-environment variables were calculated at both home and job locations: (1) Euclidian distance to the nearest park (*destination accessibility*); (2) distance to the city center (*destination accessibility*); (3) rail station within one quarter and one half mile (*distance to transit*); (4) number of bus stops within one quarter and one half mile (*distance to transit*); (5) average block size within one quarter and one half mile (*design*); (6) ratio of commercial land use (includes: shopping mall, retails, restaurants, and recreational sites) within one quarter and one half mile (*diversity*); (7)

proportion of green land use (includes: open space, city green buffer, park, square) within one quarter and one half mile (*diversity*); (8) street nodes density (# street intersections with 4 or more directions) within one quarter and one half mile (*design*). There are some inconsistencies between the 5Ds and the built environment variables measured in this study, but were limited to the GIS data I have. The census data of Xi'an only includes population data at the district level, without disaggregate data at the street level, thus the population density could not be measured in this study. Other built-environment variables that are also important were not measured in this study due to lack of data, such as quality of streetscape and sidewalk coverage. Further, this study does not include any subjective measures on the built environment. The objective and subjective measures may have different effects on travel behavior, travel satisfaction, and SWB. Lacking a comprehensive measurement of the built environment characteristics, the results that are relevant to the built environment in this study should be interpreted with caution.

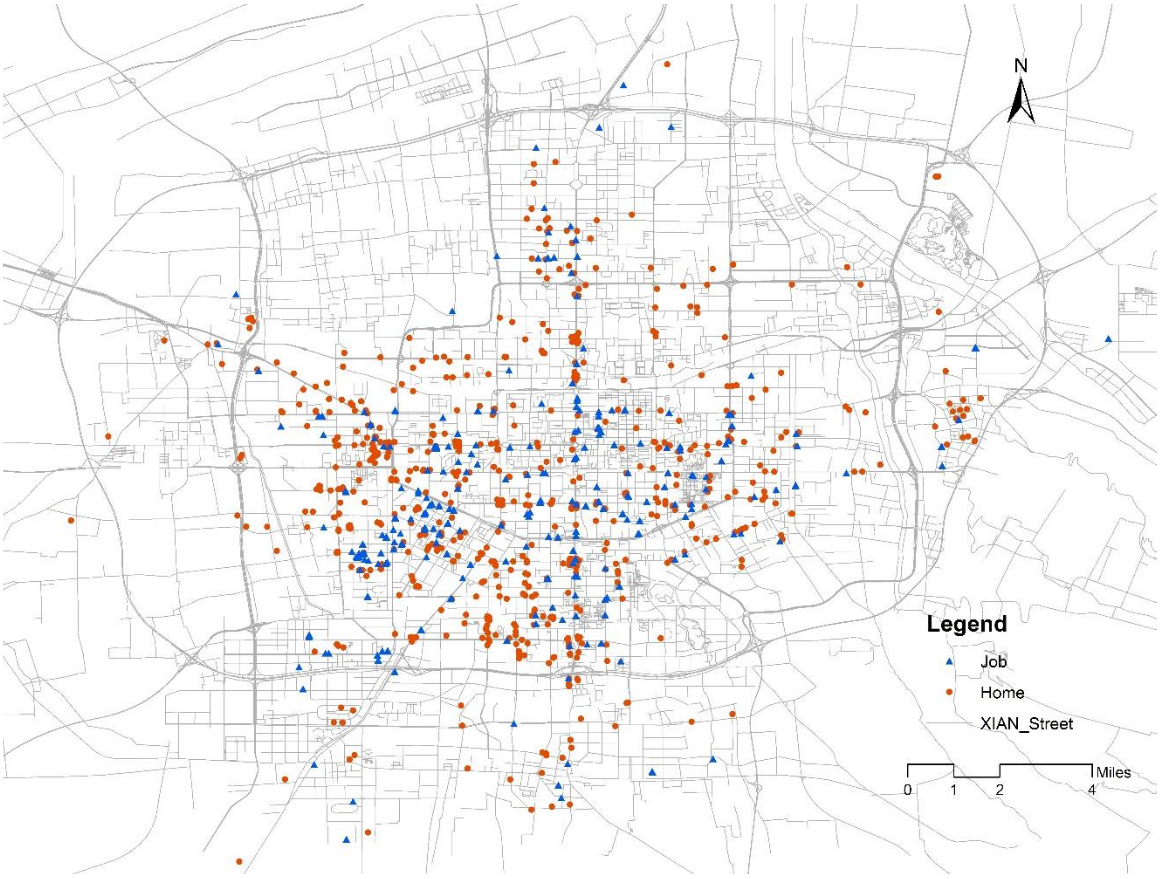

Figure 16 Distribution of home and job locations of the sampling employees

Due to the collinearity of the individual built-environment variables, exploratory factor analysis was conducted to extract the underlying dimensions of the built environment at home and job locations. Through the factor analysis, the dimensions of the built environment reduced, and this helps to keep the SEM model parsimonious. The factor analysis also helps to reduce the measurement errors from each individual measures. The following built-environment variables were included for the factor analysis: (1) distance to the park; (2) distance to the city center; (3) rail station within quarter mile; (4) rail station within half mile; (5) number of bus stops within quarter mile (6) average block size; (7) ratio of commercial land use within quarter mile; (8) ratio of green land use within quarter mile; (9) street nodes density. The factor analysis was conducted separately for the built environmental variables at home and job. Through the factor analysis (Varimax rotation method was used) based on the nine indicators of home environment, three principal factors were extracted: (1) access to transit (characteristics: bus stops and rail stations are within walking distance); (2) suburban big block (characteristics: far away from city center, transit is not accessible, and many cul-de-sacs); and (3) access to green (characteristics: close to park and green areas). The three factors for home environment explained about 61% of the variance. Similarly, three principal factors were extracted for job environment: (1) access to transit; (2) access to green; and (3) suburban big block. The three factors for job environment accounted for about 63% of the variance. The factor loadings of each individual built-environmental variable were presented in Table 7 and Table 8.

Table 7 Factor analysis on indicators of home environment

	Access Transit	Suburban Big Block	Access Green
Airline distance from home to nearest park	0.095	**0.562**	**-0.578**
Airline distance from home to city center	-0.123	**0.765**	0.085
Whether rail station present within 1/4-mile of home	**0.886**	-0.030	0.070
Whether rail station present within 1/2-mile of home	**0.903**	-0.008	0.070
Average perimeter of the street blocks within 1/4-mile of home	-0.073	**0.714**	0.024
% green land use within 1/4-mile of home	0.075	0.087	**0.893**
Number of bus stops within 1/4-mile of home	**0.605**	**-0.528**	-0.052
% commercial land use within 1/4-mile of home	0.462	-0.301	-0.081
Number of street intersections with 4+ directions within 1/4-mile of home	0.141	**-0.539**	0.155

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Bold fonts indicate absolute value of loading is larger than 0.5.

Table 8 Factor analysis on indicators of job environment

	Access Transit	Access Green	Suburban Big Block
Airline distance from job to nearest park	0.135	-0.493	**0.658**
Airline distance from job to city center	-0.334	0.283	**0.685**
Whether rail station present within 1/4-mile of job	**0.838**	-0.176	-0.004
Whether rail station present within 1/2-mile of job	**0.863**	-0.226	-0.042
Average perimeter of the street blocks within 1/4-mile of job	-0.081	**0.598**	0.163
% green land use within 1/4-mile of job	-0.049	**0.865**	0.001
Number of bus stops within 1/4-mile of job	**0.518**	-0.337	**-0.506**
% commercial land use within 1/4-mile of job	**0.617**	0.308	-0.076
Number of street intersections with 4+ directions within 1/4-mile of job	-0.020	-0.070	**-0.700**

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Bold fonts indicate absolute value of loading is larger than 0.5.

Attitudes

Attitudes were measured based on 31 survey questions adapted from (Handy et al., 2005) that assess the respondents' attitudes regarding their daily travel using a 5-point Likert scale from strongly disagree (1) to strongly agree (5). In order to reduce the dimensions, exploratory factor analysis was conducted based on the 31 survey questions. The initial eigenvalues showed that the first eight factors explained 58% of the variance, with values greater than one. Different factor solutions were examined using varimax rotations of the factor loading matrix which did not improve the results. I chose the original eight factor solution, because of the 'leveling off' of eigenvalues on the scree plot (Figure 17) after eight factors, the insufficient number of primary loadings, and the difficulty of interpreting the ninth and subsequent factors. The factor loading matrix of this eight factor solution is presented in Table 9. The eight factors are: (1) Fuel efficiency; (2) Pro-bike; (3) Car safer; (4) Pro-transit; (5) Pro-walk; (6) Pro-driving; (7) Environment friendly; (8) Positive Travel. The results of my factor analysis is slightly different from Handy et al. (2005), who identified six underlying dimensions from factor analysis.

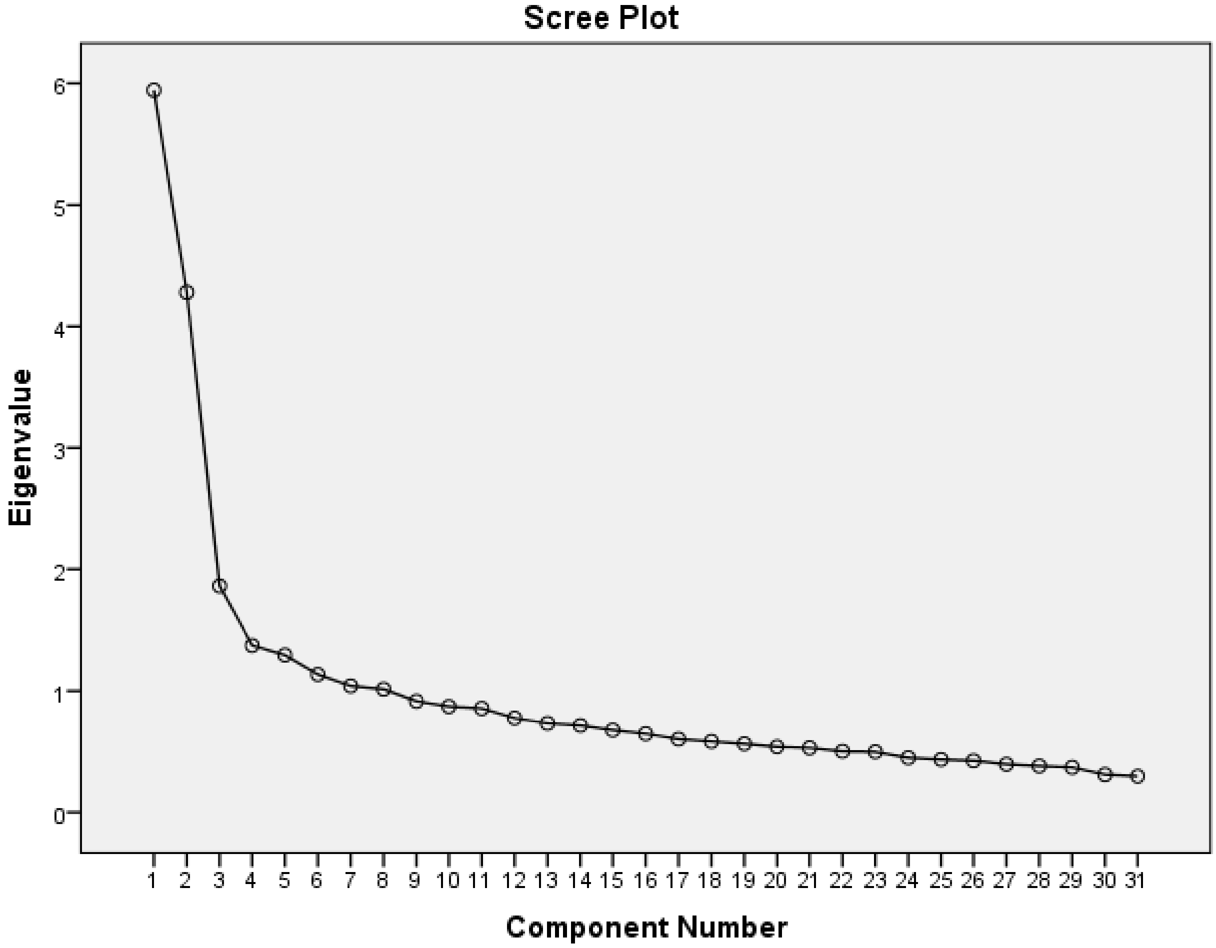

Figure 17 Scree plot of factor analysis on travel attitudes

Table 9 Factor analysis for attitudes

	Fuel Efficiency	Pro Bike	Car Safer	Pro Transit	Pro Walk	Pro Driving	Environment	Positive Travel
I prefer to organize my errands so that I make as few trips as possible	**0.545**	0.063	0.006	-0.054	0.432	0.182	0.060	0.192
The price of gasoline affects the choices I make about my daily travel	**0.658**	-0.033	0.131	0.231	-0.073	-0.034	0.136	-0.053
The region needs to build more highways to reduce traffic congestion	**0.568**	0.200	0.103	-0.226	0.076	0.246	-0.025	-0.123
Fuel efficiency is an important factor for me in choosing a vehicle	**0.662**	0.009	0.117	0.154	0.061	0.066	0.293	0.020
I often use the telephone or the Internet to avoid having to travel somewhere	**0.656**	0.048	0.078	-0.066	0.208	0.064	0.154	-0.039
When I need to buy something, I usually prefer to get it at the closest store possible	**0.484**	0.287	-0.098	0.028	0.153	0.420	-0.024	-0.043
My household spends too much money on owning and driving our cars	**0.405**	0.108	0.474	0.137	-0.166	-0.034	-0.274	0.035
I like riding a bike	0.047	**0.769**	-0.058	0.242	-0.033	-0.010	0.023	-0.077
I prefer to walk rather than drive whenever possible	0.020	**0.555**	-0.030	0.369	0.469	-0.132	-0.019	0.158
I prefer to bike rather than drive whenever possible	0.021	**0.782**	-0.012	0.177	0.115	0.046	0.120	-0.014
Biking can sometimes be easier for me than driving	0.123	**0.609**	-0.126	0.004	0.258	0.114	0.334	0.078
We could manage pretty well with one fewer car than we have (or with no car)	0.193	**0.414**	-0.311	0.263	-0.110	0.258	0.169	0.136
Traveling by car is safer overall than walking	-0.009	-0.089	**0.655**	0.180	0.109	0.100	0.067	-0.142
I need a car to do many of the things I like to do	0.324	-0.170	**0.504**	-0.139	0.308	0.232	-0.093	-0.136
Traveling by car is safer overall than riding a bicycle	0.024	-0.074	**0.563**	0.045	0.009	0.259	0.320	-0.108
Traveling by car is safer overall than taking transit	0.029	-0.009	**0.736**	-0.059	0.012	0.063	0.081	0.119
Getting to work without a car is a hassle	0.231	-0.025	**0.674**	-0.182	-0.034	0.122	-0.232	0.010
I prefer to take transit rather than drive whenever possible	0.083	0.398	-0.047	**0.691**	-0.004	-0.045	0.020	-0.071
I like taking transit	0.031	0.211	-0.010	**0.725**	0.145	-0.037	0.108	0.141
Walking can sometimes be easier for me than driving	0.082	0.154	-0.191	0.315	**0.544**	0.318	0.143	-0.044
Air quality is a major problem in this region	0.245	0.075	0.215	-0.069	**0.615**	-0.011	0.158	-0.161
I like walking	0.016	0.429	0.025	0.224	**0.550**	0.009	0.105	0.295
I am willing to pay a toll or tax to pay for new highways	0.084	0.080	0.217	-0.010	0.114	**0.688**	-0.030	0.051
I like driving	0.143	-0.067	0.430	-0.055	-0.118	**0.646**	0.111	0.044
I would like to own at least one more car	0.283	-0.120	0.278	-0.037	0.343	**0.431**	0.039	-0.301
Public transit can sometimes be easier for me than driving	0.175	0.078	0.006	0.357	0.143	0.111	**0.612**	-0.008

I try to limit my driving to help improve air quality	0.256	0.321	0.053	0.069	0.246	0.008	**0.581**	0.115
Vehicles should be taxed on the basis of the amount of pollution they produce	0.284	0.334	0.030	-0.176	-0.038	-0.117	**0.506**	0.082
I use my trip to/from work productively	-0.073	0.195	0.186	0.449	-0.043	0.075	0.012	**0.506**
The trip to/from work is a useful transition between home and work	0.371	0.025	0.053	0.132	0.156	0.215	0.118	**0.592**
Travel time is generally wasted time	0.267	0.096	0.248	0.077	0.086	0.168	-0.015	**-0.679**

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Bold fonts indicate absolute value of loading is larger than 0.4.

Method of Analysis

Various statistical methods were applied to analyze the data, primarily including ANOVA test, descriptive analysis, multivariate regression models, and structural equation modeling.

Descriptive analyses were conducted to explore the basic characteristics of the sample. Correlations between any independent variables and dependent variables (e.g. travel satisfaction, subjective wellbeing) were examined using bivariate correlation analysis to identify which variables are significantly correlated with travel satisfaction or subjective wellbeing. The selected variables were then used for the next regression analysis.

Multivariate regression analyses were then conducted to examine the unique contribution of each factor on travel satisfaction or subjective wellbeing after controlling for other factors. For instance, I tested whether the association between commuting time and subjective wellbeing are still significant after controlling for socio-demographics of commuters. The analyses primarily included five types of variables: subjective wellbeing, the built environment, travel attitudes, travel characteristics, and socio-demographics. Since some dependent variables, such as commuting satisfaction and subjective wellbeing, was measured using scales with limited range. I also employed the Tobit model (Tobin, 1958) to handle the censoring characteristic of the dependent variables. The Tobit model is based on an unobserved (latent) continuous dependent variable y_i^* that can take on any value:

$$y_i = \begin{cases} y_i^* & if yL < y_i^* < yU \\ yL & if\ y_i^* \leq yL \\ yU & if\ y_i^* \geq yU \end{cases}$$

$$y_i^* = \beta_0 + \beta_1 S_i + \beta_2 E_i + \beta_3 A_i + \beta_3 C_i + \varepsilon$$

where y_i is the observed variable (commuting satisfaction or subjective wellbeing in this case) for individual i, yL is the value of the left-censoring and yU is the value of right-censoring of the dependent variable, S_i is the socio-demographic characteristics of individual i, E_i is the built environment around individual i's home and job locations, A_i is the individual i's attitudes towards travel, and C_i is the characteristics of the commuting trip by individual i. The Tobit model can be estimated with maximum likelihood estimation (Tobin, 1958).

A limitation of regression analysis, however, is that the interactions within the explanatory variables cannot be examined simultaneously (Fornell and Larcker, 1987). Commuting mode choice and commuting satisfaction, for example, could be two independent variables in regression model to explain the wellbeing, while commuting mode choice might influence commuting satisfaction. This logic relationship cannot be reflected in regression model. Actually, besides direct effect, there are many indirect effects, including moderation and mediation effects, may exist among the variables in this study.

In order to better model the structural relationships between the variables, Structure Equation Model (SEM) was employed to explore the potential direct and indirect effects. For example, does the commuting characteristics directly affect SWB (direct effects), or does it affect commuting satisfaction which then influences travel satisfaction (indirect effects)? The Figure 18 illustrates the direct and indirect effects. Paths b and c are direct effects of commuting satisfaction and commuting behavior on SWB, respectively, and the commuting behavior's influence on SWB through commuting satisfaction is called an indirect effect, which can be calculated by multiplying the coefficients of paths a and b. The indirect effect indicates the portion of the relationship between commuting behavior and SWB that is mediated by commuting satisfaction.

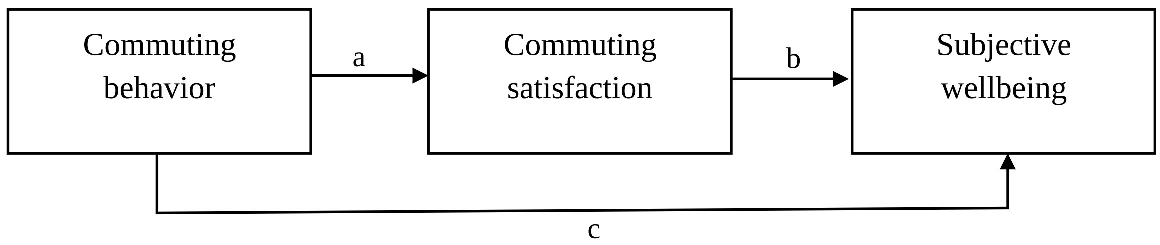

Figure 18 Direct and indirect effects

Structural Equation Modeling (SEM) was used to test the conceptual model examining the relationships among socio-demographics, travel time, travel mode choice, travel attitude and preference, commuting well-being, and overall well-being. Compared to multivariate regression models, SEM enables the researcher to solve simultaneous equations to disentangle causal relationships between many independent variables and many dependent or intermediate variables (Maruyama, 1997). Another advantage of SEM model is its latent variable structure, which allows researchers to use several measured indicators to represent an unobserved factor; in this structure, the latent variable is free of random error (Maruyama, 1997). SEM has been increasingly used in studying the travel behavior.

SEM assumes that observed variables are multivariate normal, and violating this assumption can lead to underestimation of standard errors, even though does not affect parameter estimates (Kline, 2005). The Bollen-Stine bootstrap process and the bootstrapped parameter estimates can help to get the corrected model fit and standard errors when the assumption of multivariate normal is violated (Maruyama, 1997).

Different types of indices are developed to test the model fit of SEM, including absolute fit indices (e.g. $\chi2$, GFI, AGFI, RMR, SRMR etc.), relative fit indices (e.g. IFI, TLI, NFI), parsimony fit indices (e.g. PGFI, PNFI, PNFI2, PCFI), and those based on the noncentrality parameter (RMSEA, CFI, RNI, CI). There is no agreement about a single optimal index or even a set of optimal indices (Maruyama, 1997). Hu and Bentler (1999) empirically examine various cutoffs for many of these measures, and they recommend using a combination of one of the relative fit indices and the SRMR (good models < 0.08) or the RMSEA (good models < 0.06) to minimize Type I and Type II errors. For the relative fit indices, Hu and Bentler concluded that a cutoff value close to 0.95 is needed to conclude there is a relatively good fit. In this study, I reported $\chi2$, CFI and SRMR for each model to judge the model fit. Although it is commonly reported, Chi-square ($\chi2$) is inappropriate as a model fit index because it is sensitive to sample size and several other conditions.

The SEM models were estimated using AMOS 21.0, and the full information maximum likelihood (FIML) procedure was used to estimate the models. FIML works by estimating a likelihood function for each individual based on the variables that are present so that all the variable data are used. FIML outperforms the common methods of handing missing data, such as listwise and pairwise data deletion (Enders and Bandalos, 2001). Because of this, the variables that are only relevant to transit commuters, such as crowd and transfer, were kept in the model, and including them did not reduce sample size in estimation. In addition, for a large sample size, which is the case of this study, the maximum likelihood approach is fairly robust against violations of multivariate normal distribution assumptions of SEM, as shown by many simulation studies (Golob, 2003). It should also be noted that exploratory factor analysis (EFA) on the built environment and travel attitudes were conducted separately from the SEM model. A summary of data and methods used in the following three chapters is in Table 10.

Table 10 Summary of data and methods used in Chapter 4-6

Chapters	***Research Questions***	***Data***	***Methods***
Chapter 4	(1) What commute characteristics, such as journey distance, travel time, travel mode, congestion, level of service etc., influence travel satisfaction, after accounting for socio-demographics? (2) Does travel satisfaction influence overall life satisfaction and well-being, after accounting for socio-demographics and other important domains of life?	survey data	Descriptive analysis Multilinear regression model SEM
Chapter 5	(3) How do the characteristics of the built environment at people's home and job locations influence their travel satisfaction? (4) How do people's attitudes influence their travel satisfaction?	survey data + GIS data	Descriptive analysis Multilinear regression model SEM
Chapter 6	(5) Do people with low income have lower travel satisfaction comparing with those with higher income, and what factors contribute to the differences in travel satisfaction between the two groups?	survey data + GIS data	Descriptive analysis Tobit model

Table 11 Socio-Demographic Variables

Variable	Measurement	Code or unit	sources
HH_Size	Including yourself, how many people live in your household?	count	survey
Children	Do you have children?	Dummy: 1=yes	survey
Worker	Including yourself, how many household members work full-time?	count	survey
Driver_license	Do you have a valid driver's license?	Dummy: 1=yes	survey
Vehicles	How many vehicles are available to you at your home?	count	survey
Bicycles	How many working bicycles do you own?	count	survey
Marital	Which status you belong to?	1= Single, never been married; 2= Married; 3= Living with partner; 4= Separated or divorced ; 5= Widowed	survey
Age	What is your age (in years)?		survey
Gender	Which gender do you most identify with?	Dummy: 1=Female	survey
BMI	Weight in Kilograms / (Height in Meters x Height in Meters)		survey
Health	How do you evaluate your general health condition?	1=Poor; 2=Fair; 3=Good; 4=Very good; 5=Excellent	survey
Education	How many years of school have you completed?	1=Some high school or less; 2=High school; 3=Some college; 4=Travel/vocational school; 5=Associate degree; 6=Bachelor; 7=Master; 8=Doctor	survey
Income	What is your approximate annual income before taxes?	1=Less than 10,000; 2=10,000-19,999; 3=20,000-29,999; 4=30,000-49,999; 5=50,000-74,999; 6=75,000-99,999; 7=100,000-199,999; 8=200,000 or more	survey
Income_relative	Comparing with your close friends, do you think your income is lower or higher?	1=Lower; 2=Equal; 3=Higher	survey
Income_satisfy	Do you satisfy with your current income?	1=Very dissatisfied; 2=Somewhat dissatisfied; 3=Netural; 4=Someshat satisfied; 5=Very satisfied	survey
Immigrant	Are you an immigrant?	Dummy: 1=yes	survey
Employment	What is your current employment status?	1=Not employed; 2=Full time; 3=Part time	Survey

Industry	Please select the industry you work in	1= Agriculture, forestry, fishing and hunting, and mining;2= Construction;3= Manufacturing;4=Wholesale trade;5= Retail trade;6=Transportation and warehousing, and Utilities;7= Information;8= Finance and insurance, and real estate and rental and leasing;9= Professional, scientific, and management, and administrative and waste management services;10= Educational services, and health care and social assistance;11= Arts, entertainment, and recreation, and accommodation and food services;12= Other services, except public administration;13= Public administration;14= Other	survey

Table 12 Transportation Variables

Variable	Measurement	Code or unit	sources
DriveAlone_freq	At this time of year, how often do you use each of the following as your primary mode of transportation to work?	1=4-5 days/week; 2=2-3 days/week; 3=1 day/week; 4=1-3 days/month; 5=Less than once a month; 6=Never	Survey
Carpool_freq	At this time of year, how often do you use each of the following as your primary mode of transportation to work?	1=4-5 days/week; 2=2-3 days/week; 3=1 day/week; 4=1-3 days/month; 5=Less than once a month; 6=Never	Survey
E_bicycle_freq	At this time of year, how often do you use each of the following as your primary mode of transportation to work?	1=4-5 days/week; 2=2-3 days/week; 3=1 day/week; 4=1-3 days/month; 5=Less than once a month; 6=Never	Survey
Underground_freq	At this time of year, how often do you use each of the following as your primary mode of transportation to work?	1=4-5 days/week; 2=2-3 days/week; 3=1 day/week; 4=1-3 days/month; 5=Less than once a month; 6=Never	Survey
Taxi_freq	At this time of year, how often do you use each of the following as your primary mode of transportation to work?	1=4-5 days/week; 2=2-3 days/week; 3=1 day/week; 4=1-3 days/month; 5=Less than once a month; 6=Never	Survey
Bus_freq	At this time of year, how often do you use each of the following as your primary mode of transportation to work?	1=4-5 days/week; 2=2-3 days/week; 3=1 day/week; 4=1-3 days/month; 5=Less than once a month; 6=Never	Survey
Bicycle_freq	At this time of year, how often do you use each of the following as your primary mode of transportation to work?	1=4-5 days/week; 2=2-3 days/week; 3=1 day/week; 4=1-3 days/month; 5=Less than once a month; 6=Never	Survey
Companycar_freq	At this time of year, how often do you use each of the following as your primary mode of transportation to work?	1=4-5 days/week; 2=2-3 days/week; 3=1 day/week; 4=1-3 days/month; 5=Less than once a month; 6=Never	Survey
Workbus_freq	At this time of year, how often do you use each of the following as your primary mode of transportation to work?	1=4-5 days/week; 2=2-3 days/week; 3=1 day/week; 4=1-3 days/month; 5=Less	Survey

		than once a month; 6=Never	
Motorbike_freq	At this time of year, how often do you use each of the following as your primary mode of transportation to work?	1=4-5 days/week; 2=2-3 days/week; 3=1 day/week; 4=1-3 days/month; 5=Less than once a month; 6=Never	Survey
Walk_freq	At this time of year, how often do you use each of the following as your primary mode of transportation to work?	1=4-5 days/week; 2=2-3 days/week; 3=1 day/week; 4=1-3 days/month; 5=Less than once a month; 6=Never	Survey
Other_freq	At this time of year, how often do you use each of the following as your primary mode of transportation to work?	1=4-5 days/week; 2=2-3 days/week; 3=1 day/week; 4=1-3 days/month; 5=Less than once a month; 6=Never	Survey
Car_Type	If you do drive or if you were to drive to work, what type of car do you drive?	1=Private owned; 2=Work unit provided	
Parking	If you do drive or if you were to drive to work, would you have to pay to park?	Dummy: 1=yes	Survey
#Transfers	If you take transit to work, how many transfers needed during the trip?	count	Survey
OnTimeImportant	How important is it to you to arrive at work on time?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey
Reason_Cheap	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey
Reason_Comfort	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey

Reason_Timesaving	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey
Reason_Flexible	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey
Reason_Mental_Relax	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey
Reason_Physical_Relax	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey
Reason_Enjoyable	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey
Reason_Impresses_people	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey
Reason_Privacy	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey

Reason_health	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey
Reason_Exporsure	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey
Reason_Enviornment	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey
Reason_Safety	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey
Reason_Lifestyle	How important the factor is for you to choose a travel mode to work?	1=Not at all Important; 2= Somewhat Unimportant; 3= Neither Important nor Unimportant; 4= Somewhat Important; 5= Very Important	Survey
TravelMode	For your most recent commute to work, please select how you travelled	1=Drive alone; 2=Carpool; 3=Taxi; 4=Walk; 5=Rail (Underground); 6=Bus; 7=Shuttle bus (worker bus); 8=Bicycle; 9=E-bicycle; 10=Company car; 11=Motorbike taxi; 12=Motorbike	Survey
Limitation_car_drive	Do you have physical limitation which not allowed you to access following mode?	1=Yes; 2=No	Survey

Limitation_Bicycle	Do you have physical limitation which not allowed you to access following mode?	1=Yes; 2=No	Survey
Limitation_Bus	Do you have physical limitation which not allowed you to access following mode?	1=Yes; 2=No	Survey
Limitation_Walking	Do you have physical limitation which not allowed you to access following mode?	1=Yes; 2=No	Survey
Home_to_Busstop_YD	If you take bus, how did you get to the bus stop yesterday?	1=walk; 2=bike; 3=e-bike; 4=public bus;5=taxi;6= carpool;7=drive alone; 8=other;9=motorbike	Survey
Crowding	How crowded was the shuttle bus/bus/subway?	1=Not at all crowded; 2=Somewhat crowded; 3=Very crowded	Survey
Transfer	Did you have to make any transfers?	Dummy: 1=yes	Survey
Congestion	How congested were the streets?	1=Not at all congested 2=Somewhat congested; 3=Very congested	Survey
CommutingTime	How long did the total trip take, from the time you left home to the time you arrived at work?	Minutes	Survey
CommutingCost	How much cost you spent on commuting monthly?	Yuan	Survey

Table 13 Built-environment Variables

Variable	Measurement	Code or unit	Sources
D_Park_H	Airline distance from home to nearest park	meter	GIS
d_cbd_H	Airline distance from home to city center	meter	GIS
Rail_Qtr_H	Whether rail station present within 1/4-mile of home	1= yes	GIS
Rail_Hlf_H	Whether rail station present within 1/2-mile of home	1= yes	GIS
BlockSize_H	Average perimeter of the street blocks within 1/4-mile of home	meter	GIS
P_Green_H	% green land use within 1/4-mile of home	%	GIS
Busstops_H	Number of bus stops within 1/4-mile of home	count	GIS
P_Com_H	% commercial land use within 1/4-mile of home	%	GIS
Connected_H	Number of street intersections with 4+ directions within 1/4-mile of home	count	GIS
D_Park_J	Airline distance from job to nearest park	meter	GIS
d_cbd_J	Airline distance from job to city center	meter	GIS
Rail_Qtr_J	Whether rail station present within 1/4-mile of job	1= yes	GIS
Rail_Hlf_J	Whether rail station present within 1/2-mile of job	1= yes	GIS
Blocksize_J	Average perimeter of the street blocks within 1/4-mile of job	meter	GIS
P_Green_J	% green land use within 1/4-mile of job	%	GIS
Busstops_J	Number of bus stops within 1/4-mile of job	count	GIS
P_Com_J	% commercial land use within 1/4-mile of job	%	GIS
Connected_J	Number of street intersections with 4+ directions within 1/4-mile of job	count	GIS
Dis_H_J	Airline distance from home to job	meter	GIS

Table 14 Attitudinal Variables

Measurement	Code or unit	Sources
Walking can sometimes be easier for me than driving	1=Strongly Disagree; 2=Disagree; 3=Neutral; 4=Agree; 5= Strongly Agree	Survey
I would like to own at least one more car		
Travel time is generally wasted time		
I prefer to take transit rather than drive whenever possible		
I like riding a bike		
I use my trip to/from work productively		
I like taking transit		
Traveling by car is safer overall than walking		
Air quality is a major problem in this region		
I need a car to do many of the things I like to do		
I prefer to walk rather than drive whenever possible		
I am willing to pay a toll or tax to pay for new highways		
I like driving		
I prefer to bike rather than drive whenever possible		
Traveling by car is safer overall than riding a bicycle		
Public transit can sometimes be easier for me than driving		
I try to limit my driving to help improve air quality		
Traveling by car is safer overall than taking transit		
Getting to work without a car is a hassle		
I like walking		
Biking can sometimes be easier for me than driving		
I prefer to organize my errands so that I make as few trips as possible		
The price of gasoline affects the choices I make about my daily travel		
The trip to/from work is a useful transition between home and work		
Fuel efficiency is an important factor for me in choosing a vehicle		
I often use the telephone or the Internet to avoid having to travel somewhere		
We could manage pretty well with one fewer car than we have (or with no car)		
When I need to buy something, I usually prefer to get it at the closest store possible		
The region needs to build more highways to reduce traffic congestion		
My household spends too much money on owning and driving our cars		
Vehicles should be taxed on the basis of the amount of pollution they produce		

Table 15 Well-being Variables

Variable	Measurement	Code or unit	sources
Commuting Well-being	Seven items that measuring the experience of the trip (The satisfaction with travel scale)	-3-3	survey
Subjective Well-being	Five items that measuring satisfaction of life (SWLS)	1-7	survey
Satisfaction_Health	Satisfaction with health	0-10	survey
Satisfaction_Relationship	Satisfaction with personal relationship	0-10	survey
Satisfaction_ Community	Satisfaction with Community involvement	0-10	survey
Satisfaction_ Spirituality	Satisfaction with Spirituality	0-10	survey
Satisfaction_ security	Satisfaction with future security	0-10	survey

Chapter 4. Commuting Characteristics, Travel Satisfaction and Life Satisfaction

Introduction

This chapter addresses research questions 1-2 mentioned in chapter 1: What commute characteristics, such as journey distance, travel time, travel mode, congestion, level of service etc., influence travel satisfaction, after accounting for socio-demographics? And does travel satisfaction influence overall life satisfaction and well-being, after accounting for socio-demographics and other important domains of life? The theoretical framework for this chapter is in Figure 19. This chapter aims to contribute to the literature in three aspects. First, the chapter explores the relationships between commuting characteristics, commuting satisfaction and SWB simultaneously in a structural equation model, controlling for socio-demographics. Second, both commuting satisfaction and subjective well-being are measured using latent variables, which help to improve the measurement accuracy by removing the measurement and specification error from the observed indicators (Maruyama, 1997). Third, this chapter provides evidence from a developing country, where the research on the relationship between travel and well-being is rather sparse.

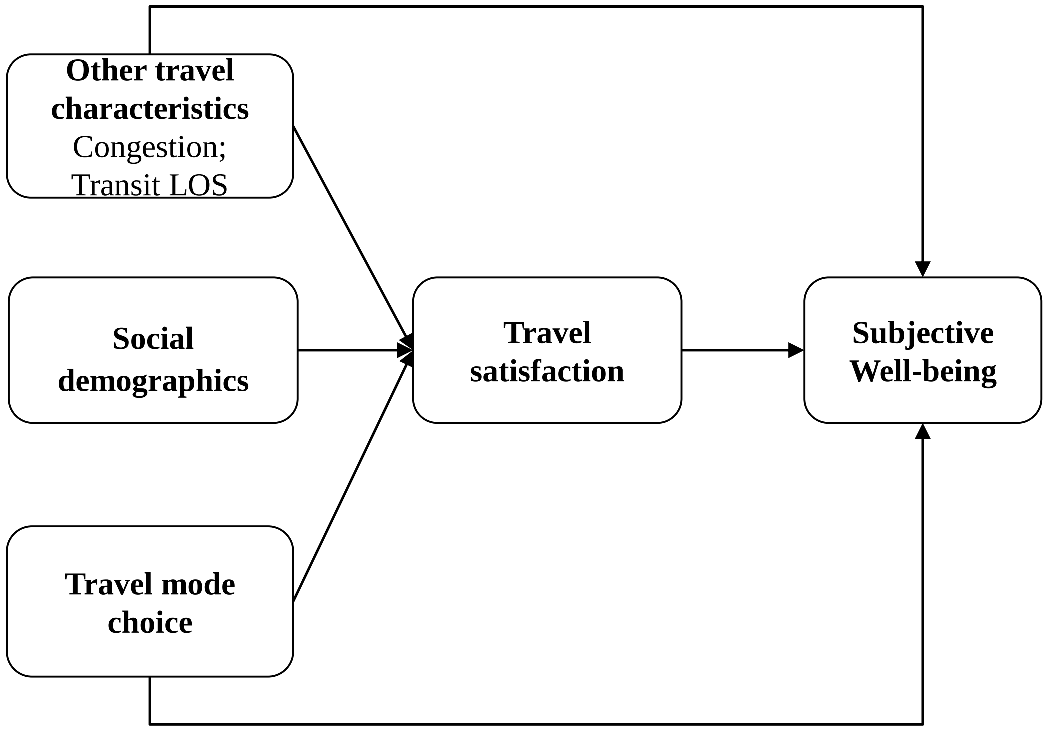

Figure 19 Conceptual model of Chapter 4

Methodology

This chapter begins with the descriptive analysis to explore the sample characteristics and to extract general information related to the commute and subjective well-being. Then it expands the correlation between those three elements before presenting the SEM. OLS models were then estimated to investigate the factors associated with commuting satisfaction and SWB respectively. Please note the term SWB is used interchangeably with life satisfaction in this study. Structural Equation Modeling (SEM) was finally used to test the conceptual model (Figure 19), examining the relationships among socio-demographics, travel time, travel mode choice, commuting satisfaction, and subjective well-being. SEM was chosen because of its ability to solve simultaneous equations enabling the relationships between the independent, dependent and intermediate variables to be disentangled (Maruyama, 1997). Commuting satisfaction and subjective well-being were incorporated as latent variables. The latent constructs for commuting satisfaction and SWB are illustrated in Figure 20, where λ is the regression coefficient, δ is the residual (uniqueness) for the observed measures, cs1-cs7 are the seven observed indicators for commuting satisfaction, and sw1-sw5 are the five observed indicators for SWB. The details of the measurement of commuting satisfaction and subjective wellbeing are introduced in Chapter 3. This latent constructs help to remove the measurement and specification error from these variables (Maruyama, 1997). The models were estimated using AMOS 21.0, and the full information maximum likelihood (FIML) procedure was used to estimate the models. FIML outperforms the common methods of handing missing data, such as listwise and pairwise data deletion (Enders and Bandalos, 2001). In addition, for a large sample size, which is the case of this study, the maximum likelihood approach is fairly robust against violations of multivariate normal distribution assumptions of SEM, as shown by many simulation studies (Golob, 2003; Scheiner and Holz-Rau, 2007).

The analysis includes five types of variables: socio-demographics, commuting characteristics, commuting satisfaction, subjective well-being, and satisfactions with important domains of life. Socio-demographic variables including age, gender, education, income, employment, and marriage status, were assumed to be associated with both commuting satisfaction and subjective well-being. Commuting characteristics, including mode choice, times of transfer needed for riding transit, congestion level, level of crowding in transit, and commuting time, were assumed to affect commuting satisfaction, which in turn influences subjective well-being. Further, satisfaction with important domains of life, such as health condition, personal relationship, community involvement, spirituality, and future security, may also affect subjective well-being and therefore were also incorporated in the model. In model estimation, the commuting characteristics, socio-demographics and satisfaction with other domains of life were exogenous variables and the covariances between them were specified. The summary of the variables used in this chapter is in Table 16.

Table 16 Summary statistics of the variables in Chapter 4

Variable	Mean	Std. Dev.	Min	Max
Socio-demographics				
Age	33.78	9.83	18	75
Female	0.51	0.50	0	1
Education	3.43	0.97	1	6
Income	3.61	1.98	1	10
Relative income	2.21	0.65	1	3
Income satisfaction	2.25	0.99	1	5
Married	0.65	0.48	0	1
BMI (Body Mass Index)	22.43	3.41	14	43
Self-reported Health	3.50	0.90	1	5
Commuting characteristics				
Car	0.29	0.45	0	1
Rail	0.04	0.20	0	1
Worker bus	0.02	0.15	0	1
Walk	0.19	0.39	0	1
Bike	0.04	0.20	0	1
E-Bike	0.05	0.23	0	1
Bus	0.36	0.48	0	1
Congestion	2.22	0.62	1	3
Commuting time (minutes)	38.83	30.53	0	300
Crowding in bus/train	2.49	0.55	1	3
Transfer (needed for transit)	0.43	0.50	0	1
Commuting satisfaction				
Mean of seven STS items	0.20	1.45	-3	3
Subjective well-being				
Mean of five SWLS items	3.67	1.24	1	7
Feel happy yesterday	5.39	2.39	0	10
Feel anxious yesterday	4.75	2.66	0	10
Satisfactions with important domains of life				
Satisfaction with Health	5.68	2.36	0	10

Satisfaction with Personal relationship	5.71	2.23	0	10
Satisfaction with Community involvement	4.50	2.38	0	10
Satisfaction with Spirituality	5.20	2.41	0	10
Satisfaction with Future security	4.64	2.47	0	10

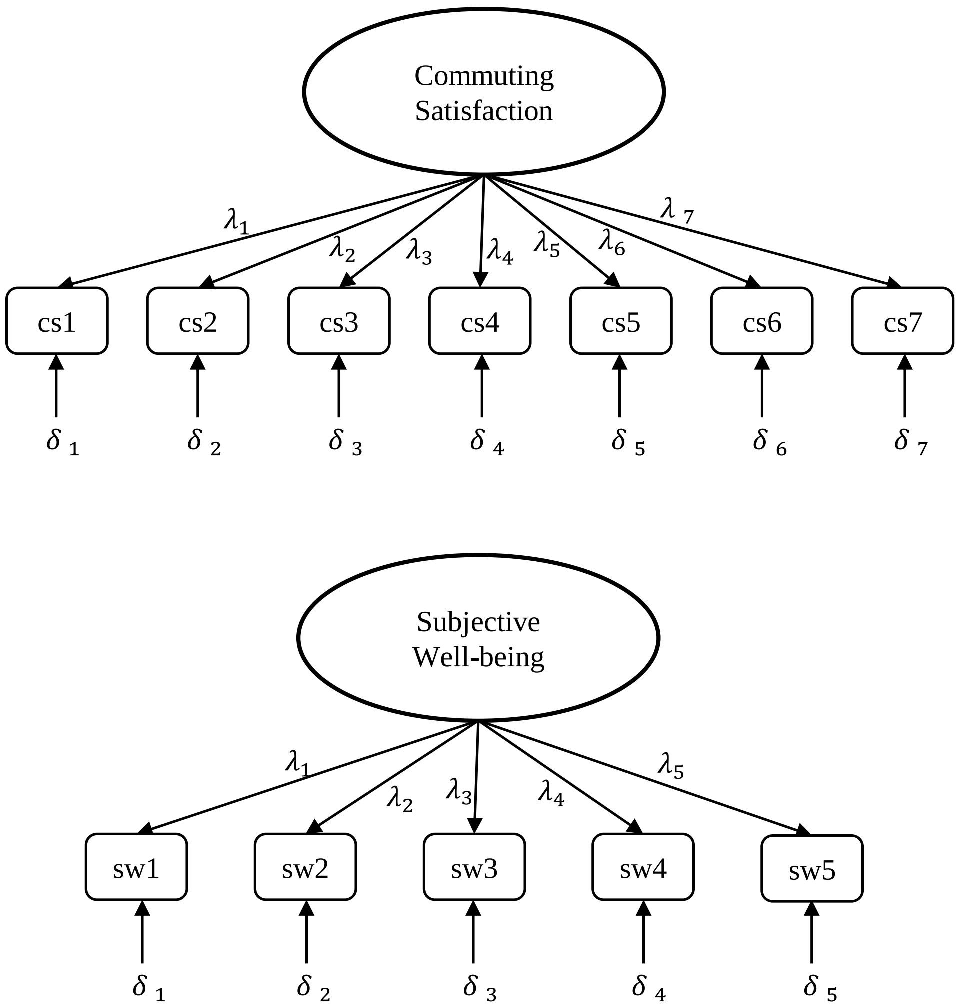

Figure 20 Latent constructs for commuting satisfaction and SWB

Descriptive Analysis and OLS model Results

Before estimating the model, box plots were first drawn to illustrate the simple relationship between commute mode choice and commuting satisfaction and SWB, as shown in Figure 21 and Figure 22. Figure 21 illustrates the distribution of commuting satisfaction among different commuting mode groups, where the box plots for drive alone (n=215), walking (n=212), bicycling (n=47), and shuttle bus (n=27) commuters are relatively higher than the equivalent plots for carpool (n=72), taxi (n=33), rail (n=45), bus (n=394), and e-bike (n=60) commuters, suggesting that commuters using these modes may have higher commuting satisfaction than others. However, it is worth noting that different people might have different standards on evaluating the satisfaction due to their socio-economic backgrounds. For example, car drivers per se might be more critical than pedestrian and cyclists, therefore, the differences in travel satisfaction we observed might mainly attribute to the differences of the travel-mode users than the characteristics of travel modes. Similarly, Figure 22 illustrates the distribution of SWB among different commuting mode groups, where over 50% of respondents who use drive alone, car sharing, rail and shuttle bus for commuting reported their SWB is over four, which is the cutoff value for differentiating the satisfying and dissatisfying with life, suggesting these groups of people have relatively higher life satisfaction than others. Further, the ranges of commuting satisfaction for walking and bicycling commuters are wider than that of other modes, suggesting that significant variations in commute satisfaction within active travel commuters.

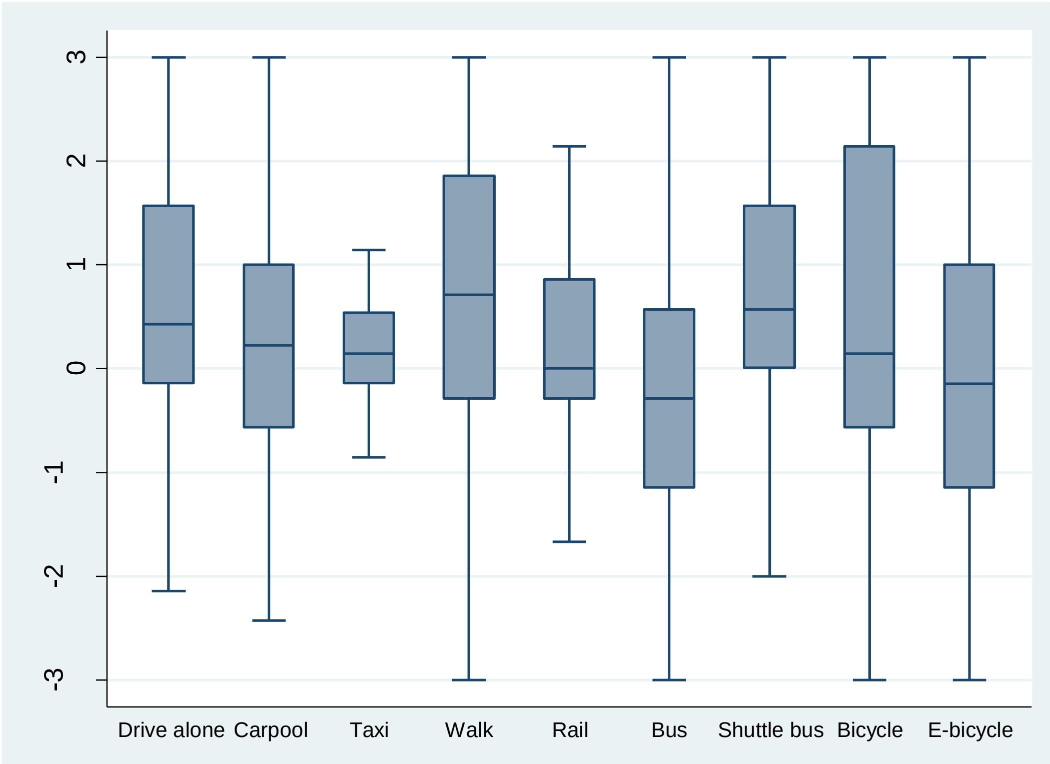

Figure 21 Box plots of commuting satisfaction among different commuting modes

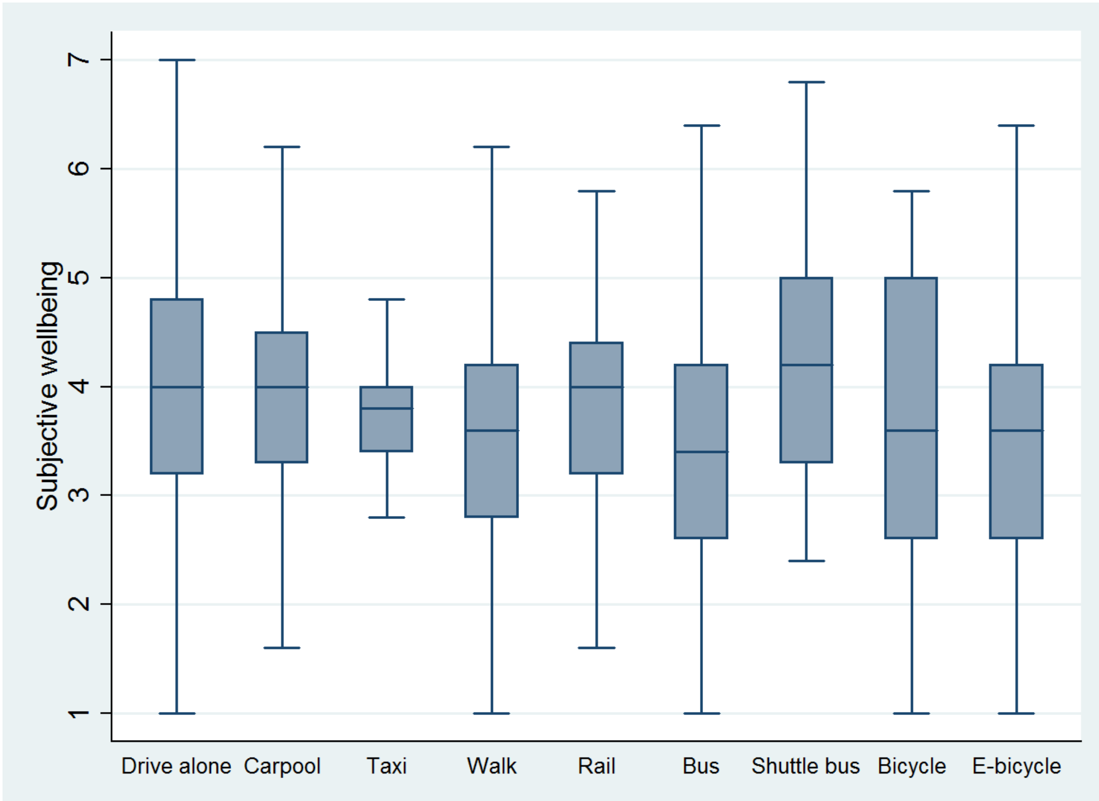

Figure 22 Box plots of SWB among different commuting modes

Comparing with the distribution of life satisfaction among different commuting modes, the pattern of moods (Figure 23 and Figure 24) is slightly different. People who use drive alone, car sharing, and bicycling for commuting are happier than others using other modes, while those who use shuttle bus and bicycling for commuting are less anxious than others using other modes. Although the differences, there are much overlapping areas in the distributions of both “happy” and “anxious” among different travel modes, suggesting that those differences are not very significant.

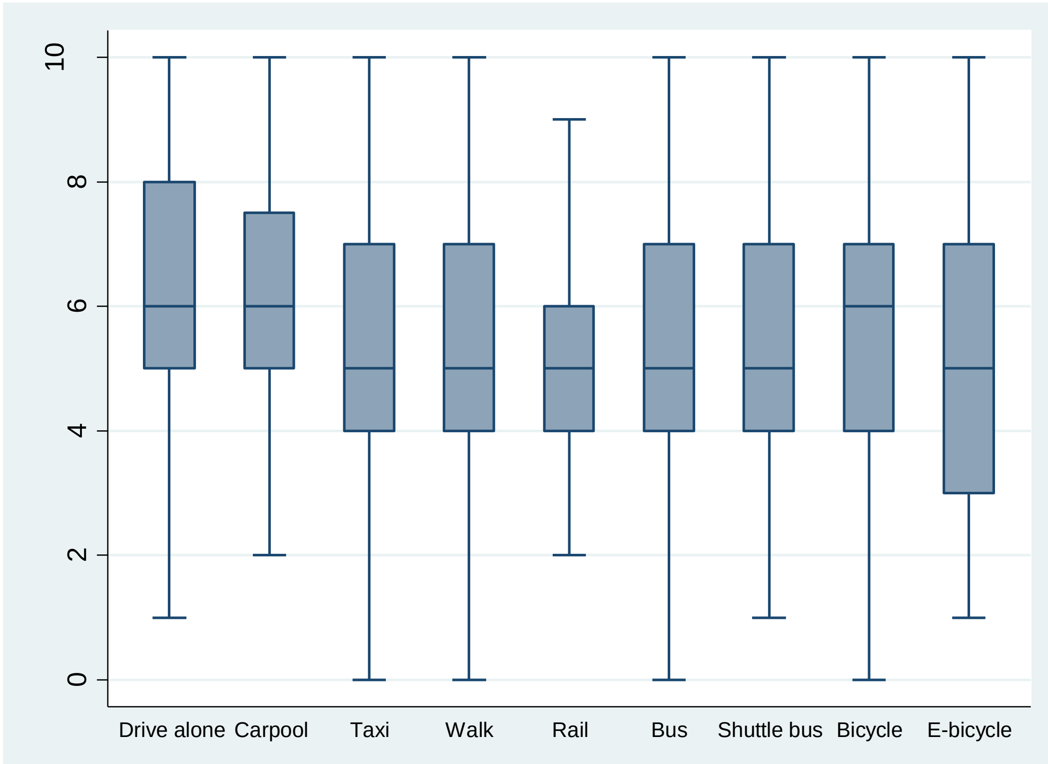

Figure 23 Box plots of “happy” mood among different commuting modes

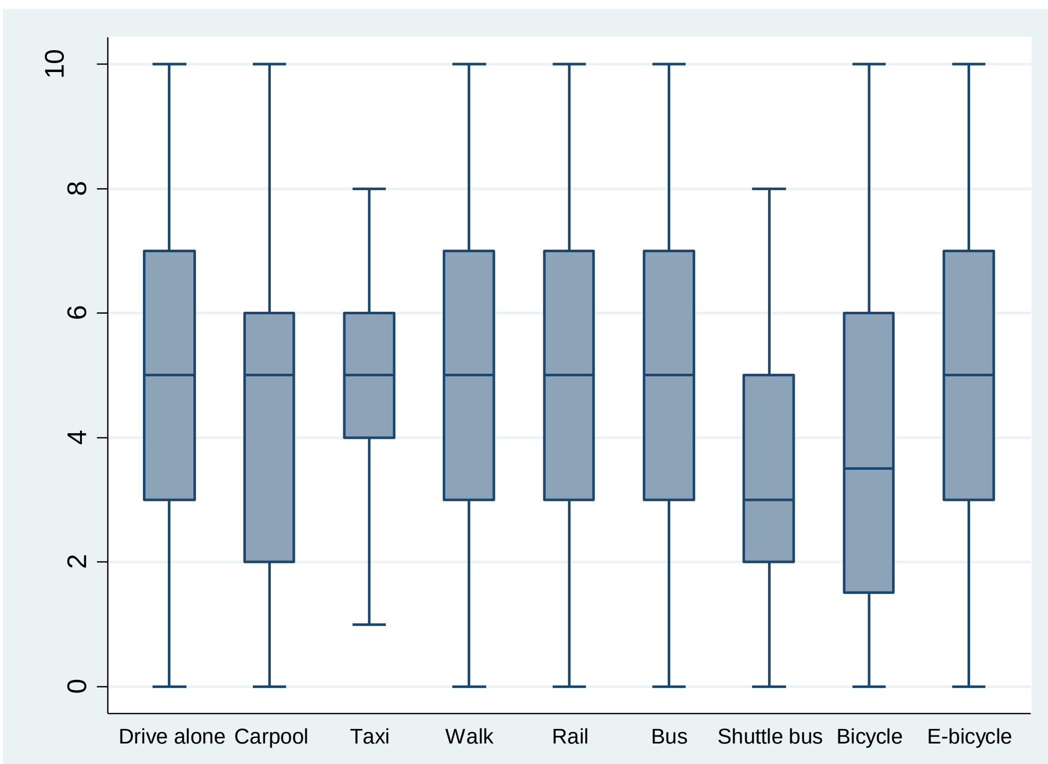

Figure 24 Box plots of “anxious” mood among different commuting modes

Scatter plots were also drawn to illustrate the simple relationship between commuting time and commuting satisfaction and between commuting time and SWB. As shown in Figure 25, there is a declining trend of commuting satisfaction over the commuting time, but this trend is not evident within 60 minutes of commuting time. Similarly, SWB tends to decrease as commuting time increase as indicated in Figure 26, however, the slope of decrease in SWB if much flatter than the slope of decrease in commuting satisfaction, suggesting commuting time may have a less impact on SWB than on commuting satisfaction.

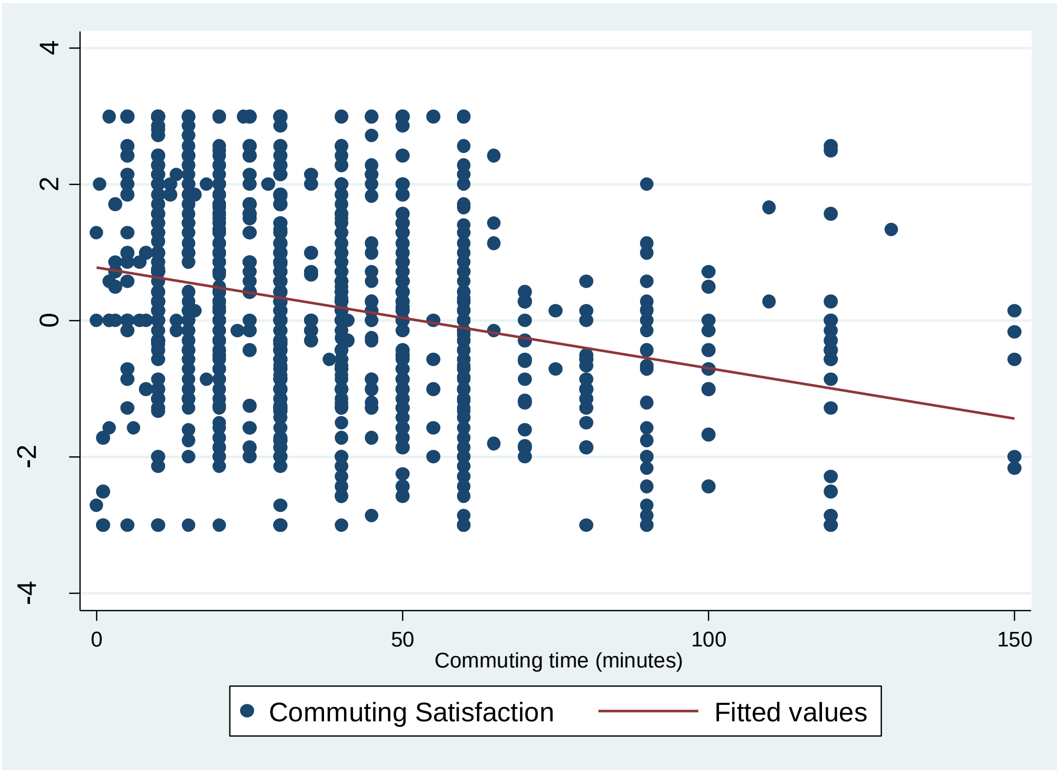

Figure 25 Scatter plots of commuting satisfaction with commuting time

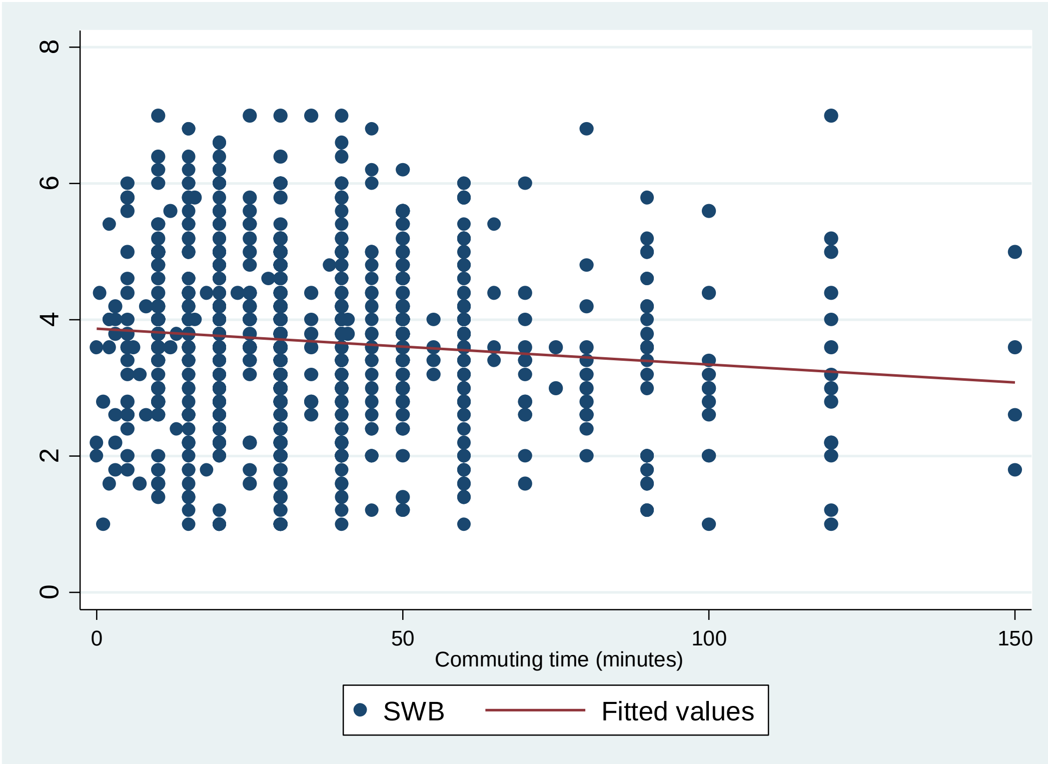

Figure 26 Scatter plots of SWB with commuting time

To further confirm the associations between the commuting characteristics and commuting satisfaction and SWB, two sets of OLS models were estimated to predict commuting satisfaction and SWB respectively. Before model estimation, three categories of travel modes including drive alone, carpool, and taxi were combined into one category-Car, to have enough sample in each category. Models were first estimated only using the variables that measure commuting characteristics, including commuting mode choice, commuting time and level of congestion experienced during the commute (Model 1), and then the models further accounted for socio-demographic characteristics of the commuters (Model 2). Regression diagnostics were conducted after estimation for all the models. Variance inflation factors (VIF) for all variables for each model are all below 2, indicating that no serious multicollinearity problems exist in the models. Heteroscedasticity was checked by plotting the residuals plotted against the fitted values.

In addition to the plots, the Breusch–Pagan tests were also used to detect the presence of heteroskedasticity.

Table 17 presents the OLS model results for commuting satisfaction. Although the residual plot (Figure 27) show a clear pattern against the fitted value, the result of Breusch-Pagan test was not significant (χ^2=1.72, p=0.189), indicating that heteroskedasticity is not a serious problem. To confirm the standard errors estimated from OLS are not biased due to heteroscedasticity, I also run the model using robust standard errors, which relax the OLS assumption of independent and identically distributed errors. The results from the model with robust standard errors are very similar with the results from previous OLS model. Overall, the model without and with socio-demographics explains about 19.4% and 22.7% of the variations in commuting satisfaction, respectively. Comparing with bus commuters, those using car, shuttle bus and walking for commuting have significantly higher level of satisfaction with their commuting. Higher level of congestion is associated with lower level of commuting satisfaction. People with longer commutes tend to be less satisfied with their commute. All these significant associations still hold after controlling for the socio-demographic characteristics of the commuters, suggesting that commuting characteristics do matter in influencing people’s commuting wellbeing. In terms of the associations between socio-demographic characteristics and commuting wellbeing, older adults, people with good health condition, and those who are satisfied with their income are more likely to satisfy with their commuting trips than others.

Table 18 presents the OLS model results for SWB. The residual plot (Figure 28) does not show evident pattern, indicating no serious heteroskedasticity problem, and this is further confirmed by the Breusch-Pagan test (χ^2=0.42, p=0.516). Overall, the model without and with socio-demographics explains about 6.3% and 19.6% of the variations in commuting satisfaction, respectively. This highlights the more important role of socio-demographics in determining the SWB than the role of travel characteristics. Without controlling socio-demographics, car and shuttle bus commuters have higher levels of life satisfaction than bus commuters. People experienced higher level of congestion during the commute and with longer commuting time tend to have lower level of subjective wellbeing. However, all of these significant associations become insignificant after accounting for the socio-demographic characteristics of the commuters, except the association between the commuting time and SWB. Further, there are more socio-demographic variables are significant in SWB models than in models predicting commuting satisfaction, suggesting that subjective wellbeing is more influenced by people's socio-demographic characteristics than commuting characteristics. In particular, older adults, people with good health condition, those who have higher income than their peers/friends, those who are satisfied with their income, and those who are married have higher level of life satisfaction than others.

SWB only focuses on the cognitive assessment of life satisfaction, while the affective evaluations of life might have different and independent associations with commuting. Further, the positive and negative affect were measured by asking people's moods of yesterday. The measures of affect are more consistent with the measures of commuting characteristics, which were measured based on yesterday's commuting trip, than SWB. Two models, therefore, were estimated to explore the associations between the positive affect (happy), negative affect (anxious), and commuting characteristics, respectively.

Model diagnostics were conducted following the same procedures as described above. The models did show moderate heteroskedasticity problem. The robust standard errors, therefore, were used in final models to reduce the estimation bias. The model results are reported in Table 19. As expected, higher level of traffic congestion in yesterday's commuting makes people significantly less happy and more anxious. A longer commuting reduces people's feeling of happiness significantly, but does not influence the level of anxiety. Similar with SWB models, all the travel modes are not significant in predicting the moods, except that the two modes – shuttle bus and bicycle- are marginally significant in predicting the level of anxiety. Both are negatively associated with anxiety, indicating that using shuttle bus and bicycle for daily commuting helps to reduce the level of anxiety.

In addition the commuting characteristics, female, older adults, people with good health condition, and those who are satisfied with their income are all significantly and positively associated with level of happiness. Surprisingly, none of these socio-demographics are associated with level of anxiety.

Table 17 OLS estimation of commuting satisfaction

	Model 1			Model 2		
	Coef.	t	P>t	Coef.	t	P>t
Travel Mode (Bus is the reference)						
Car	**0.445**	**3.980**	**0.000**	**0.315**	**2.640**	**0.008**
Rail	0.355	1.540	0.124	0.312	1.370	0.171
Shuttle bus	**0.912**	**2.780**	**0.006**	**0.687**	**2.110**	**0.035**
Walk	**0.499**	**3.820**	**0.000**	**0.540**	**4.160**	**0.000**
Bike	0.386	1.650	0.099	0.373	1.600	0.110
E-Bike	0.031	0.150	0.883	0.031	0.140	0.885
Congestion	**-0.697**	**-9.320**	**0.000**	**-0.653**	**-8.820**	**0.000**
Commuting time	**-0.009**	**-5.270**	**0.000**	**-0.008**	**-4.700**	**0.000**
Female				0.003	0.030	0.978
Age				**0.014**	**2.640**	**0.008**
BMI				-0.009	-0.610	0.541
Health				**0.193**	**3.770**	**0.000**
Education				-0.008	-0.150	0.883
Income				-0.017	-0.610	0.541
Relative income				-0.007	-0.050	0.964
Income satisfaction				**0.165**	**3.210**	**0.001**
Married				0.069	0.620	0.536
Constant	1.842	9.770	0.000	0.446	0.900	0.368
Number of obs	890			890		
Adj R-squared	0.194			0.227		

Note: bold fonts indicate coefficient is statistically significant at 5% level.

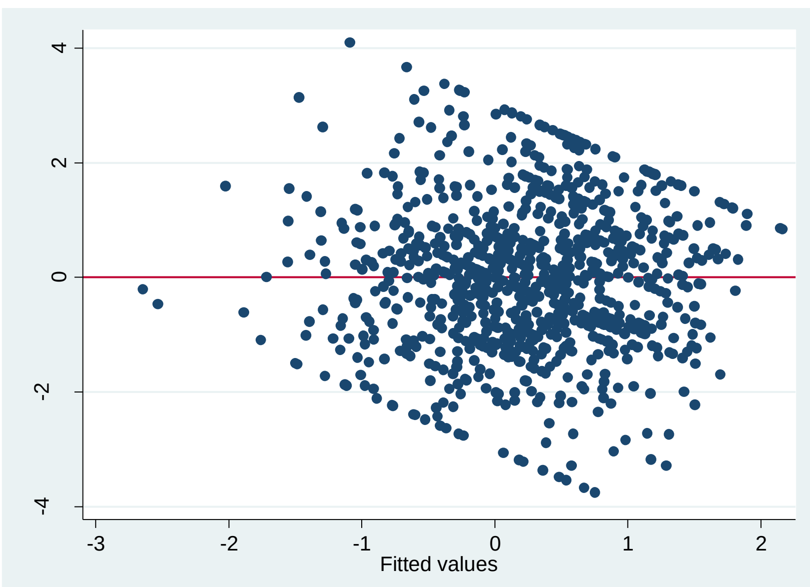

Figure 27 Residual plot of full model for commuting satisfaction

Table 18 OLS estimation of SWB

	Model 1			Model 2		
	Coef.	t	P>t	Coef.	t	P>t
Travel Mode (Bus is the reference)						
Car	**0.440**	**3.960**	**0.000**	0.141	1.240	0.214
Rail	0.182	0.820	0.413	0.111	0.540	0.592
Shuttle bus	**0.910**	**2.970**	**0.003**	0.535	1.860	0.064
Walk	-0.021	-0.160	0.871	0.062	0.510	0.611
Bike	-0.279	-1.190	0.235	-0.279	-1.260	0.209
E-Bike	-0.164	-0.790	0.429	-0.144	-0.730	0.465
Congestion	**-0.204**	**-2.710**	**0.007**	-0.131	-1.860	0.064
Commuting time	**-0.006**	**-3.230**	**0.001**	**-0.004**	**-2.260**	**0.024**
Female				-0.017	-0.180	0.854
Age				**0.016**	**3.130**	**0.002**
BMI				-0.026	-1.910	0.057
Health				**0.193**	**3.990**	**0.000**
Education				-0.008	-0.180	0.860
Income				0.019	0.710	0.475
Relative income				**0.272**	**1.970**	**0.049**
Income satisfaction				**0.287**	**5.920**	**0.000**
Married				**0.241**	**2.320**	**0.021**
Constant	4.199	22.480	0.000	2.517	5.410	0.000
Number of obs	784			784		
Adj R-squared	0.063			0.196		

Note: bold fonts indicate coefficient is statistically significant at 5% level.

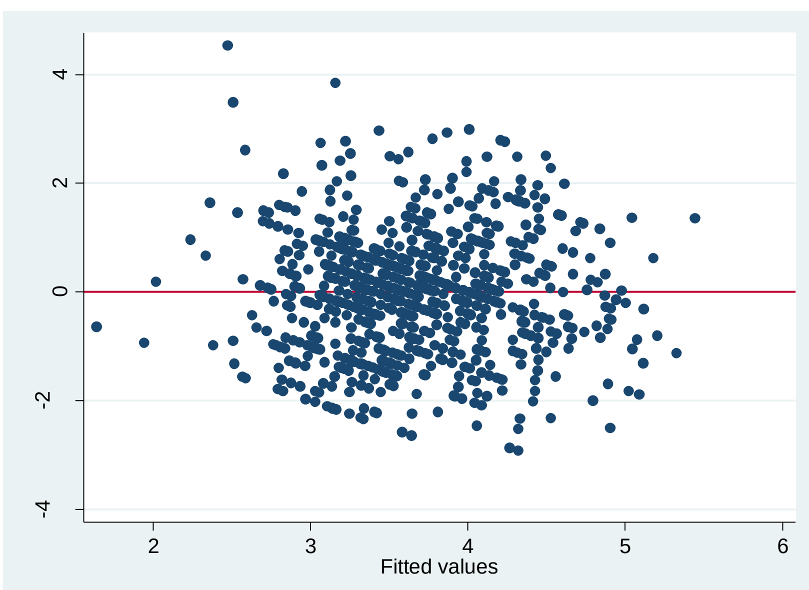

Figure 28 Residual plot of full model for SWB

Table 19 OLS estimation of moods yesterday

	Feel happy yesterday			Feel anxious yesterday		
	Coef.	t	P>t	Coef.	t	P>t
Female	**0.361**	**2.270**	**0.023**	-0.279	-1.410	0.158
Age	**0.032**	**3.570**	**0.000**	-0.003	-0.230	0.821
BMI	0.020	0.840	0.402	-0.022	-0.780	0.434
Health	**0.499**	**5.730**	**0.000**	0.152	1.320	0.188
Education	0.025	0.300	0.767	0.031	0.270	0.785
Income	-0.057	-1.210	0.227	0.039	0.610	0.540
Relative income	0.123	0.510	0.608	-0.458	-1.540	0.124
Income satisfaction	**0.549**	**6.250**	**0.000**	0.042	0.370	0.709
Married	-0.045	-0.240	0.814	-0.115	-0.480	0.634
Congestion	**-0.306**	**-2.360**	**0.018**	**0.350**	**2.180**	**0.030**
Commuting time	**-0.009**	**-2.880**	**0.004**	0.000	-0.070	0.943
Travel Mode (Bus is the reference)						
Car	0.250	1.190	0.233	-0.235	-0.940	0.347
Rail	-0.502	-1.300	0.193	-0.355	-0.750	0.452
Shuttle bus	-0.057	-0.140	0.891	-1.147	-1.830	0.067
Walk	-0.125	-0.570	0.566	-0.320	-1.160	0.245
Bike	0.011	0.020	0.980	-0.936	-1.730	0.085
E-Bike	-0.416	-1.100	0.272	-0.095	-0.230	0.820
Constant	1.864	2.250	0.025	4.207	4.010	0.000
Number of obs	852			847		
R-squared	0.186			0.025		
Adj R-squared	0.169			0.005		

Note: bold fonts indicate coefficient is statistically significant at 5% level.

SEM Model Results

First, a model specified as the conceptual model (Figure 19) was estimated. However, the model results indicated that none of the commuting characteristics variables were significantly associated with SWB. I, therefore, deleted the direct link from commuting characteristics to the SWB in the final model estimation to acquire a better model fit. The standardized loadings (Table 20) for the seven indicators assessing commuting satisfaction and the five indicators measuring SWB are of sufficient magnitude (0.588 to 0.870). This indicates that the two instruments measuring the commuting satisfaction and

SWB are well applied in Chinese context. The model results, including model fits, standardized coefficients and significance, are provided in Table 21. The fit indices suggest a good fit (CFI = 0.935, RMSEA = 0.043) based on Hu and Bentler (1999), who suggest a cutoff value close to 0.95 for CFI and a cutoff value close to 0.06 for RMSEA are needed to conclude there is a relatively good fit between the hypothesized model and the observed data.

Table 20 Latent variable loadings

Latent variable	Survey items	Standardized loading
Commuting Satisfaction		
	(cs1) I felt time was pressed - I felt time was relaxed during commuting	0.694***
	(cs2) I was worried I would not be in time – I was confident I would be in time	0.688***
	(cs3) I was stressed – I was calm	0.788***
	(cs4) I was tired – I was alert	0.751***
	(cs5) I was bored – I was enthusiastic	0.824***
	(cs6) I think this commuting is worst – I think this commuting is best I can think of	0.819***
	(cs7) I think this commuting worked well – I think this commuting worked poorly	0.830***
Subjective Well-being		
	(sw1) In most ways my life is close to my ideal	0.799***
	(sw2) The conditions of my life are excellent	0.870***
	(sw3) I am satisfied with my life	0.867***
	(sw4) So far I have gotten the important things I want in life	0.713***
	(sw5) If I could live my life over, I would change almost nothing	0.588***

Note: All coefficients are standardized
*** p<.01; ** p<.05; *p<.1; n=1215

Overall, the model explains about 27% of the variation in commuting satisfaction and about 47% of the variation in SWB (Table 21). Most of socio-demographic characteristics are significantly associated with SWB. For example, women, those working in government and educational institutions, those who perceived they had higher income than their peers, and those who were married, were more likely to have higher level of SWB. Interestingly, absolute income was not significantly associated with SWB. However, none of the socio-demographic variables were significantly associated with commuting satisfaction except age.

Both commuting mode choice and level of service are associated with commuting satisfaction. Active travel (i.e. walking and bicycling) commuters had the highest levels of commuting satisfaction. Car commuters were more satisfied with their most recent commuting than those relying on other motorized modes. However, the association between rail use and commuting satisfaction was not statistically significant, even though it is positive. For transit commuters, having to transfer and over-crowding were associated with lower levels of commuting satisfaction. For car commuters, congestion on the road could significantly reduce their commuting satisfaction. As expected, commuting time was significantly and negatively associated with commuting satisfaction. In terms of the importance, congestion is the biggest deterrent to the commuting satisfaction, while active travel contributes most to improve commuting satisfaction.

Even though the direct effects were not significant, the commuting characteristics indirectly influence SWB via commuting satisfaction. For example, the congestion could reduce the SWB by 0.0355 (-0.218*0.163) standard deviations, while active travel could increase the SWB by 0.0344 (0.211*0.163) standard deviations. In addition, though the individual effect of each commuting characteristic on SWB is marginal, the combined effects of all commuting factors could be large.

Furthermore, the five dimensions of life, including health condition, personal relationships, community involvement, spiritual life, and future security, were all significantly associated with SWB. After controlling for social demographics and these important dimensions of life, commuting satisfaction remained a significant relationship with SWB. Comparing with other domains of life, commuting satisfaction is the second most important factor that affects SWB. This indicates the strong associations between commuting and SWB in Xi-an, China.

Table 21 SEM Model results

	Commuting satisfaction		Subjective well-being	
Commuting satisfaction			0.163	***
Commuting characteristics				
Car	0.068	*		
Active travel	0.211	***		
Rail	0.045			
Transfer	-0.137	***		
Congestion	-0.218	***		
Crowding	-0.169	**		
Commuting time	-0.113	***		
Social demographics				
Age	0.075	*	0.020	
Female	0.034		0.054	**
Work in government/Education institute	0.017		0.056	**
Income	0.028		0.044	
Relative income	0.050		0.070	**
Married	0.014		0.112	**
Satisfaction with other domains of life				
Health			0.138	***
Personal relationship			0.068	*
Community involvement			0.129	***
Spirituality			0.252	***
Future security			0.147	***
Model fit statistics:				
n		1215		
Chi-square/degrees of freedom		3.593		
CFI		0.935		
RMSEA		0.043		
R^2	0.265		0.465	

Note: All coefficients are standardized
*** p<.01; ** p<.05; *p<.1; n=1215

Conclusions

This chapter aims to explore the relationships between commuting characteristics, commuting satisfaction and SWB. OLS models were first estimated to investigate the associations between commuting characteristics and commuting satisfaction as well as the associations between commuting characteristics and SWB, after controlling for socio-demographics. SEM models were then estimated to further explore the structural relationships between these variables following the conceptual model. Based on the data from a megacity of China, Xi-an, this chapter finds that commute characteristics, including travel mode choice and level of service, significantly influence commuting satisfaction, which in turn significantly affects overall satisfaction with life (SWB). The finding of a significant association between commuting satisfaction and SWB is consistent with Bergstad et al. (2011). Commuting satisfaction is more determined by the travel mode choice and level of service than the socio-demographic characteristics of commuters. In contrast, most of the socio-demographic variables are significantly associated with SWB.

In particular, OLS model results suggest that those relying on shuttle bus, walk and car are more satisfied with their commuting trip than the bus commuters. Bicycling commuters are also positively associated with commuting satisfaction, but the association is just not statistically significant. When regrouping the travel modes in SEM, where walking and bicycling are combined as one mode – active travel, the SEM model results indicated that people who choose the active modes of walking and bicycling are most satisfied with their commute. It is also worth noting that car is also positively associated with commuting satisfaction in SEM, but the magnitude of association is much smaller than that of active travel. Unexpectedly, in both OLS and SEM models, the rail commuters are not significantly more satisfied with their commuting comparing with other mode users (e.g. bus, taxi, motorbike). However, this study (Cao, 2013) finds that accessibility to rail transit is positively associated with travel satisfaction. In addition to travel modes, model results from both OLS and SEM models indicate that traffic congestion and commuting time severely affect commuting satisfaction. By comparing the standardized coefficients reported in SEM, congestion is the most important negative factor that influence commuting satisfaction.

For public transit commuters, having to transfer between services and crowding on services significantly affect their travel experience. These findings are consistent with previous studies, as discussed in literature review. Crowding in public transit is significantly associated with negative psychological-outcome, including anxiety, stress and feeling of exhaustion (Cheng, 2010; Lundberg, 1976; Mahudin et al., 2012). Transfer between services also increases stress level (Wener et al., 2005).

Finally, the effects of commuting characteristics on SWB are much weaker than on commuting satisfaction. All the travel modes are not significantly associated with either cognitive evaluation (life satisfaction) or affective assessment (happy or anxious yesterday) of life, after controlling for socio-demographics. This is consistent with Morris and Guerra (2014). However, the effects of commuting time on life satisfaction is significant, and the effects of congestion on life satisfaction is marginally significant. Both commuting time and congestion significantly affect positive affect of wellbeing, while only congestion significantly affect negative affect of wellbeing. These results may suggest that commuting time has more influences on long-term quality of life, while the traffic congestion more affects moods and emotions of a specific moment.

Chapter 5. Satisfaction with the Commute: The Role of Travel Mode Choice, Built Environment and Attitudes

Introduction

This chapter addresses questions 3-4 mentioned in chapter 1: How do the characteristics of the built environment at people's home and job locations influence their travel satisfaction? And how do people's attitudes influence their travel satisfaction? Chapter 3 has established the associations between the travel satisfaction and subjective wellbeing, and therefore this chapter emphasizes to further investigate what factors contributing to the travel satisfaction by investigating the roles of the built environment and travel preferences (Figure 29). This chapter also aims to contribute to the literature in three aspects. First, very few previous studies have explored the role of the built environment or travel attitudes in influencing travel satisfaction. Exploring this question helps to not only build a comprehensive framework linking the built environment, travel behavior and satisfaction with travel, but will also help identify potential interventions to improve individual satisfaction with travel and levels of wellbeing. Second, all of previous studies treat the built environment, travel attitudes and other travel characteristics as separate determinants of travel satisfaction; few of them explore the potential interactions between various types of factors and the structural relationships between these factors. This chapter quantitatively explored the structural relationships between the built environment, travel attitudes, and travel characteristics and travel satisfaction, focusing on commuting trips. Finally, the unique context of this study also contributes to the literature by providing empirical evidence from a developing country and fast growing city.

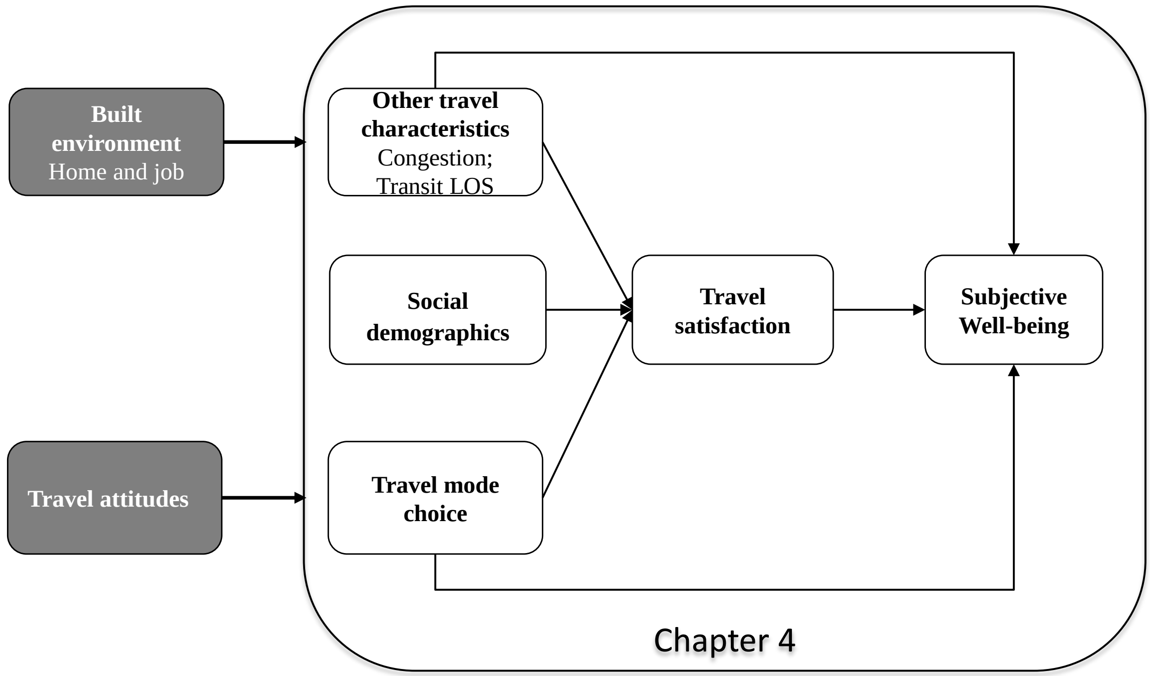

Figure 29 Conceptual model of Chapter 5

Methodology

As described in Chapter 3, the built environment was measured at both respondent's home and job locations using GIS. The travel attitudes were measured based on 31 survey questions. The data was first analyzed using descriptive analysis to explore the possible relationships between the variables of interests. OLS models were then estimated to investigate the effects of the built environment and travel attitudes on travel satisfaction and life satisfaction, after controlling for socio-demographics of the respondents. Structural equation modeling (SEM), which is described in detail in Chapter 3, was finally employed to confirm the results revealed in descriptive analysis and OLS models and further investigate the direct and indirect effects of the built environment and travel attitudes on travel satisfaction and life satisfaction. The models were estimated using AMOS 21.0, and the full information maximum likelihood (FIML) procedure was used to estimate the models. FIML works by estimating a likelihood function for each individual based on the variables that are present so that all the variable data are used. FIML outperforms the common methods of handing missing data, such as listwise and pairwise data deletion (Enders and Bandalos, 2001). Because of this, the variables that are only relevant to transit commuters, such as crowd and transfer, were kept in the model, and including them did not reduce sample size in estimation. In addition, for a large sample size, which is the case of this study, the maximum likelihood approach is fairly robust against violations of multivariate normal distribution assumptions of SEM, as shown by many simulation studies (Golob, 2003). It should also be noted that exploratory factor analysis (EFA) on the built environment and travel attitudes were conducted separately from the SEM model. The variables that are used in this chapter are summarized in Table 22.

Table 22 Summary statistics of the variables in Chapter 5

Variable	Mean	Std. Dev.	Min	Max
Subjective well-being				
Mean of five SWLS items	3.67	1.24	1	7
Commuting satisfaction				
Mean of seven STS items	0.20	1.45	-3	3
Demographics				
Age	33.78	9.83	18	75
Female	0.51	0.50	0	1
Education	3.43	0.97	1	6
Income	3.61	1.98	1	10
Self-reported Health	3.50	0.90	1	5
Built environment				
Access to transit (home)	0.00	0.99	-0.98	3.18
Car dependent (home)	0.01	1.01	-2.87	5.00
Close to greenery (home)	0.00	1.00	-2.15	6.58
Access to transit (job)	-0.01	0.99	-1.82	3.73
Close to greenery (job)	0.00	1.00	-1.65	3.10
Car dependent (job)	0.00	0.99	-6.32	5.09
Travel Attitudes				
Fuel Efficiency	0.01	1.00	-3.95	3.17
Pro Bike	0.00	1.01	-3.20	3.53
Car Safer	0.00	1.00	-3.25	3.02
Pro Transit	0.00	1.01	-4.31	3.60
Pro Walk	0.00	1.00	-4.01	3.08
Pro Driving	0.00	1.00	-3.37	3.53
Environment Friendly	0.00	1.00	-3.99	3.15
Positive Travel	-0.01	1.00	-3.71	3.30
Travel characteristics				
Congestion	2.22	0.62	1	3
Commuting time	38.83	30.53	0	300
Car	0.29	0.45	0	1
Rail	0.04	0.20	0	1
Worker bus	0.02	0.15	0	1
Walk	0.19	0.39	0	1
Bike	0.04	0.20	0	1
E-Bike	0.05	0.23	0	1
Bus	0.36	0.48	0	1
Crowding in bus/train	2.49	0.55	1	3
Transfer (needed for transit)	0.43	0.50	0	1

Descriptive Analysis and OLS Model Results

Table 23 reports the Pearson's bivariate correlation coefficients between different dimensions of the built environment and travel satisfaction and life satisfaction, and Table 24 reports the Pearson's bivariate correlation coefficients between travel attitudes and travel satisfaction and life satisfaction. For the built-environment variables, close to greenery at home location is significantly and positively associated with both travel satisfaction and life satisfaction, however, close to greenery at job location is negatively associated with travel satisfaction. In addition, access to transit at job location is positively associated with life satisfaction, though the association was marginally significant. Comparing with the built environment, more attitudinal variables are associated with travel satisfaction. Those having a positive attitude towards transit, walk, and car as a travel mode, environmental friendly people, and those having a general positive attitude towards travel tend to have a higher level of travel satisfaction than others. In addition, those who think car is safer and have a positive attitude towards travel tend to have a higher level of life satisfaction than others.

Table 23 Bivariate correlation between the built environment and travel satisfaction and life satisfaction

	Travel Satisfaction		Life Satisfaction	
	Coeff.	p-value	Coeff.	p-value
Access to transit (home)	-0.006	0.876	0.007	0.875
Suburban big block (home)	-0.043	0.275	-0.025	0.548
Access to greenery (home)	**0.078**	0.048	**0.096**	0.020
Access to transit (job)	-0.009	0.808	**0.065**	0.097
Access to greenery (job)	**-0.132**	0.000	-0.035	0.364
Suburban big block (job)	0.035	0.344	-0.008	0.834

Note: bond font indicates p<0.1

Table 24 Bivariate correlation between travel attitudes and travel satisfaction and life satisfaction

	Travel Satisfaction		Life Satisfaction	
	Coeff.	p-value	Coeff.	p-value
Fuel Efficiency	-0.052	0.150	-0.044	0.235
Pro Bike	0.006	0.861	0.002	0.966
Car Safer	0.020	0.581	**0.191**	0.000
Pro-transit	**0.061**	0.088	0.059	0.113
Pro-walk	**0.117**	0.001	0.040	0.289
Pro-driving	**0.100**	0.005	0.031	0.408
Pro-environment	**0.088**	0.014	0.023	0.531
Positive Travel	**0.346**	0.000	**0.192**	0.000

Note: bond font indicates p<0.1

Effects of the built environment on travel satisfaction and SWB

Bivariate correlation analysis reveals preliminary relationships between the built environment, travel attitudes, travel satisfaction and life satisfaction. To further explore these associations after controlling for the demographic characteristics and travel characteristics, OLS models were estimated. Considering the possible correlations between the built environment and travel characteristics, and correlations between travel attitudes and travel characteristics, separate models were estimated with and without travel characteristics included. Regression diagnostics were conducted after estimation for all the models. Variance inflation factors (VIF) for all variables for each model are all below 2, indicating that no serious multicollinearity problems exist in the models. Heteroscedasticity was also checked by plotting the residuals plotted against the fitted values, and no evident pattern was found. In addition to the plots, the Breusch–Pagan tests were also used to detect the presence of heteroskedasticity, and the tests were not significant for all the models.

Table 25 reports the model results for the effects of the built environment on travel satisfaction. Without controlling the travel characteristics, the associations between the built environment and travel satisfaction shown in OLS model are consistent with the results of bivariate correlation analysis. However, after controlling for travel characteristics, the effects of the built environment become insignificant. This suggests that the built environment may only affect travel satisfaction by influencing travel characteristics. In addition, the model with only demographics and the built environment explains less than 6% of the variations in travel satisfaction, while the model adding travel characteristics explains about 23% of the variations. This further suggests that the direct effects of the built environment on travel satisfaction are marginal, and the travel satisfaction is more influenced by travel characteristics than the built environment. Consistent with the model results in Chapter 4, people with higher income and better health condition have higher level of travel satisfaction than others.

Table 26 presents the model results for the effects of the built environment on life satisfaction. Only one variable, access to greenery at home location, was positively associated with life satisfaction in the model without controlling for the travel characteristics. Similarly, after controlling for travel characteristics, this variable becomes insignificant. This suggests that the built environment may interact with the travel characteristics. The mode without travel characteristics explains about 9% of the variations in life satisfaction, and adding travel characteristics helps to improve the model explanation power to 12%. Finally, older adults and those with high income and good health condition have higher level of life satisfaction than others. In addition to life satisfaction, two models (Table 27) were also estimated for positive affect and negative affect of wellbeing respectively. The two models explain about 13% and 6% of the variations in happy level yesterday and anxious level yesterday respectively. Similar with the results of life satisfaction, most of the built environment characteristics are not associated with the positive affect nor the negative affect, except the close to greenery at job location, which is negatively associated with level of anxiety. It is also worth noting that the relationship between moods and travel modes are not significant in Chapter 4, while after controlling for the built environment, using car for commuting is positively associated with the level of happiness of yesterday and bicycling for commuting is negatively associated with the level of anxiety of yesterday.

Table 25 Effects of the built environment on travel satisfaction

	Coef.	P>t	Coef.	P>t
Demographics				
Age	0.008	0.230	0.003	0.596
Female	0.124	0.318	0.111	0.337
Education	-0.087	0.217	-0.085	0.197
Income	**0.083**	**0.018**	0.064	0.052
Self-reported Health	**0.292**	**0.000**	**0.235**	**0.000**
Built environment				
Access to transit (home)	-0.001	0.983	0.010	0.869
Suburban big block (home)	-0.062	0.308	-0.048	0.398
Access to greenery (home)	**0.142**	**0.017**	0.070	0.196
Access to transit (job)	-0.008	0.889	0.004	0.937
Access to greenery (job)	**-0.135**	**0.033**	-0.069	0.240
Suburban big block (job)	0.070	0.230	0.015	0.774
Travel characteristics				
Congestion			**-0.604**	**0.000**
Commuting time			**-0.009**	**0.001**
Car			**0.517**	**0.001**
Rail			0.384	0.217
Worker bus			0.696	0.081
Walk			**0.705**	**0.000**
Bike			**0.555**	**0.041**
E-Bike			-0.120	0.652
Bus (reference)			-	-
constant	-1.159	0.009	0.595	0.225
Number of obs	540		531	
Adj R-squared	0.059		0.239	

Note: bold fonts indicate coefficient is statistically significant at 5% level.

Table 26 Effects of the built environment on life satisfaction

	Coef.	P>t	Coef.	P>t
Demographics				
Age	**0.025**	**0.000**	**0.023**	**0.000**
Female	0.094	0.404	0.100	0.386
Education	-0.038	0.545	-0.055	0.398
Income	**0.098**	**0.002**	**0.080**	**0.016**
Self-reported Health	**0.265**	**0.000**	**0.237**	**0.000**
Built environment				
Access to transit (home)	0.026	0.653	0.016	0.778
Suburban big block (home)	0.008	0.881	0.019	0.742
Access to greenery (home)	**0.115**	**0.037**	0.089	0.108
Access to transit (job)	0.084	0.122	0.072	0.185
Access to greenery (job)	0.075	0.203	0.085	0.155
Suburban big block (job)	0.027	0.605	0.008	0.882
Travel characteristics				
Congestion			-0.172	0.080
Commuting time			**-0.005**	**0.046**
Car			0.273	0.076
Rail			0.396	0.191
Worker bus			0.444	0.245
Walk			0.092	0.588
Bike			-0.159	0.568
E-Bike			-0.336	0.211
Bus (reference)			-	-
constant	1.549	0.000	2.315	0.000
Number of obs	482		474	
Adj R-squared	0.090		0.115	

Note: bold fonts indicate coefficient is statistically significant at 5% level.

Table 27 Effects of the built environment on moods

	Feel happy yesterday		Feel anxious yesterday	
	Coef.	P>t	Coef.	P>t
Demographics				
Age	**0.027**	**0.012**	**-0.043**	**0.001**
Female	**0.412**	**0.046**	**-0.582**	**0.017**
Education	-0.101	0.393	0.060	0.664
Income	0.062	0.295	0.133	0.058
Health	**0.572**	**0.000**	0.070	0.611
Built environment				
Access to transit (home)	0.093	0.376	0.149	0.227
Suburban big block (home)	-0.032	0.748	0.193	0.102
Access to greenery (home)	0.148	0.123	0.098	0.391
Access to transit (job)	-0.171	0.080	0.142	0.226
Access to greenery (job)	-0.075	0.480	**-0.321**	**0.010**
Suburban big block (job)	0.019	0.842	-0.012	0.911
Travel characteristics				
Congestion	**-0.395**	**0.022**	**0.598**	**0.003**
Commuting time	**-0.015**	**0.001**	-0.001	0.899
Car	**0.589**	**0.032**	0.020	0.950
Rail	-0.406	0.458	-0.491	0.457
Shuttle bus	0.191	0.778	-1.015	0.220
Walk	-0.113	0.709	-0.211	0.558
Bike	-0.229	0.652	**-1.160**	**0.045**
E-Bike	-0.722	0.136	-0.081	0.884
Bus (reference)				
Constant	3.708	0.000	4.330	0.000
Number of obs	514		514	
Adj R-squared	0.131		0.062	

Note: bold fonts indicate coefficient is statistically significant at 5% level.

Effects of travel attitudes on travel satisfaction and life satisfaction

Table 28 reports the model results for the effects of travel attitudes on travel satisfaction. Overall, the model without travel characteristics explains about 19% of the variations in travel satisfaction, and this number increases to 29% after including travel characteristics. Consistent with bivariate analysis, pro-transit, pro-walk, pro-driving, environmental friendly, positive travel are all positive associated with travel satisfaction. Further, those who feel fuel efficiency is important are less likely to satisfy their travel. After controlling for travel characteristics, most of these significant attitudinal variables retain significant, suggesting the independent effects of travel attitudes and travel characteristics on travel satisfaction. Table 29 presents the effects of travel attitudes on life satisfaction. The two models with and without travel characteristics explain about the same percentage (16.5%) of the variations in life satisfaction. Those who think car is safer than other modes, like transit and like travel in general have higher level of life satisfaction than others, while those who think fuel efficiency is important have lower level of life satisfaction than others. After controlling for travel characteristics, all these significant associations are still significant. Interestingly, all the travel characteristics are not significantly associated with life satisfaction when travel attitudes are included in the model. Table 30 presents the effects of travel attitudes on both positive affect and negative affect of wellbeing. The "happy" model explains about 16.7% of the variations in happy level, while the "anxious" model only explains less than one percent of the variations in anxious level. In "happy" model, those who like driving and think travel is positive have higher level of happiness yesterday than others. None of the travel attitudinal variables are significant in predicting level of anxiety yesterday.

Table 28 Effects of travel attitudes on travel satisfaction

	Coef.	P>t	Coef.	P>t
Demographics				
Age	**0.016**	**0.002**	**0.013**	**0.009**
Female	0.006	0.951	-0.064	0.506
Education	-0.075	0.164	-0.083	0.121
Income	0.054	0.052	0.016	0.569
Self-reported Health	**0.283**	**0.000**	**0.236**	**0.000**
Travel Attitudes				
Fuel Efficiency	-0.098	0.039	-0.027	0.569
Pro Bike	0.004	0.934	0.020	0.672
Car Safer	0.006	0.901	0.005	0.925
Pro Transit	0.079	0.090	0.084	0.064
Pro Walk	**0.169**	**0.001**	**0.139**	**0.005**
Pro Driving	**0.153**	**0.002**	**0.154**	**0.001**
Environment Friendly	0.084	0.074	0.082	0.077
Positive Travel	**0.423**	**0.000**	**0.290**	**0.000**
Travel characteristics				
Congestion			**-0.576**	**0.000**
Commuting time			**-0.007**	**0.000**
Car			**0.377**	**0.003**
Rail			0.433	0.089
Worker bus			**0.873**	**0.012**
Walk			**0.299**	**0.032**
Bike			0.260	0.309
E-Bike			-0.118	0.595
Bus (reference)			-	-
constant	-1.237	0.000	0.547	0.166
Number of obs	761		738	
Adj R-squared	0.190		0.293	

Note: bold fonts indicate coefficient is statistically significant at 5% level.

Table 29 Effects of travel attitudes on life satisfaction

	Coef.	P>t	Coef.	P>t
Demographics				
Age	**0.028**	**0.000**	**0.027**	**0.000**
Female	**0.239**	**0.010**	**0.192**	**0.045**
Education	0.004	0.944	-0.012	0.816
Income	**0.090**	**0.001**	**0.072**	**0.011**
Self-reported Health	**0.256**	**0.000**	**0.234**	**0.000**
Travel Attitudes				
Fuel Efficiency	**-0.092**	**0.037**	-0.083	0.077
Pro Bike	0.012	0.779	0.033	0.477
Car Safer	**0.210**	**0.000**	**0.185**	**0.000**
Pro Transit	**0.092**	**0.036**	**0.098**	**0.032**
Pro Walk	-0.018	0.708	-0.011	0.832
Pro Driving	0.037	0.431	0.043	0.368
Environment Friendly	0.029	0.521	0.033	0.490
Positive Travel	**0.157**	**0.001**	**0.137**	**0.006**
Travel characteristics				
Congestion			-0.099	0.216
Commuting time			-0.003	0.127
Car			0.129	0.310
Rail			0.065	0.795
Worker bus			0.306	0.357
Walk			-0.141	0.315
Bike			-0.302	0.261
E-Bike			-0.202	0.341
Bus (reference)				
constant	1.302	0.000	1.891	0.000
Number of obs	695		676	
Adj R-squared	0.165		0.165	

Note: bold fonts indicate coefficient is statistically significant at 5% level.

Table 30 Effects of travel attitudes on moods

	Feel happy yesterday		Feel anxious yesterday	
	Coef.	P>t	Coef.	P>t
Demographics				
Age	**0.041**	**0.000**	-0.003	0.813
Female	**0.390**	**0.026**	-0.064	0.762
Education	0.041	0.677	0.013	0.916
Income	0.024	0.636	0.011	0.855
Self-reported Health	**0.590**	**0.000**	0.066	0.585
Travel Attitudes				
Fuel Efficiency	0.086	0.308	0.146	0.160
Pro Bike	-0.005	0.956	0.150	0.145
Car Safer	0.145	0.100	0.135	0.215
Pro Transit	0.048	0.559	0.025	0.802
Pro Walk	0.138	0.126	-0.064	0.564
Pro Driving	**0.216**	**0.013**	-0.035	0.743
Environment Friendly	0.137	0.102	-0.182	0.079
Positive Travel	**0.239**	**0.007**	-0.076	0.480
Travel characteristics				
Congestion	**-0.345**	**0.017**	0.342	0.052
Commuting time	**-0.009**	**0.008**	-0.001	0.782
Car	0.382	0.098	-0.332	0.239
Rail	-0.521	0.249	-0.284	0.612
Worker bus	-0.042	0.947	-1.138	0.134
Walk	-0.116	0.646	-0.182	0.555
Bike	-0.195	0.688	-0.737	0.197
E-Bike	-0.693	0.077	0.157	0.739
Bus (reference)				
constant	2.618	0.000	4.050	0.000
Number of obs	721		721	
Adj R-squared	0.167		0.004	

Note: bold fonts indicate coefficient is statistically significant at 5% level.

SEM Model Results

A model specified as in Figure 30, which is a simplified version of the conceptual model proposed in Chapter 2, was estimated. In SEM, because I used Euclidean distance between home and job as a measure of the built environment, the variable, commuting time, was taken out to avoid collinearity. In addition, to keep the SEM parsimonious and align with the focus of this chapter, which addresses the built-environment and attitudinal factors that influence travel satisfaction, the SEM model reported here only includes travel satisfaction. Although an expanded SEM model that includes both travel satisfaction and life satisfaction was also estimated and presented in Appendix B, the interpretations and discussions following will only focus on travel satisfaction.

The model results, including model fits, standardized coefficients and significance, are provided in Table 31. The RMSEA fit index suggests a good fit and CFI fit index suggests an acceptable fit (CFI = 0.938, RMSEA = 0.035) based on Hu and Bentler (1999), who suggest a cutoff value close to 0.95 for CFI and a cutoff value close to 0.06 for RMSEA are needed to conclude there is a relatively good fit between the hypothesized model and the observed data.

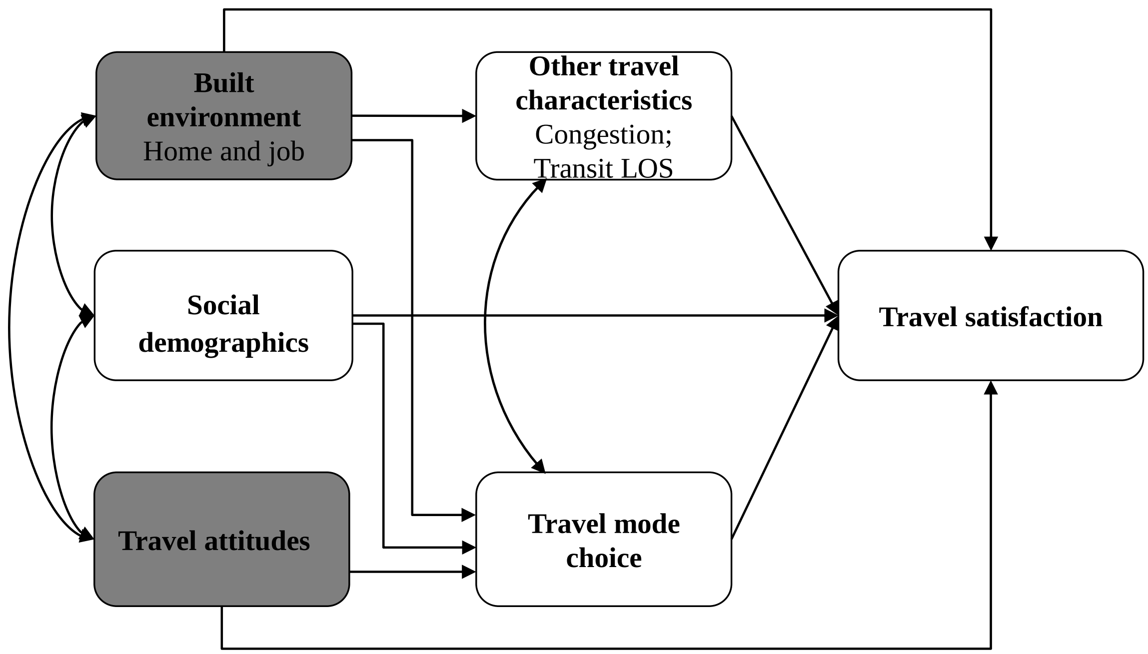

Figure 30 Model specification

Note: Curved line indicates a covariance between the two variables, and straight line represents the path from the causal variable toward the effect variable.

Effects of travel characteristics on travel satisfaction

Different levels of travel satisfaction were observed among commuters with different travel modes. Using the bus commuters as the reference group, bicycling commuters had the highest level of travel satisfaction, and walk and car commuters follow this. It is very interesting to note that e-bike commuters had the lowest level of travel satisfaction. The lower level of satisfaction with bus commuting has been reported in several studies (De Vos et al., 2015; Smith, 2013; St-Louis et al., 2014), but no studies have explored the relationship between using e-bike as a commuting mode and commuting satisfaction. The associations between rail and worker-bus commuting and travel satisfaction were not significant, though they were positive. For transit commuters, over-crowding in the carriage and having to transfer were associated with lower levels of travel satisfaction. Congestion had strong and negative associations with the travel satisfaction.

Effects of socio-demographics on travel satisfaction

Only age and general health condition had direct effects on travel satisfaction. Older people and those with a better self-reported health condition were associated with higher levels of travel satisfaction. The positive association between age and travel satisfaction has also been reported in previous studies (Cao and Ettema, 2014; De Vos et al., 2015). Further, all of the socio-demographic characteristics were associated with travel mode choice, which in turn influences travel satisfaction. The model results suggested quite a difference in socio-demographic characteristics of respondents using different commuting modes. In particular, the car commuters were more likely to be the older and have higher levels of education and income; while walking commuters were more likely to be those who were young and have lower levels of education and income; bicycling commuters were more likely to be older, male, and have poor health; e-bike commuters were more likely to be male and have lower levels of education; and those who relied on worker buses were more likely to be older and have higher levels of education. In general, people with a high level of income and education and good health were more likely to use car and worker bus for daily commuting, while those with a low level of income and education and are in poor health were more likely to rely on walking, bicycling, and e-bicycling for commuting, suggesting the important role of socio-economic status in travel mode choice.

Effects of built environment on travel satisfaction

None of the measured built-environment characteristics at both home and job locations had direct effects on travel satisfaction. However, most of the built-environment variables were associated with travel mode choice and other travel characteristics, which had direct effects on travel satisfaction. Access to transit at the home location was associated with more transit use and less car use for commuting, while access to transit at the job location was associated with more car use. The latter might suggest a mismatch between the demand and supply of public transit at the job locations. Those who worked at locations with good accessibility to public transit may not depend on transit for daily commuting. The different associations between access to transit and car use observed at home and job locations may also suggest that the commuting mode choice is more determined by the self-selection (i.e. transit commuters choose to live in transit-accessible neighborhoods) rather than by the built environment. Unlike western countries especially North America (Giuliano, 1991), where accessing to public transit is not necessarily an important factor influencing people's residential choice, good accessibility to public transit is an important consideration for many urban Chinese when making their residential choices because the majority of people do not have access to private cars (Wang and Lin, 2014). In addition, it is surprising to note that a suburban environment with big street blocks (i.e., suburbs with few bus transit services and less connected streets) at the home location was associated with more bike and e-bike use for commuting, and a car-dependent environment (i.e. suburban big blocks) at the job location was associated with more walking for commuting. This is a stark difference from the findings of previous literature. In part, this is because in Chinese cities, low-income population tend to live in suburban neighborhoods, and they are more likely to use walking, bicycling, and e-bicycling for commuting due to economic constraints. Additionally, there are many Danwei (or work units) distributed within the suburbs of the city. A work unit or Danwei in Chinese, as a legacy of socialist planning, is a place for people to work as well as live. In a typical

Danwei compound, people can acquire (gain access to) all the resources and facilities they need for work and life, including offices, housing, schools, canteens, daily-use grocery stores, etc. Studies have found that Danwei housed commuters have shorter commuting distances and higher usage of non-motorized transport mode (Wang and Chai, 2009) than those living in other types of accommodation. Furthermore, being close to greenery at the home location was associated with more car use and being close to greenery at both the home and job location was associated with less transit use. This is probably because people living close to greenery are relatively rich and thus are more likely to use car. Finally, longer home-job distances were associated with more car and rail transit use and less walking and bicycling for commuting. Comparing with the significance levels and magnitudes of the coefficients of home- and job-based built-environment variables, the home environment may have stronger effects on commuting mode choice than the job environment. This is probably due to the spatial clustering of the job locations and thus the variation of job environments is limited.

In addition to the indirect effects on travel satisfaction via travel mode choice, the built environment may also influence travel satisfaction by affecting other travel characteristics. The model results suggested that living in suburban big blocks was associated with higher levels of crowd in the bus or train carriage when commuting by transit. This is probably because of the high percentage of transit-dependent population located in suburban residential blocks, where fewer public transit services are available. Further, it is interesting to note that being close to greenery at home was associated with less congestion. This is probably because there are fewer roads around the large green land lots and thus traffic volumes are relatively low. It is also possible that being close to greenery moderates the subjective assessment of the congestion. However, being close to greenery at the job location was associated with higher levels of crowding on transit and of congestion on roads. This is probably because job locations that are close to greenery are located around the city wall, which is a traffic bottleneck in Xi'an. In addition, people whose working location is close to transit stations were less likely to make a transfer when commuting by bus or rail transit. Finally, it is no surprise that longer home-job distances were associated with more transfers for transit commuters and more congestion on roads.

Effects of attitudes on travel satisfaction

Compared with the socio-demographics and the built environment, a greater proportion of attitudinal variables were directly associated with travel satisfaction. It is interesting to note that positive attitudes towards car, transit, and walking all had positive effects on travel satisfaction. Also, people who think travel has positive utility were more satisfied with the commute than those who think travel is wasting time. Taken together, positive attitudes towards travel in general and any travel mode specifically is associated with higher levels of travel satisfaction. Further, environmentally-friendly commuters were more likely to be satisfied with their commute.

In addition to the direct effects, travel-related attitudes also indirectly influence travel satisfaction through travel mode choice. Most of the associations between attitudes and travel mode choice in my model have the expected sign and are consistent with previous research. Pro-bike, pro-walk and pro-transit attitudes were associated with less car use but more active travel and transit use for commuting. By contrast, people who think the car is safer and those who like driving were more likely to use car and less likely to use transit and active travel for daily commuting. Further, environmentally-friendly commuters were less likely to use the car and more likely to use active travel for commuting. Finally, people who enjoy travel in general were associated with more car use and walking for daily commuting.

Table 31 Model results

	Car	Rail	Walk	Bike	E-bike	Worker bus	Crowd	Transfer	Congestion	Travel Satisfaction
Travel characteristics[2]										
Car										0.167 ***
Rail										0.043
Walk										0.209 ***
Bike										0.220 ***
E-bike										-0.157 **
Worker bus										0.047
Crowd										-0.233 **
Transfer										-0.129 **
Congestion										-0.197 ***
Socio-demographics										
Age	0.119 ***	-0.025	-0.109 ***	0.062 **	-0.026	0.096 ***				0.060 **
Female	-0.044	-0.024	-0.043	-0.068 **	-0.049 *	0.022				0.017
Education	0.055 **	0.017	-0.077 **	0.019	-0.096 ***	0.059 *				-0.025
Income	0.231 ***	-0.021	-0.079 **	-0.036	-0.009	0.012				0.027
Health	0.044	0.040	-0.025	-0.058 **	-0.030	0.029				0.138 ***
Built-environment										
Access to transit (home)	-0.100 ***	0.127 ***	0.011	0.019	0.015	0.112 ***	-0.026	0.049	-0.055	0.008
Suburban big block (home)	-0.012	-0.040	0.039	0.109 ***	0.088 **	-0.042	0.099 **	0.010	-0.011	-0.004
Close to greenery (home)	0.073 **	-0.084 **	0.005	0.033	-0.004	0.033	-0.003	-0.049	-0.075 **	0.046
Access to transit (job)	0.079 **	0.052	-0.044	-0.042	-0.040	-0.053	-0.008	-0.130 **	0.026	-0.016
Suburban big block (job)	0.002	0.049	0.063 *	0.051	0.005	-0.005	0.069	-0.096 *	-0.116 ***	0.023
Close to greenery (job)	0.027	-0.098 ***	-0.032	-0.048	-0.027	0.036	0.093 **	0.012	0.089 **	-0.035
Distance from home to job	0.108 ***	0.110 **	-0.316 ***	-0.100 **	-0.057	-0.078 *	-0.009	0.271 ***	0.242 ***	0.060
Attitudes										
Fuel Efficiency	0.008	0.002	-0.068 **	-0.010	-0.007	-0.094 ***				-0.025
Pro Bike	-0.049 *	-0.002	0.035	0.168 ***	0.126 ***	-0.055				0.006
Car Safer	0.209 ***	0.034	-0.053	-0.110 ***	-0.061 **	-0.015				0.011
Pro-transit	-0.109 ***	0.094 ***	0.082 **	-0.021	-0.035	-0.008				0.069 **
Pro-walk	-0.051	-0.002	0.161 ***	-0.068 **	0.027	-0.083 **				0.093 ***
Pro-driving	0.015	-0.093 ***	0.036	0.048	0.022	0.015				0.102 ***
Pro-environment	-0.184 ***	-0.024	0.020	0.058 *	0.037	0.040				0.052
Positive Travel	0.079 **	-0.023	0.108 ***	0.048	-0.015	-0.058				0.211 ***

*p<.1; **p<.05; ***p<.01

Goodness of fit: CFI = 0.938; RMSEA = 0.035

[2] Bus is the reference group for the travel mode choice

Conclusion

This chapter addresses the effects of the built environment and travel-related attitudes on commute (travel) satisfaction. Through conducting descriptive analysis, OLS models and SEM models, this chapter reveals that the built environment (mainly refers to the accessibility in this study) has no direct effect on commute satisfaction, while it could indirectly affect commute satisfaction through the path of travel characteristics. This finding is different from two previous studies (Cao and Ettema, 2014; De Vos et al., 2015), which find that the built environment characteristics have direct and independent effects on travel satisfaction, in addition to travel attitudes and travel characteristics. However, the measurements of the built environment variables (GIS measured vs. self-reported; disaggregate vs. aggregate) and travel purposes (commuting trip vs. recreational trip vs. transit trip) are different between my study and those two studies, the direct comparison on the findings is not straightforward. Further, most of the travel-related attitudes were found to have both direct and indirect effects on commute satisfaction.

Among the factors that have direct effect on commute satisfaction, subjective attitudes seem to influence commute satisfaction more than other environmental and travel characteristics. This is consistent with Cao and Ettema (2014). Positive attitudes towards travel in general, for example, have a strong and positive effect on commute satisfaction. In terms of travel mode choice for commuting, bicycling and walking commuters had the highest levels of commute satisfaction, and car commuters, who also had higher levels of commute satisfaction than transit commuters, come third. E-bike commuters had the lowest level of commute satisfaction.

In terms of the built environment, this chapter finds that a short distance from home to job encourages active travel use and reduces car use for the commute. A short commuting distance also reduces the level of congestion on the roads and times of transit transfer needed. Finally, this chapter finds that improving access to public transit at the home location encourages transit use and reduces car use for commuting, and improving access to public transit at job locations helps to reduce the number of times a transfer needs to be made during the commute.

While not the focus of this chapter, the effects of the built environment and travel attitudes on SWB are also investigated. In general, the association between the built environment and SWB is weak. The only two variables that are significant in any of the SWB models are close to greenery at home and close to greenery at job location. The former one is positively associated with the life satisfaction and level of happiness yesterday when the travel characteristics are not controlled in the models. The latter one is negatively associated with the level of anxiousness yesterday. This might suggest that the importance of accessibility to green space in improving SWB. This is consistent with Cao and Wang (2016), who also found that being close to parks and open space improves residential satisfaction. While my study does not find significant effects of other built environment features on SWB, this study (Cao, 2016) finds that street connectivity positively affects life satisfaction. Comparing with the built environment, more travel attitudes are significantly associated with SWB. In general, positive attitudes towards driving and travel are positively associated with life satisfaction and level of happiness yesterday. However, none of the travel attitudes are significantly associated with level of anxiety yesterday.

Chapter 6. Commuting Satisfaction in Lower Income Population

Introduction

This chapter addresses research question 5 raised in the Chapter 1: Do people with low income have lower travel satisfaction comparing with those with higher income, and what factors contribute to the differences in travel satisfaction between the two groups?

This chapter also aims to contribute to the literature on travel and subjective wellbeing by focusing low-income population, who are more likely to live in the outskirts of the city for more affordable flats, and thus may have longer commuting distances, spend a higher share of their income on commuting cost, have less choice of travel modes (Choi et al., 2013; Morris and Guerra, 2014). Understanding the factors contributing to the lower levels of travel and life satisfaction of lower income populations is important for improving society wellbeing overall.

Methodology

The survey collected data on the characteristics of the respondents' commute, their satisfaction with various aspects of their commute, their attitudes towards different modes and aspects of travel, their socio-economic characteristics and their overall satisfaction with various non-travel aspects of their life. All respondents were then divided into two groups, lower income group and higher income group, using median income splits. Due to lack of household income data, individual income was used to define the groups. Using individual income to differentiate between the low- and high-income groups may affect results slightly because some low-income individuals might belong to a higher-income household and vice-versa. However, I also compared other socio-economic characteristics between the two groups as I defined them, and I found that the low-income group was less likely to own a car and a property than the high-income group. Around 50% of the respondents have an annual income of below 30,000 Yuan, which is about 60% of the average annual income (49,350 Yuan) of all employees in the urban area of Xi’an in 2013 (Xi'an Bureau of Statistics, 2013). These were classified as lower income workers. Table 32 provides a comparison of socio-demographic characteristics between the lower income and higher income groups. Compared to the higher income group, low-income workers are more likely to be female, young, with a lower level of education and poor health condition, and live in a bigger household, while they are less likely to hold a driver license, own a car or a flat.

Descriptive analysis was first conducted to explore the differences between low-income and higher income respondents in terms of their socio-demographic characteristics, their commuting characteristics, their home and job environment and their attitudes towards travel.

Table 32 Sample characteristics for low and higher income employees

	Lower income	Higher income	p-value*
Household number	3.60	3.33	0.00
# children	0.57	0.65	0.06
# full-time worker	2.01	2.07	0.21
% hold driver license	40%	72%	0.00
# cars	0.42	0.83	0.00
# bikes/e-bikes	0.82	0.73	0.07
Female	58%	46%	0.00
Age	31.71	35.62	0.00
Body Mass Index (BMI)	22.05	22.82	0.00
Self-reported health (1-5)	3.44	3.55	0.03
Education (1-6)[3]	3.12	3.75	0.00
Annually income before tax (1-10)[4]	2.01	5.25	0.00
Owner or renter of the property (1=owner)	44%	78%	0.00

*p-values are from ANOVA or chi-square tests as appropriate

Regression models were then used to further explore the relative contributions of socio-demographics, the built environment, commuting characteristics, and attitudes to commuting satisfaction. Since the measurement of the dependent variable, commuting satisfaction, is bounded at -3 on the left and 3 on the right, I employed the Tobit model (Tobin, 1958) to handle the censoring characteristic of the dependent variable. The Tobit model is based on an unobserved (latent) continuous dependent variable y_i^* that can take on any value:

[3] 1 - Junior high school or less; 2 - High school or technical secondary school; 3 - Some College; 4 - Bachelor's degree; 5 - Master's degree; 6 - Doctoral or professional degree.

[4] 1- less than RMB10,000; 2- ¥10,000-¥19,999; 3- ¥20,000-¥29,999; 4 ¥30,000-¥49,999; 5- ¥50,000-¥74,999; 6- ¥75,000-¥99,999; 7- ¥100,000-¥149,999; 8-¥150,000 and ¥199,999; 9- ¥200,000 and ¥399,999; 10-¥400,000 and over.

$$y_i = \begin{cases} y_i^* & if -3 < y_i^* < 3 \\ -3 & if\ y_i^* \le -3 \\ 3 & if\ y_i^* \ge 3 \end{cases}$$

$$y_i^* = \beta_0 + \beta_1 S_i + \beta_2 E_i + \beta_3 A_i + \beta_3 C_i + \varepsilon$$

where y_i is the observed variable (commuting satisfaction in my case) for individual i, S_i is the socio-demographic characteristics of individual i, E_i is the built environment around individual i's home and job locations, A_i is the individual i's attitudes towards travel, and C_i is the characteristics of the commuting trip by individual i. The Tobit model can be estimated with maximum likelihood estimation (Tobin, 1958).

Descriptive Analysis

Satisfaction with commute and life

As discussed in chapter 3, commuting satisfaction was measured using seven items: (1) I felt time was pressed - I felt time was relaxed during the commute; (2) I was worried I would not be in time – I was confident I would be in time; (3) I was stressed – I was calm; (4) I was tired – I was alert; (5) I was bored – I was enthusiastic; (6) I think this commute is the worst – I think this commute is the best I can think of; (7) I think this commute worked well – I think this commute worked poorly. Figure 31 provides a comparison in each item of commuting satisfaction between lower income respondents and others. A lower level of satisfaction was reported for every item of commuting satisfaction by lower income respondents, and follow-up ANOVA tests indicate that these differences were statistically significant ($p<0.01$).

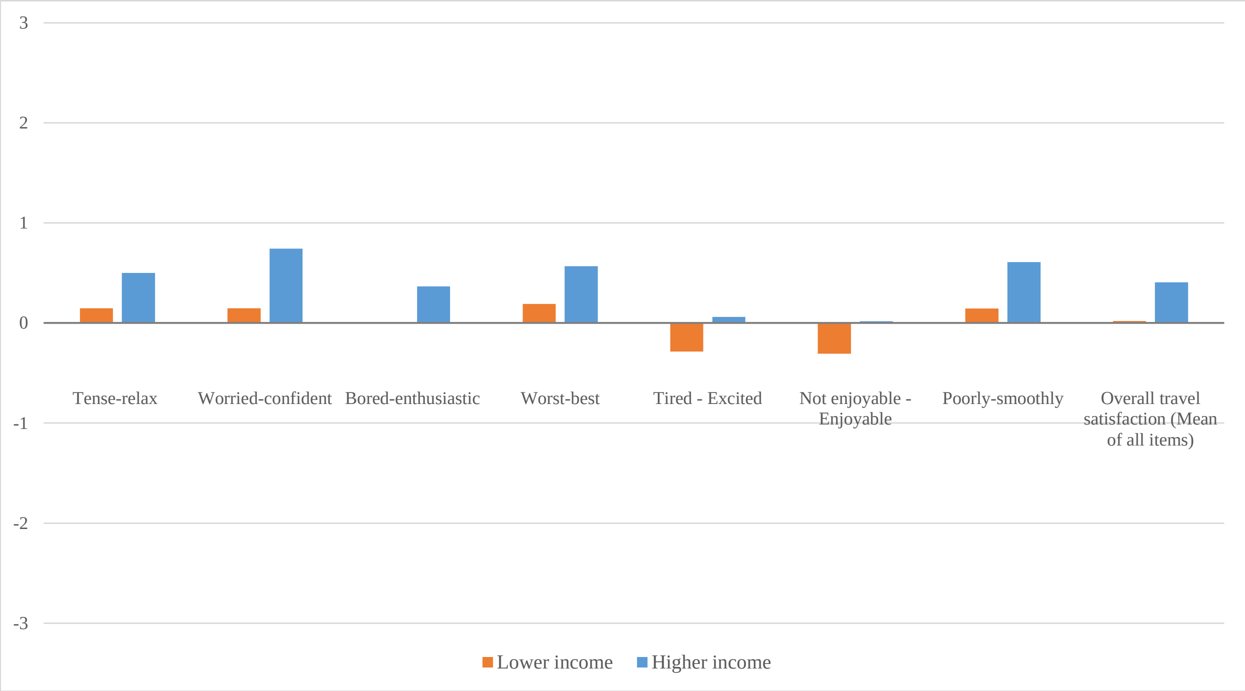

Figure 31 Mean satisfaction with commute by income group

As discussed in chapter 3, five items were used to measure satisfaction with life. These are: (1) In most ways my life is close to my ideal; (2) The conditions of my life are excellent; (3) I am satisfied with my life; (4) So far I have gotten the important things I want in life; (5) If I could live my life over, I would change almost nothing. Each item is measured on a 1-7 scale, where 1 is strongly disagree and 7 is strongly agree. Figure 32 illustrates the difference between lower income respondents and others in each item of life satisfaction. Similarly, the lower income respondents reported lower level of life satisfaction comparing with others. However, the differences in life satisfaction between the two groups of respondents were not as much as the differences in travel satisfaction. This indicates that life satisfaction is more affected by other factors in addition to income.

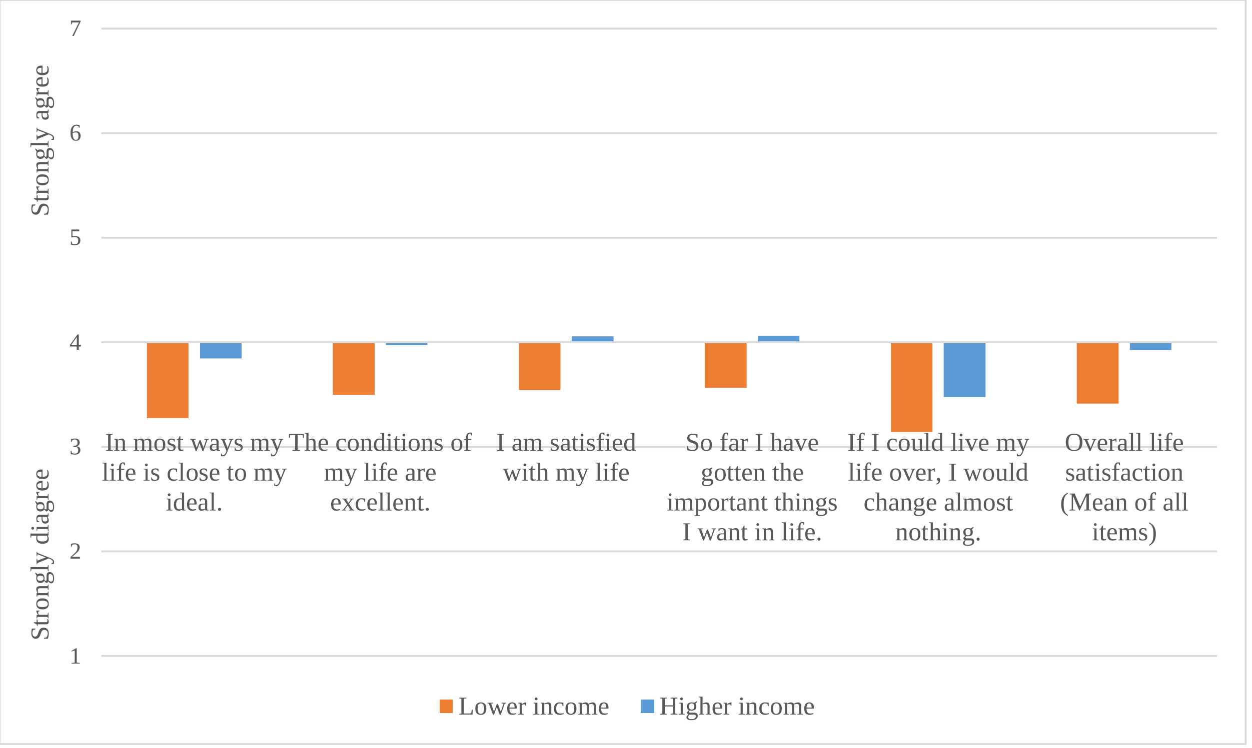

Figure 32 Mean satisfaction with life by income group

Travel Characteristics

Figure 33 provides the commuting mode choice between the lower income respondents and the higher income group. Comparing with others, lower income respondents were more likely to use bus (44% vs. 27%) for their daily commuting. About one in four lower income respondents walked to work, higher than for higher income respondents (23% vs. 15%). In total, nearly 70% of lower income respondents relied on the bus or walking for commuting. There was also a higher level of bike/E-bike use amongst lower income respondents compared with the higher income group (14% vs. 6%). As expected, compared to the higher income group, lower income respondents were much less likely to use the car (7% vs. 32%) for their commuting.

Figure 34 further illustrates the different relationship between travel modes and commuting satisfaction in the lower income group and higher income group. Commuting satisfaction was measured using the mean of the seven items. The lower income group reported lower travel satisfaction than the higher income group across all the travel modes except taxi and underground. For bike and e-bike commuters, it is interesting to note that, the overall travel satisfaction level among the lower income group is negative, while it is positive among the higher income group.

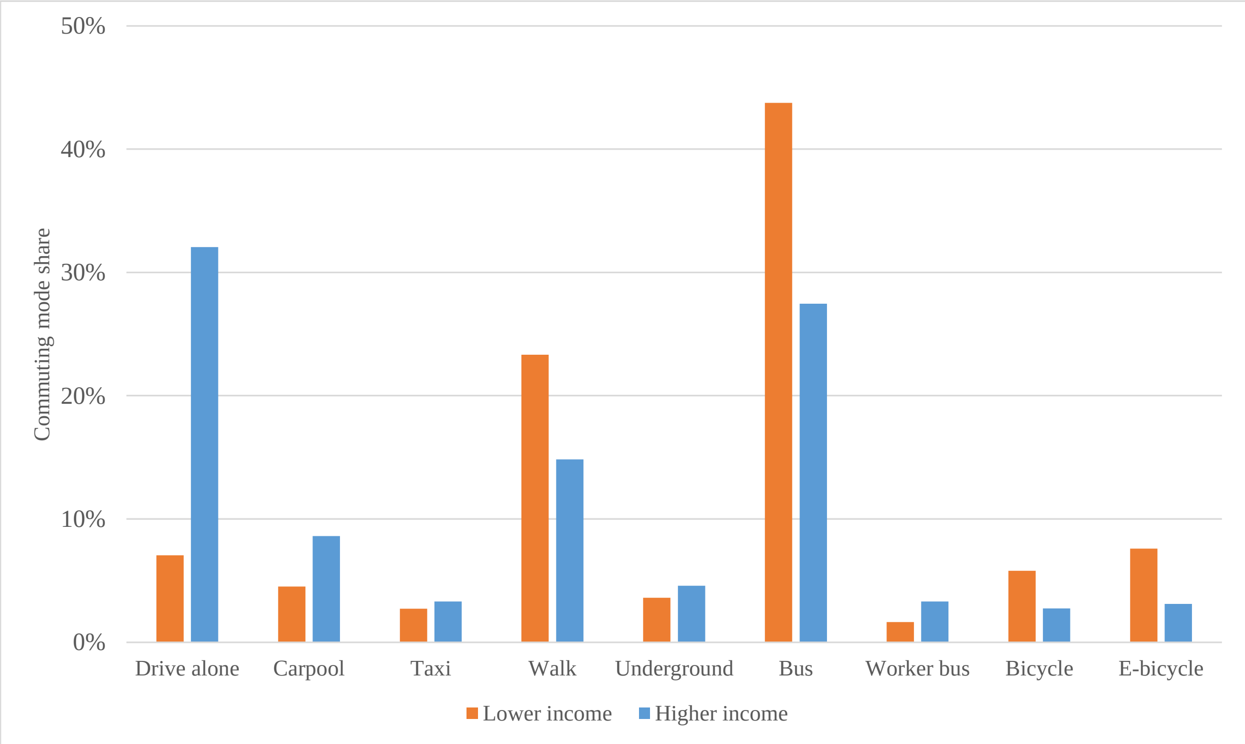

Figure 33 Commuting mode share by income group

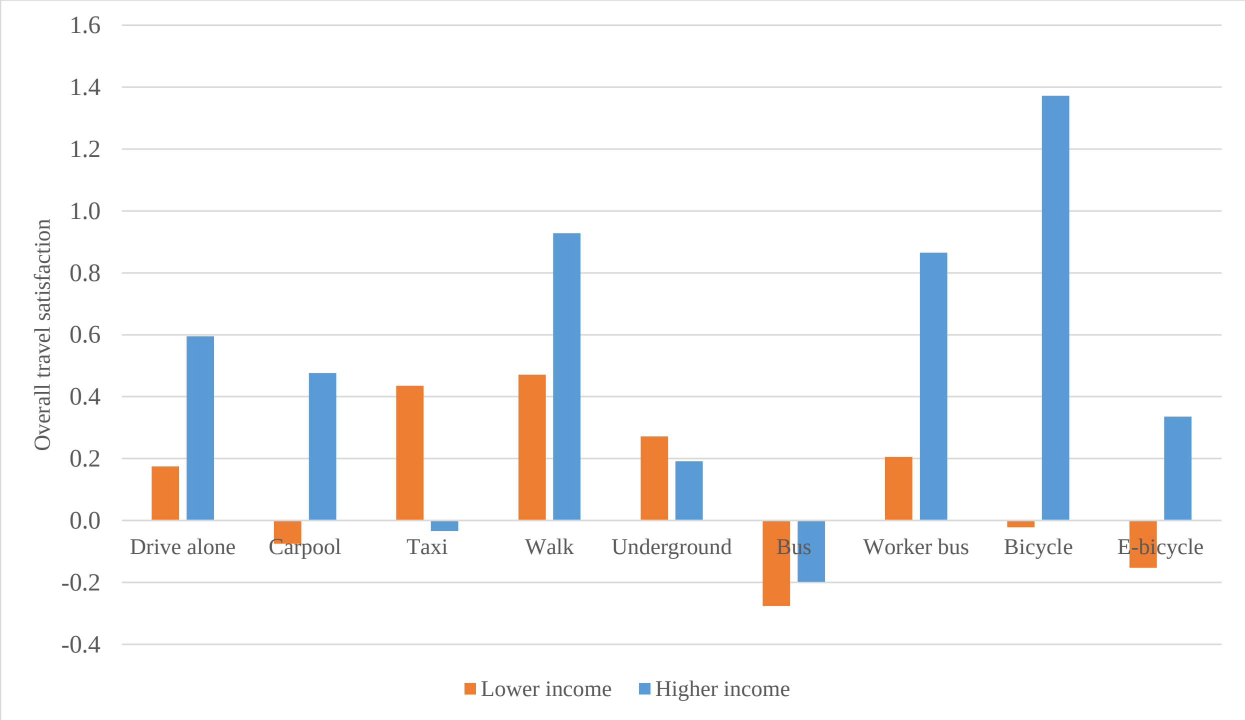

Figure 34 Mean commuting satisfaction by travel mode and income group

Table 33 compares the self-reported commuting time and distance by travel modes between the lower income and higher income groups. The lower income respondents had longer perceived commute times across almost all of the travel modes, with the exception of underground, bus and worker bus. Similarly, the lower income respondents had longer perceived commuting distances across all travel modes except worker bus. The longer perceived commuting time and distance by the lower income respondents could result from actual differences in commuting time and distances between the two groups, but could also be attributed to differences in perception per se between the two groups. It is possible that overall experiences of the commute are different between the two groups even if they use the same mode for commuting. For example, driving in a luxury and spacious car is more comfortable than in an old and compact car for commuting, and thus the perceived time and distance in latter may be longer. For transit commuters, waiting time and level of crowding could increase perceived travel time.

Table 33 Mean self-reported commuting time and distance by mode and by income group

	Self-reported commuting time (minutes)		Self-reported commuting distance (km)	
	Lower income group	Higher income group	Lower income group	Higher income group
Drive alone	41.4	33.8	16.9	10.6
Carpool	42.0	31.8	11.8	9.2
Taxi	40.2	37.5	13.6	9.6
Walk	28.4	20.3	6.3	4.0
Underground	41.2	48.5	11.4	10.9
Bus	49.1	53.0	12.5	11.6
Worker bus	29.2	49.7	16.5	22.4
Bicycle	30.6	22.3	15.7	6.0
E-bicycle	32.3	20.1	10.7	7.5

Among the lower income respondents who chose public transit to commute, around 39% need to transfer during the trip. This is lower than the transit commuters of the higher income group. However, a higher percentage of low-income transit commuters needed to transfer more than once. This group possibly have no choice other than using transit for their commute. Almost all of the transit riders reported that the carriage of their bus or train was crowded during the commute, but more low-income respondents reported “very crowded” compared with higher income respondents (Table 34).

Table 34 Characteristics of the transit commute by income group

	Lower income	Higher income
How crowded were bus or rail?		
Not at all	3%	2%
Somewhat	43%	50%
Very crowded	54%	48%
Need transfer?		
No interchange	61%	52%
Interchange needed	39%	48%
Number of transfer		
1	59%	70%
2	33%	28%
3 and over	8%	2%

Travel Attitudes

The lower income group has more positive attitudes towards bike and transit than the higher income group (Table 35); conversely, less people in this group are prone to car or think car is safer than other modes; As for walk, although from figure 1 we can see 25% of people in this group walk to work, which is much higher than higher income group (16%), their attitudes towards walk is negative comparing with other group. This implies that there is a mismatch between the walking behavior and attitudes towards walk among lower income respondents. Being forced to walk may also contribute to the lower level of satisfaction in lower income respondents.

Table 35 Mean travel attitudes rating between different income groups

	Lower income	Higher income	p-value*
Fuel Efficiency	-0.05	0.05	0.150
Pro Bike	0.12	-0.12	**0.000**
Car Safer	-0.17	0.17	**0.000**
Pro Transit	0.05	-0.05	0.179
Pro Walk	-0.14	0.13	**0.000**
Pro Driving	-0.06	0.07	0.057
Environment	0.05	-0.05	0.140
Positive Travel	-0.04	0.04	0.225

*p-values are from ANOVA tests

Built environment

Table 36 shows the characteristics of the built environment around the home and job locations for the lower and higher income groups. Compared to the higher income group, lower-income people are more likely to live in the suburb area and in bigger land blocks, and have fewer bus stops and less commercial land use around their home as well. While for job location, there are less rail/bus stops, the percentage of commercial land use around the work place of lower income group, and the street connectivity around their work place is not as good as higher income group.

It is worth pointing out that although the GIS measured average home-job (Euclidean) distances are quite similar for the two groups, those from the lower income group report longer commuting distance than those from the higher income group. It is possible that streets from home and job for the lower income group is less connected so they need to make detours during commute. It is also possible that, because the lower income group is more likely to use bus, e-bike, walking and bicycling, where the former two are associated with low travel satisfaction and the latter two require more efforts than other travel modes, the lower income group is more likely to overestimate the actual commuting time than the higher income group. The Figure 35 and Figure 36 further compares the commute patterns between lower and higher income group. They show that there are more lower income commuters travel very long distance (over 10 km) from the outer suburbs to the city center and more lower income commuters travel very short distance (within 2 km) than other income group. The former are probably those lived in suburbs and travelled primarily on bus and e-bike, and the latter might be those lived in city villages and travelled by walking and bicycling.

Table 36 Built environment around home location between two different income groups

	Lower income	Higher income	p-value*
Distance from home to CBD (meters)	7,545	7,081	0.052
Rail station within ¼-mile of home	11%	10%	0.696
Rail station within ½-mile of home	18%	18%	0.969
Average perimeter of the blocks around home	1,171	1,083	**0.030**
Street connectivity (nodes ratio) around home	88%	88%	0.817
% commercial land use around home	7%	10%	**0.004**
% green land use around home	6%	6%	0.464
# bus stops within ¼-mile of home	23	27	**0.005**
# bus stops within ¼-mile of job	21	25	**0.002**
Distance from job to CBD (meters)	7,170	6,867	0.148
Rail station within ¼-mile of job	6%	12%	**0.003**
Rail station within ½-mile of job	11%	19%	**0.003**
Average perimeter of the blocks around job	1,048	1,088	0.198
Street connectivity (nodes ratio) around job	89%	92%	**0.037**
% commercial land use around job	8%	11%	**0.000**
% green land use around job	7%	6%	0.197
Home-job distance (GIS measured, km)	5.11	5.24	0.737
Home-job distance (self-reported, km)	11.39	9.83	**0.027**

*p-values are from ANOVA tests or chi-square tests as appropriate.

Figure 35 Comparison of home-job linear distance between low- and other- income residents

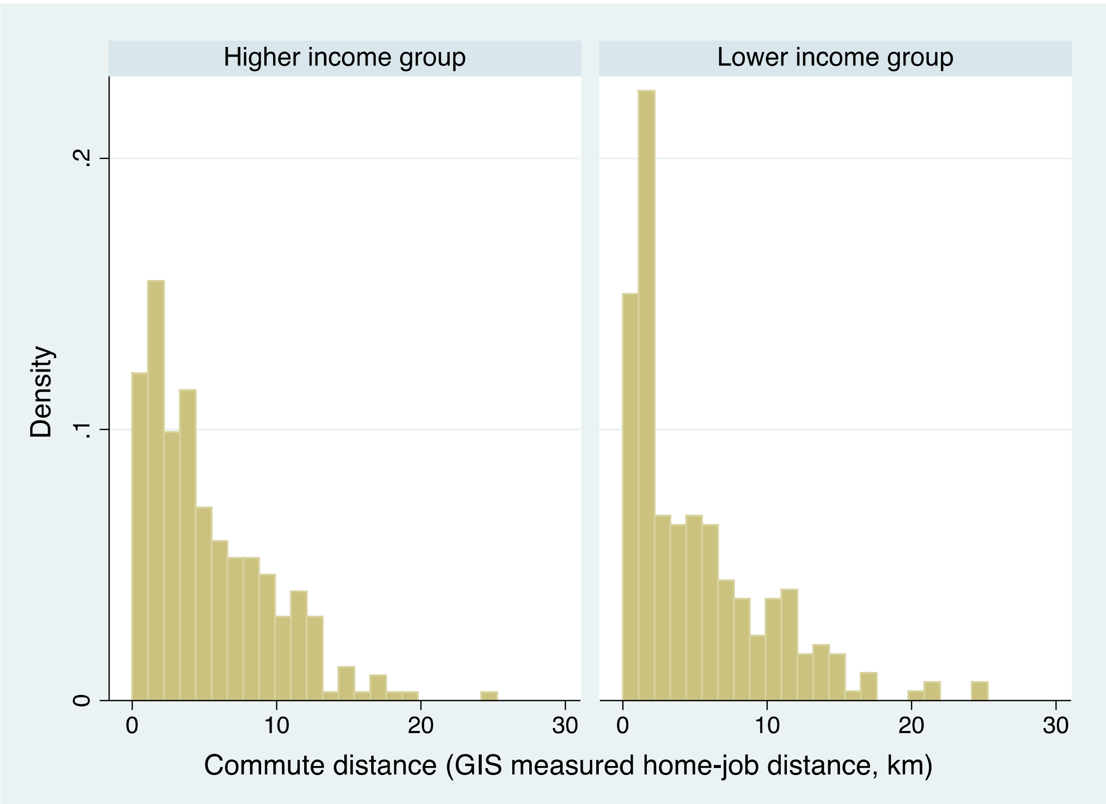

Figure 36 Comparison of distribution of commute distance between low- and other-income residents

Model Results

A Tobit model was employed to investigate the factors contributing to the commuting satisfaction. To compare the differences between the lower income group and higher income group, separate models were conducted for the two groups. The independent variables include four sections: social-demographics, commuting characteristics, the travel attitudes, and the built environment. The models were tested using these four sets of variables at the beginning; however, I found that none of the built environmental variables were statistically significant. Further, because many respondents did not report either their home or job location or both, including the built environmental variables decreases the sample size for model estimation. The built environment variables, therefore, were excluded in the next step model development. All the models were checked for multi-collinearity and heteroscedasticity, which may bias the estimation. The plots of residuals against the predicted value did not show strong trend, indicating no serious heteroscedasticity in the models.

Although the built-environment variables were not statistically significant in the models after accounting for the socio-demographics, travel characteristics and attitudes, this does not mean the built-environment contributes nothing to commuting satisfaction. The built environment could affect commuting characteristics (e.g. travel mode choice) as well as the travel attitudes, which directly influence commuting satisfaction. As indicated in Table 36, the lower income respondents were more likely to live in areas with big blocks, disconnected streets and less bus services, which were associated with less walking, bicycling and transit use for their commuting, and lower level of satisfaction with these modes. A structural equation model would test this indirect effect of the built environment on commuting satisfaction. Different from the results of my study, a recent study of the Twin Cities, Minnesota (Cao & Ettema,

2014) found independent effects of the built environment on travel satisfaction after accounting for attitudes, though the contribution of the built environment is relatively small, ranging from 3-4%. The difference in results could be from the different measurements of the built environment. All the built environment variables in my study were calculated in GIS, while Cao and Ettema (2014) used a number of self-reported (or perceived) measures. Objective and perceived measures of the built environment could influence travel satisfaction in different ways.

The model results are reported in Table 37. Each of the two models explained approximately 11-13% of the variations in commuting satisfaction, however, there are some differences in contributory factors between the two models. For both the lower income group and the higher income group, congestion and longer commute times were associated with lower levels of commuting satisfaction. These findings are in line with previous studies (Smith, 2013; Stutzer & Frey, 2008). However, age was positivity associated with a high level of commuting satisfaction only for the low-income group, whilst those who are married and those with good health were more likely to be satisfied with their commuting trip, but only for those on higher incomes.

A striking difference between the two groups is the effect of travel mode choice on commuting satisfaction. For the lower income group, travel mode choice makes no difference to commuting satisfaction. For the higher income group, however, travel mode choice does matter for commuting satisfaction. In particular, bus commuters are less likely to be satisfied with their commute than those relying on car, rail transit, worker bus, walking or cycling to get to work. Bus and e-bike commuters had the lowest levels of satisfaction with commuting amongst those in the higher income group. The lower level of satisfaction with bus commuting has been reported in several studies (De Vos, et al., 2015; Smith, 2013; St-Louis, et al., 2014), but no studies have explored the relationship between using e-bike as a commuting mode and commuting satisfaction. The negative perception on e-bike commuting in Xi'an could result from the frequent conflicts between e-bike commuters and commuters using other traffic modes. The different effects of travel mode on commuting satisfaction between the two groups may imply that a quite different experience between the two groups while they are using the same travel modes for commuting. As shown in the descriptive analysis, both the trip distance and trip time for walking and bicycling commuting are lower for higher income group relative to lower income group. Further, given the possible feedback effect from SWB on travel satisfaction, the lower level of SWB of the lower income group might lead to the lower level of commuting satisfaction.

The effects of attitudes on commuting satisfaction also showed differences between the two groups. Among the lower income respondents, those who hold positive attitudes towards transit, walking, and driving were more satisfied with their commuting than those who hold negative attitudes. Interestingly, attitudes towards travel modes had no impact on commuting satisfaction in the higher income group. As suggested above, the lower income commuters perhaps had limited capacity to choose the commute mode they like, and thus their attitudes towards the mode they chose would become more important to influence their subjective evaluation of the commuting trip. Further, environment friendly respondents were more likely to be satisfied with their commute than those who had less environmentally-friendly attitudes, but this is only significant for the higher income group. Finally, for both groups, those who hold positive attitudes towards travel were more likely to be satisfied with their commuting trip.

Table 37 Factors contributing to commuting satisfaction for lower income and higher income groups.

	Lower income group		Higher income group	
	Coef.	P>t	Coef.	P>t
Socio-demographics				
Age	0.022	**0.012**	-0.004	0.576
Female	-0.080	0.588	-0.080	0.544
Education	-0.049	0.536	-0.080	0.310
Income	-0.056	0.513	0.000	0.996
Married	0.138	0.436	0.391	**0.018**
Self-reported Health	0.142	0.068	0.444	**0.000**
Travel Characteristics				
Congestion[5]	-0.651	**0.000**	-0.520	**0.000**
Commuting time	-0.007	**0.007**	-0.006	**0.041**
Car	0.237	0.259	0.541	**0.002**
Rail	0.356	0.361	0.693	**0.047**
Worker bus	0.746	0.325	1.031	**0.009**
Walk	0.044	0.817	0.909	**0.000**
Bike	-0.407	0.211	1.776	**0.000**
E-Bike	-0.237	0.429	-0.088	0.805
Bus	Ref.		Ref.	
Attitudes				
Fuel Efficiency	-0.012	0.861	-0.041	0.565
Pro Bike	0.068	0.355	-0.042	0.518
Car Safer	-0.070	0.308	0.056	0.455
Pro Transit	0.225	**0.000**	-0.097	0.176
Pro Walk	0.235	**0.001**	0.079	0.273
Pro Driving	0.232	**0.000**	0.086	0.251
Environment Friendly	0.005	0.942	0.189	**0.004**
Positive Travel	0.359	**0.000**	0.258	**0.000**
constant	0.866	0.154	-0.145	0.818
Log-Lik Intercept Only	-661.704		-661.809	
Log-Lik Full Model	-588.264		-576.399	
McFadden's R2	0.111		0.129	
Number of observation	363		373	

Note: Bold font indicates significant at 5% level.

Conclusion

This chapter explored the commuting satisfaction of the lower income population in Xi’an, China. Lower income respondents consistently reported lower levels of

[5] 1= not at all congested; 2= somewhat congested; 3= very congested.

commuting and life satisfaction. A previous chapter has found that commuting satisfaction is significantly associated with life satisfaction (see Chapter 4 and Ye & Titheridge, 2015), and this highlights the importance of exploring the factors that contribute to commuting satisfaction. This chapter further investigated various factors contributing to the lower level of commuting satisfaction among the lower income population compared with the rest of the population.

The effects of travel mode choice on commuting satisfaction were only significant in the higher income group, and this suggested that there were significant differences in satisfaction with different commuting modes for the higher income group, while the satisfaction with different modes were similar for the lower income group. The overall lower level of SWB of the lower income group might contribute to the lower level of reported commuting satisfaction and smaller variations in the level of satisfaction across modes among the lower income group. Consistent with previous studies, attitudes have significant effects on commuting satisfaction in all income groups, though different associations were found between lower and higher income groups.

As indicated in Figure 33, the lower income population of Xi'an is more likely to choose the bus, walking or bicycling as their primary commuting mode. However, the bus was rated with the lowest level of satisfaction by both income groups (Figure 34). This suggests that overall the quality of bus services in Xi'an is low. In addition, those on lower incomes may experience poorer services. Higher levels of in-vehicle crowding and higher levels of +2 interchanges are reported by lower income respondents. For walking commuting, the lower income group holds negative attitudes towards walking despite walking being chosen as the commuting mode by a significant share of lower income respondents. This implies that many walking commuters in lower income group may not have other travel options and this leads to the lower level of satisfaction with walking commuting in that group compared with the higher income group. For bicycling commuters, the lower income group reported much lower levels of commuting satisfaction compared with the higher income group, even though the attitudes of lower income group on bicycling are positive overall. When comparing the commuting distance for cyclists, I find that the distances cycled to work are much higher among the lower income group than for the higher income group.

Finally, the built-environment immediately around the home and job locations tends to be different for the two income groups. A greater proportion of lower income respondents lived in suburban areas in big-block neighborhoods, with fewer bus services. A greater proportion of lower income respondents worked in areas with a low percentage of commercial land use, less connected streets, and less public transport services. It is interesting to note that the objectively measured (GIS) commuting distance was similar between the lower income and higher income groups, however, self-reported commute distances were significantly longer for the lower income group compared with the higher income group. This implies that creating a walking, bicycling, and transit friendly environment may help the lower income population to overcome actual and perceived difficulties with commuting, thereby improving their overall satisfaction with commuting.

Chapter 7. Conclusions, Policy Implications and Future Research

This chapter summarizes the key findings of this study and highlights the major contributions of this study to the state of the art and state of the practice. Limitations of this study and future research are also discussed.

Summary

Through collecting the first-hand survey data and supplemented GIS data in Xi'an, China, this study quantitatively explored the relationships between travel and subjective wellbeing. This research has particularly focused on commuting behavior and its association with commuting satisfaction and subjective wellbeing, because fewer empirical studies on this topic are on commuting travel, and commuting is the major concern of transport policy in China. The major findings of this study are summarized below and in Table 38.

First, the average score of the SWLS measure (M=3.67; SD=1.24; scale: 1-7) and the PWI measure (M=5.08; SD=1.84; scale: 0-10) reported in this study imply that residents of Xi'an are not quite satisfied with their life. Though the sample of this study is not perfectly representative of whole population, it captures a variety of population and a wide area of the Xi'an city. This finding is quite different from a review study (Davey and Rato, 2012) that concludes that SWB is overall positive and PWI score is in a range of 61.2 to 67.1 (using a scale of 0-100) across Chinese cities. The reasons for this inconsistent finding are largely unknown, but this review study does not include any sample from a city of western China, which has relatively lower level of economic development comparing with eastern Chinese cities. However, another study that compares the SWB of university students between two Chinese cities, Beijing and Xi'an, and an USA city, Los Angeles, using the SWLS measure, reported a very similar average score of SWLS for Xi'an (M = 3.23, SD = 1.00) as my study, and this study also found that SWB in Xi'an was lower than in Beijing (M = 4.09, SD = 1.08) , and SWB in both Chinese cities (M = 3.78, SD = 1.12) was lower than in the USA (M = 5.10, SD = 1.12).

Second, consistent with the hypothesis, this study finds that commute characteristics, including travel mode choice and level of service, significantly influence commuting satisfaction, and indirectly affects overall satisfaction with life (SWB) through commuting satisfaction. The direct effects of most commute characteristics on SWB are weak after controlling for the socio-demographic characteristics of the commuters. However, commuting time and congestion are the two factors that still have direct and significant effects on SWB after controlling for socio-demographics. In particular, the commuting time significantly affects the cognitive component of wellbeing (life satisfaction), both the commuting time and the congestion significantly affects the positive affect, while only the congestion influences the negative affect. As summarized in the literature review section, previous studies have explored the relative effects of travel characteristics, including travel time, congestion, travel mode choice, and level of service of transit, on SWB. These studies, however, did not explore the mechanisms of the relationship between travel and SWB. My study contributes to the previous research by further exploring both the direct and indirect effects of commuting characteristics on SWB using the structural equation modeling. The finding of this study supports the causal path from travel characteristics to SWB through travel satisfaction. In addition, previous research on the links between travel and SWB has either focused on cognitive assessment of SWB or the affect components. Little has included both components and compared the impact of travel on different components of SWB. My study contributes to this research gap by investigating the different effects of commuting characteristics on cognitive and affective components of SWB. This study finds commuting characteristics affect cognitive SWB, positive and negative affect differently, and this suggests that future research on travel and SWB should model different components of SWB separately.

Third, consistent with the hypothesis, commuting satisfaction is significantly associated with SWB, even after accounting for the satisfaction with other important domains of life and socio-demographics. This highlights the important role of commuting in affecting the quality of life in China. Although theoretically travel satisfaction should be associated with SWB since travel satisfaction is an important dimension of SWB, the previous empirical studies on this relationship have mixed results. For example, Abou-Zeid (2009) found the association between the commuting satisfaction and overall life satisfaction was not statistically significant. While a number of technical issues, including measurement of travel satisfaction and SWB, model specifications, and control variables used in the model, could contribute to the mixed results, the inconsistent findings may also suggest that the association between travel satisfaction and SWB varies among different areas, regions, or countries. For example, many Chinese cities have been experiencing fast urbanization over the last 20 years, and as a result, people's commuting behavior in those cities changed dramatically. Not only the primary commuting modes changed from walking and cycling to transit and car, but also the much longer commuting time and the increasing congestions on road, and all of these significant changes have remarkable impacts on people's daily life. By contrast, Western cities are relatively stable in terms of urban form as well as people's travel behavior over the past decades, and people may already adapt to their daily commuting. It is therefore the variations of commute satisfaction within the Western cities may be smaller than that in Chinese cities. This highlights the importance of this empirical study that based on the evidence from China on constructing the theoretical framework linking travel and SWB.

Fouth, as expected, most of the commute characteristics measured in this study are significantly associated with commuting satisfaction. Consistent with most of the previous literature, this study finds that people who choose the active modes of walking and bicycling are most satisfied with their commute, and this is followed by worker bus and car commuters, while those rely on bus and E-bike are least satisfied with their commute. However, it is worth noting that the order of the level of commuting satisfaction varies depending on the controlling variables used in the model. For example, without controlling for socio-demographics, worker-bus commuters are most happy with their commute, and then followed by active commuters (i.e. worker bus > walking > bicycling), however, the order reverses (i.e. walking > bicycling > worker bus) after controlling for the socio-demographics. This might help to explain the mixed results in terms of whom the happiest commuters are reported by previous studies. It is also worth noting that the differences in means of commuting satisfaction between each pair of worker bus, walking, bicycling and car are not statistically significant, indicating commuter using these travel modes may have the same level of commuting satisfaction. Further, among all commuting characteristics, congestion is the biggest deterrent to the commuting satisfaction. For public transit commuters, having to transfer between services and crowding on services significantly dampen their travel experience. This study is one of the first to compare the importance of different travel characteristics on travel satisfaction. The order of importance identified in this study might be quite different from the studies that are based on different social and transport contexts, and therefore more empirical studies from Chinese cities are needed to confirm the finding of this study. Further, while this study found that e-bike commuters are least satisfied with their commuting, e-bike users grow dramatically in Chinese cities over the past 10 years. For many citizens of Chinese cities, they still cannot afford a private car and do not have access to reliable public transit, the e-bike has become a primary travel mode for their daily life because of its low-cost, flexibility, and ability to travel long distance and over hills with relative ease, which help to overcome some barriers to bicycling for women and older people (Dill and Rose, 2012; Weinert et al., 2007). Therefore, future research is needed to address the low level of satisfaction with e-bike uses.

Fifth, partially consistent with the hypothesis, the built environment characteristics measured in this study (mainly refers to the accessibility in this study) have no direct effect on commute satisfaction after controlling for socio-demographics of the commuters and commute characteristics, while they could indirectly affect commute satisfaction through influencing commute characteristics (e.g., travel mode choice, congestion, transit level of services). Further, the only built-environment variable that positively affects SWB is being close to greenery at home and job location after controlling for socio-demographics. In particular, being close to greenery at home location is positively associated with life satisfaction and level of happiness yesterday, and being close to greenery at job location is negatively associated with level of anxiety yesterday. However, the effects of being close to greenery at home location on SWB are not significant after controlling for both socio-demographics and commute characteristics. Some of the findings of this study do not align well with previous studies. For example, Cao (2016) found that street connectivity has a positive effect on life satisfaction based on the US context, while my study does not support this finding. As mentioned early, the incomplete measurement of the built environment in this study limits to compare the findings of this study with others. By saying that, the unique built-environment characteristics of Chinese cities also contribute to the different results. The land-use configuration in Chinese cities is much denser, more compact, and mixed than the cities in US, Canada, and Australia. Although many Chinese cities have expanded dramatically over the last several decades, most of residents are still able to access their daily needs within a walking or cycling distance. However, the neighborhoods featured with low-density, singular land use, spread-out, and automobile-dependent patterns are quite common in North America and other car-dependent countries. Therefore, the key built-environment characteristics that matter for SWB are different between Chinese cities and North American cities.

Sixth, consistent with the hypothesis, travel-related attitudes have both direct and indirect effects on commute satisfaction even after controlling for socio-demographics of the respondents and commute characteristics. In particular, positive attitudes towards travel in general and any travel mode specifically are associated with higher levels of travel satisfaction. In addition, environmentally friendly commuters are more likely to be satisfied with their commute. Further, travel-related attitudes also have both direct and indirect effects on SWB. In particular, positive attitudes towards driving and travel are positively associated with life satisfaction and level of happiness yesterday. Comparing with previous studies (Cao and Ettema, 2014; De Vos et al., 2015) that have examined the relationship between travel attitudes and travel satisfaction, my study contributes by further exploring the direct and indirect effects of travel attitudes on travel satisfaction by focusing on commuting trips. This helps to better understand the general theoretical framework that links the travel and SWB.

Seventh, among the factors that have direct effect on commute satisfaction, attitudes seem to influence commute satisfaction more than other environmental and travel characteristics. It is not surprise that travel attitudes have higher impact than the built environment and travel characteristics on satisfaction measures, because both the travel attitudes and travel satisfaction or SWB belong to intrapersonal factors, while the built environment and travel characteristics are external factors. Further, this finding implies that solely changes in the built environment or transportation system may have limited effects on improving the travel satisfaction or SWB. This finding is consistent with Cao and Ettema (2014) and De Vos (2015).

Eighth, consistent with the hypothesis, lower income respondents consistently reported lower levels of commuting and life satisfaction. Further, this study explored the factors that contribute to the different levels of commute satisfaction between the two income groups. This study finds that the effects of travel mode choice on commuting satisfaction were not significant in the low-income group. This study also finds that higher levels of in-vehicle crowding and higher levels of +2 interchanges are reported by lower income respondents. For walking commuting, the lower income group on average holds a negative attitude towards walking despite walking being chosen as the commuting mode by a significant share of lower income respondents. For bicycling commuters, the lower income group reported much lower levels of commuting satisfaction compared with the higher income group, even though the attitudes of lower income group on bicycling are positive overall.

Finally, although there are differences in transport conditions, social norms, and the built environment between Chinese cities and cities of developed countries, several findings of this study are consistent with previous research that was conducted in North America and Europe. These findings include: (1) active travel commuters have the highest levels of travel satisfaction; (2) travel attitudes are significantly associated with travel satisfaction; (3) over-crowding of bus/train carriages and having to transfer between modes or services are associated with lower levels of travel satisfaction; (4) congestion has strong and negative associations with travel satisfaction. This study, therefore, provides additional evidence from a unique context (developing country) that helps to generalize these findings. However, there are several findings that are unique to this study. These findings include: (1) the built environment only indirectly affects commute satisfaction through the path of travel characteristics (e.g. travel mode choice, congestion levels); (2) e-bike commuters have the lowest level of commute satisfaction, while the worker bus commuters have equivalent level of commuting satisfaction, if not higher, with active travel; (3) a suburban environment with big street blocks at the home location is associated with more bike and e-bike use for commuting, and a suburban environment with big street blocks at the job location is associated with more walking for commuting; (4) a suburban environment with big street blocks is associated with higher levels of crowding in bus or train carriages when commuting by transit; (5) being close to greenery at home was associated with lower level of perceived congestion. Some of these unique findings are possibly associated with the particular urban form, transport conditions and urban planning cultures in China; more studies are needed to confirm these findings.

Table 38 Summary of the Main Findings of This Study

Research questions	Main Findings
(1) Does travel satisfaction influence overall life satisfaction and well-being, after accounting for socio-demographics and other important domains of life? (Chapter 4)	• Commute characteristics indirectly affects life satisfaction through influencing commuting satisfaction. • Commuting time and congestion are the only two factors that still have significant effects on SWB, after controlling for socio-demographics. • Commuting satisfaction is significantly associated with life satisfaction.
(2) What commute characteristics, such as journey distance, travel time, travel mode, congestion, level of service etc., influence travel satisfaction, after accounting for socio-demographics? (Chapter 4)	• People who choose the active modes of walking and bicycling are most satisfied with their commute, and this is followed by worker-bus and car commuters, while those rely on bus and E-bike are least satisfied with their commute. • Transfer between transit services and crowding on services significantly reduce commute satisfaction. • Congestion is the biggest deterrent to the commuting satisfaction. • Commuting time significantly reduces commuting satisfaction.
(3) How do the characteristics of the built environment at people's home and job locations influence their travel satisfaction and well-being? (Chapter 5)	• The built environment only indirectly affects commute satisfaction through influencing commute characteristics. • Being close to greenery is positively associated with SWB after controlling for socio-demographics.
(4) How do people's attitudes influence their travel satisfaction and well-being? (Chapter 5)	• Travel-related attitudes have both direct and indirect effects on commute satisfaction. • Travel-related attitudes have both direct and indirect effects on life satisfaction. • Attitudes are more important in affecting commute satisfaction than other environmental and travel characteristics.
(5) What factors contribute to the lower level of travel satisfaction of low-income population comparing with those with higher income? (Chapter 6)	• Lower income respondents consistently reported lower levels of commuting and life satisfaction. • The effects of travel mode choice on commuting satisfaction were not significant for low-income. • Mismatch between travel preferences and availability of travel options may influence commute satisfaction.

Policy Implications

These findings have important policy implications. They illustrate that travel model choice and the efficiency and quality of the transportation network not only affects economic activities, but also has significant impact on individuals' well-being.

Policies that aim to promote active travel should be encouraged. The role of the built environment on active travel behavior has been well established. Many studies have found that a built environment featuring high density (Kitamura et al., 1997), mixed land uses (Frank and Engelke, 2005), well-connected streets (Handy et al., 2002), sidewalks (Forsyth et al., 2008) and bicycle infrastructure (Pucher et al., 2010) is associated with more walking and bicycling behavior. Chinese cities are currently experiencing fast development and thus considerable transformation. It is critical that urban planners intervene in this process to help shape an environment friendly for walking and bicycling. Xi'an used to have wide pedestrian and cycling boulevards along its main roads in 1980s and 1990s, and walking and bicycling were the primary commuting modes. Since 2000, in accordance with fast motorization, the urban planning in Xi'an had focused on prioritizing the free flow of vehicles, and thus the road spaces for pedestrian and bicyclists are significantly narrowing down. The use of walking and cycling as daily travel means has continuously declined over the last two decades due to deteriorating infrastructure as well as the built environment for walking and cycling. This declining trend of active travel as a travel mode is not unique in Xi'an, it happens in others big Chinese cities, such as Beijing (Zhao, 2014). By contrast, many Western countries, including North America, Australia, and European countries, have growing interests and efforts in promoting active travel in the last decade, after recognizing the negative consequences of car-dependent travel pattern, and the environmental, health and social (equity) benefits of walking and bicycling. Most of Chinese cities usually have very high population density, and thus a high proportion of car travel would lead to a very low level of travel efficiency and serious congestion. Further, most of socio-disadvantaged population cannot access to cars in China, it is socially unfair to prioritize the car travel and allocate most road spaces to private cars. Future transport policy in Chinese cities should aim to revive the bicycling as an important travel mode for daily activities and encourage more people to use active travel and public transit instead of private vehicles. To promote active travel and transit use, both hard measures and soft measures are needed.

Changing the built environment is a typical hard measure used in urban planning to change travel behavior. However, the built environment is different between cities in China and Western world. For example, most American and Australian cities, and some European cities are characterized with low-density, singular land use, spread-out, and automobile-dependent patterns, while Chinese cities are much compact, dense, and mixed in land use. Strategies like new urbanism and smart growth, such as higher densities and mixed land use, which are supposed to alter the time cost of traveling from one location to various other locations by concentrating trip origins closer to destinations and by influencing travel speed, are proposed in those countries to change the car-dependent travel pattern. Most of these land use and design policies, however, cannot be directly applied in China's context. The real problems for many Chinese big cities are too dense rather than too sparse in urban forms. Besides, most of neighborhood level land use and design policies, such as mixed land use and street connectivity, are proposed mainly aiming at non-work travel, such as shopping and recreational trips. Most of the non-work (e.g. daily errands) trips in most of Chinese cities are travelled by walking, biking and transit. This is because a minimum percentage of commercial and entertainment land use are required for neighborhood zoning in China. Previous studies (Lin and Shin, 2008; Zhang, 2007) have found that mixed land use and street connectivity are not significant variables in modeling the relationship between travel and built environment in Chinese cities. The real travel problem in current Chinese cities is primarily on commuting trip, which may require regional level land use policies, such as jobs-housing balance and transit oriented development, to address. Jobs-housing balance could be a good indicator for explaining the commuting behavior in Chinese cities, even though the appropriate scale for using this indicator is not clear, several studies have attempted based on the case of Beijing (Wang and Chai, 2009; Zhao et al., 2011). Xi'an has relative good jobs-housing balance because of the legacy of work-unit yard, but this balance is diminishing in accordance with city expansion and spatial separation of employment and residential areas (Zhou et al., 2014). Future urban planning policy should recognize the merits of the traditional work-unit yard in addressing the commuting problems and try to maintain the function of the current work-unit yards in the city. Similarly, although many Chinese cities including Xi'an are enthusiastic in demolishing the urban villages to improve the city image, those villages serve as important dwellings for the new immigrants of the city, who are often in lower socio-economic status, and help them maintain a low commuting cost. The urban planning should not throw the baby out with the bath water (Song et al., 2008).

In addition to the land use strategies, investing new and maintaining old pedestrian and bicycling infrastructures are also important. As mentioned above, current pedestrian and bicycling spaces in Xi'an are being eroded by the increasing cars. Urban planning should adopt regulations to protect the traditional boulevards for walking and bicycling in the city, and invest on improving the qualities of old infrastructures that are less maintained. For the new bicycling infrastructure, the routes that passing open spaces and parks should be given priority, because this study found that exposure to greenery may contribute to a higher level of commuting satisfaction. Further, future bicycling infrastructure planning should be integrated with transit stations to achieve a multi-mode commuting network, and this may also help to ease the access and egress to transit and thereby improving the experience of transit commuting. Finally, a unique bike-sharing scheme has been created in China, and it is being quickly rolled out in many Chinese cities, including Xi'an. About a dozen of companies (e.g. Ofo, Mobike) that invest in this bike-sharing business are booming in China. Comparing with traditional bike-sharing system with fixed bike docks at specified locations, the Chinese version is a non-docking platform that users can find bikes in vicinity by using an App in their cellphones, ride the bike to anywhere and park anywhere after the trip. The users do not need to return the bike to a designated dock stations. The transaction of using a bike is easily completed through the App in the cellphone. This new scheme has attracted tremendous bike use for daily errands as well as commuting and achieved a great success. In accordance with this trend, the city of Xi'an should invest to build and improve the bicycling routes linking the major residential and employment centers and encourage more people to use this bike-sharing scheme for commuting purpose.

Changing the built environment is necessary to promote healthy and happy commuting, while other soft measures are also needed to change people's attitudes and perceptions and social norms. While the increasing commuting distance contributes to the fast growth of car ownership in Chinese cities, pro-car culture in China also plays a role. Owning a car is still a symbol for higher social status in China, while to ride a bike or take transit is deemed as poor and lower social status. Once the financial condition is met, many Chinese people will choose to buy a car and travel by car in lieu of walking, biking and transit without considering its necessity in daily life. This might diminish the effects of land use strategies on travel behavior because the popularity to use the car will diminish the effect of land use on travel cost. Education and social marketing programs are needed in China to change the favorable attitudes towards cars. Social marketing programs have been implemented in many cities around the world as a travel demand management measures (Bamberg et al., 2011). The social marketing programs could change people's attitudes and perceptions towards different travel modes by providing individuals with information on using alternative transport to the car and helping them to realize the consequences of different travel modes on their health and the environment. Other soft policies may also include employer-provided incentives, such as provision of subsidized transit passes, bicycling commuting group, and provision of worker bus. This study has found worker-bus commuters have higher level of commuting satisfaction than bus and e-bike commuters.

In addition, congestion level is a strong factor among the travel characteristics that determine the levels of commute satisfaction. Policies aiming to alleviate the congestion, particularly in the inner city (the area within the city wall), may improve commute satisfaction within Xi'an. A series of congestion management strategies may help to ease the serious congestion in big Chinese cities. Possible pricing strategies include charging congestion fee in the inner city and high-occupancy toll (HOT) lanes. These strategies have been successfully implemented in some Asian and western cities. Other regulation and planning strategies that may help to reduce motorized travel and curb congestion include restricting car purchase and use, introducing parking restrictions, maintaining a jobs-housing balance in new developments (Cervero and Duncan, 2006), promoting alternative work hours, and introducing employer-based rideshare programs. Some of these strategies are not difficult to implement in Xi'an. For example, Xi'an has the natural advantage to charge the congestion fee because the city center area is enclosed by the city wall, which will make the congestion charge technically feasible. Electronic toll collection (ETC) could be installed on all the gates of the city wall, where all the vehicles need to pass through to the city center. HOT lanes can be used in the Ring 2 road, which is a major commuting link and often has serious congestions. In addition to the pricing strategies, the car sharing might be another solution that helps to reduce the car ownership and congestion level in Xi'an. Currently there are two models operated in Western countries. One is the cars that are owned by a company (e.g. Zipcar, Car-to-Go) and the other one (GetAround, HiyaCar, easyCar Club) allows private individuals to rent their vehicles to other individuals, also known as peer-to-peer car sharing. Car sharing, together with other new business models, such as on-demand ride services like Uber and real-time ride-sharing services such as Carma and Zimride, all could help to curb the increasing car ownership, potentially reduce the congestion and improve the air quality. The government of Xi'an should encourage the operation of these new business models.

Public transit is a primary mode for commuting in Xi'an, particularly for the low-income population. This highlights the importance to improve the experience of transit commuters by improving the transit level-of-service. Increasing network coverage, making interchange easier, less stressful and increasing the frequency of public transit during peak hours may help to improve the level of service, commuting satisfaction and thus well-being. This may also include adding routes and increasing frequency of transit in suburban areas, where there are low-income population clusters, and providing more direct routes between major residential areas and job locations. In addition, adding more dedicated bus lanes on major bus routes that link suburban residential neighborhoods and key employment centers will also help to improve the performance of transit and transit users' experience. In Xi'an, cars often illegally occupy current dedicated bus lanes, and thus more strict law enforcement is needed to protect the right of way of transit. Between the data collection of this thesis in 2013 and completion of this thesis in 2017, there is another metro line (Metro 3) operated, and another four metro lines under construction, with all the metro lines linking the suburbs and the city center. Based on the newest urban planning of Xi'an, there will have seven metro lines by 2021 reaching a total distance of 243 kilometers. The overall transit services will be significantly improved after the operation of these metro lines. Finally, improving transit services also include preventing crime on transit, particularly theft and sexual harassment, which were the two most common criminal offenses reported by the participants in my study. Addressing this issue is especially important for the women to use transit in Xi'an for commuting.

The negative perception of e-bike commuting in Xi'an could result from the frequent conflicts between e-bike commuters and commuters using other traffic modes. However, the e-bike is increasingly used as a travel mode in Xi'an and other Chinese cities because of its flexibility, reliability and the capacity to travel longer distance with less effort than the regular bike. It also provides a motorized travel option for the low-income population who cannot afford a car and those living in areas without access to reliable transit, thereby contributing to reduce the transport poverty and social exclusion for the socio-disadvantaged population. Further the e-bike helps women and older people to hurdle the physical barriers that are common in using regular bikes. Although several cities in China have banned the e-bike because of the high risk of traffic accidents involving e-bike, government policies should recognize the important role of e-bike in meeting the life needs for the low-income population and take action to make the travel with e-bike safe and better the travel experience of e-bike users rather than suppress it. Future transportation planning in Xi'an and other Chinese cities should integrate e-bike in their overall transport network and travel demand modeling. Also, future urban planning and road design should consider the potential risks of e-bike involving accidents, such as the frequent reported collision between the right-turn vehicles and straight going e-bikes. Other regulations on the speed of e-bikes as well as education and training programs to the e-bike users are also necessary to improve the e-bike safety.

This study finds that a short distance from home to job encourages active travel use and reduces car use for the commute. A short commuting distance also reduces the level of congestion on the roads and times of transit transfer needed. This suggests maintaining a job-housing balance is important to promote sustainable transport and a happy city. At a neighborhood level, as mentioned above, future urban planning should merit and maintain the current work-unit yards. Xi'an is currently emerging from a mono-centric city to a poly-centric city, and several employment centers were proposed in Xi'an Urban Planning 2008-2020. At a regional level, future urban planning should consider to match new residential development with the growth of jobs in those new centers, and thereby reducing the commuting needs between the centers. Further, given Xi'an is planning to build several metro lines, future planning should also consider placing new residential development and employment close to the proposed metro stations, and thus helping to reach a job-housing balance along the metro corridors. In addition, creating green spaces along the commuting route may help to moderate the negative effects of perceived congestion levels and long commuting time. Future urban planning should promote more green streets by incorporating vegetation in roadside landscape. Previous studies have reported exposure to greenery produces good moods and tension relief , and drivers viewing vegetation along the road tend to present lower level of stress, frustration and angry and thus less to commit aggressive and reckless driving (Cackowski and Nasar, 2003; Hull, 1992; Knopf, 1987; Parsons et al., 1998). Finally, this study finds that improving access to public transit at the home location encourages transit use and reduces car use for commuting, and improving access to public transit at job locations helps to reduce the number of times a transfer needs to be made during the commute. To improve transit accessibility, the urban planners should increase the number of residents within a 10 minutes walking time of major transit stations, better integrate non-motorized modes (e.g. walking and bicycling) with transit, and integrate transport and land use planning for future developments.

This study found that a greater proportion of lower income respondents lived in suburban areas in big-block neighborhoods, with fewer bus services, and a greater proportion of lower income respondents worked in areas with a low percentage of commercial land use, less connected streets, and less public transport services. This implies that creating a walking, bicycling, and transit friendly environment may help the lower income population to overcome actual and perceived difficulties with commuting, thereby improving their overall satisfaction with commuting. Future transit network planning should analyze the spatial distribution of different socio-demographic population and place the services to the areas where transit are most needed (i.e., vertical equity) rather than deliver the services only based on population density or spread the services equally over space (i.e., horizontal equity). Further, investing metros in low-income areas may not only improve the accessibility, but also help to change the built environment towards a more favorable place. Finally, this study found that mismatch between travel preferences and availability of travel options may influence commute satisfaction. This highlights the importance to enable people to live in the built environment that offers the travel modes that match their travel preferences. For the high-income population, they have the freedom to choose the location that could maximize their satisfaction with travel and other life needs. While for the low-income population, they are more likely to live in the suburbs where travel options are very limited. Future urban planning should consider embed the affordable housing and low-rent housing, which are provided by the city government, in areas that are close to employment centers.

Future Research

This study has several limitations. First, cross-sectional design of this study limits the ability to make causal references and make policy implications. Longitudinal design that evaluates the changes of subjective wellbeing in accordance with changes of the built environment and travel behavior would be enlightening. Due to this limitation, I could only estimate a model that assumes the relationships between the variables are unidirectional; I recommend future research to explore the reverse direction of the relationships I proposed in the conceptual model. For example, how might travel satisfaction influence travel mode choice and home location choice?

Second, determinants of travel satisfaction for different travel purpose might be different. For example, the factors associated with the levels of satisfaction with commuting trips and recreational trips could be different. Few of previous studies have compared the travel satisfaction between different trip purposes.

Third, this study only explored cognitive component of subjective wellbeing and its associations with travel. The affective component of subjective wellbeing might have different associations with travel. In addition, the measurement of subjective wellbeing in this study focused on hedonic approach, which is often used in previous studies, more research is needed to explore the relationship between travel and eudaimonic measurement of subjective wellbeing.

Fourth, the commuting characteristics were measured based on respondent's recall of yesterday's commuting trip, while the subjective wellbeing was measured using SWLS scale, which is an overall evaluation of life satisfaction. The extent that yesterday's commuting trip representing the overall commuting trip pattern will influence the association between the commuting characteristics and subjective wellbeing identified in this study.

Fifth, future research can also improve this study by including more precise and complete measures of the built environment. Further exploration of the factors contributing to the low levels of travel satisfaction with public transit and e-bike would also be enlightening.

Finally, several previous studies have explored the effects of dissonance between travel preferences and actual residential environment on people's travel behavior (Cao et al., 2009; Chatman, 2009; Schwanen and Mokhtarian, 2005); it would be interesting to investigate whether there are significant differences in travel satisfaction between those who self-select to live in a neighborhood that meets their travel preferences (active residential self-selection) and those who are forced to live in a neighborhood due to economic constraints (passive residential self-selection).

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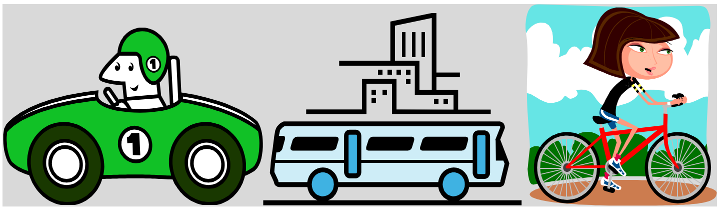
Appendix A

TRAVEL AND WELL-BEING



You are invited to participate in a research study led by Runing YE, a Ph.D. student from Transport Centre of University College London, who wants to learn more about how your commute to work makes you feel - and why.

Participating on this survey is completely volunteering and you can withdraw at any point before submitting questionnaire without giving reason. What's more, any question that makes you feel uncomfortable can be skipped. Finally, all information gathered will only ever be presented to others in such a way that no individual can be identified.

If you decide to participate, you will be asked to fill out the following survey. It should take about 15 minutes to complete and it includes questions about: (1) Feelings you experience during your commute; (2) Your commute route (time cost, travel mode, traffic congestion etc.); (3) Your general preferences about travel; (4) Where you live and work; (5) How's the feeling about life.

All of your answers will be kept as confidential material and used for this research only.

If you would like to know more about the research, please feel free to contact Runing YE. The email address is r.ye.11@ucl.ac.uk. Thank you very much!

Q1.1 Including yourself, how many people live in your household?

1 (1)

2 (2)

3 (3)

4 (4)

5 (5)

6 or more (6)

Q1.2 Of these, how many are 18 years or younger?

0 (1)

1 (2)

2 (3)

3 (4)

4 or more (5)

Q1.3 Including yourself, how many household members work full-time?

0 (1)

1 (2)

2 (3)

3 (4)

4 (5)

5 or more (6)

Q1.4 Do you have a valid driver's license?

Yes (1)

No (2)

Q1.5 How many vehicles are available to you at your home?

0 (1)

1 (2)

2 (3)

3 (4)

4 (5)

5 or more (6)

Q1.6 How many working bicycles do you own?

0 (1)

1 (2)

2 (3)

3 (4)

4 (5)

5 or more (6)

Q1.7 Are you:

Single, never been married (1)

Married (2)

Living with partner (3)

Separated or divorced (4)

Widowed (5)

Q1.8 What is your age (in years)?

Q1.9 Which gender do you most identify with?

Male (1)

Female (2)

Decline to respond (3)

What is your height?

---------------------------cm

What is your weight?

---------------------------kilogram

How do you evaluate your general health condition?

Poor (1)

Fair (2)

Good (3)

Very good (4)

Excellent (5)

Q1.10 How many years of school have you completed? (please select one)

Some high school or less (1)

High school (2)

Some college (3)

Trade/vocational school (4)

Associate degree (5)

Bachelor's degree (6)

Master's degree (7)

Doctoral or professional degree (8)

Decline to answer (9)

Q1.11 What is your approximate annual income before taxes?

Less than ¥10,000 (1)

¥10,000-¥19,999 (2)

¥20,000-¥29,999 (3)

¥30,000-¥49,999 (4)

¥50,000-¥74,999 (5)

¥75,000-¥99,999 (6)

¥100,000-¥149,999 (7)

¥150,000 and ¥199,999 (8)

¥200,000 and over (9)

Comparing with your close friends, do you think your income is lower or higher?

Lower(1)

Equal (2)

Higher(3)

Do you satisfy with your current income?

Very Dissatisfied (1)

Somewhat Dissatisfied (2)

Neither satisfied nor dissatisfied (3)

Somewhat Satisfied (4)

Very Satisfied (5)

Q1.12 Knowing where you live is essential for understanding your commute. Please provide your place of residence. Remember, all data from this survey will be kept confidential and available only to the researcher.

Address or closest intersection (1)

City (2)

Province(3)

Zip (4)

Q1.13 How long have you lived in your current home?

Years:

Months:

Do you own or rent the current house?

Rent (1)

Own (2)

Do you need to pay the monthly mortgage for the house/ car?

Yes (1)

No (2)

Q1.14 Please provide the name and location of your workplace.

Workplace name (1)

Address or closest intersection (2)

City (3)

Q1.15 How long have you worked in your current workplace?

Years:

Months:

Q1.16 Are you a local residence or immigrate?

Local residence(1)

Immigrate (2)

Q1.17 What is your current employment status?

Not Employed or Work exclusively from home (1)

Employed outside the home, Full-time (2)

Employed outside the home, Part-time (3)

Q1.18 Please select the industry you work in.

Agriculture, forestry, fishing and hunting, and mining (1)

Construction (2)

Manufacturing (3)

Wholesale trade (4)

Retail trade (5)

Transportation and warehousing, and utilities (6)

Information (7)

Finance and insurance, and real estate and rental and leasing (8)

Professional, scientific, and management, and administrative and waste management services (9)

Educational services, and health care and social assistance (10)

Arts, entertainment, and recreation, and accommodation and food services (11)

Other services, except public administration (12)

Public administration (13)

Other (please specify) (14) ____________________

Q1.19 On average, how many days per week do you work outside the home?

0 (1)

1 (2)

2 (3)

3 (4)

4 (5)

5 (6)

6 (7)

7 (8)

Q2 Questions about your commute to work in general

Q2.1 At this time of year, how often do you use each of the following as your primary mode of transportation to work? By "primary" I mean the mode you use for the longest duration of your trip. Please fill in each row.

	4-5 days/week (1)	2-3 days/week (2)	1 day/week (3)	1-3 days/month (4)	Less than once a month (5)	Never (6)
Drive alone (1)						
Carpool (2)						
E-bicycle (3)						
Subway (4)						
Bus (5)						
Bicycle (6)						
Walk (7)						
Other (specify) (8)						

Q2.2 If you do drive or if you were to drive to work, what type of car do you drive?

Private owned (1)

Work unit provided (2)

Q2.3 If you do drive or if you were to drive to work, would you have to pay to park?

Yes (1)

No (2)

Q2.4 if you take transit to work, how many transfers needed during the trip?

0 (1)

1 (2)

2 (3)

3 (4)

4 (5)

5 or more (6)

Q2.5 How important is it to you to arrive at work on time?

Not at all Important (1)

Somewhat Unimportant (2)

Neither Important nor Unimportant (3)

Somewhat Important (4)

Very Important (5)

Q2.6 Please rank how easy it is for you to commute to work by the following modes:

	Very Difficult (1)	Somewhat Difficult (2)	Somewhat Easy (3)	Very Easy (4)	Don't Know (5)
Drive alone (1)					
1.1. Carpool (2)					
1.2. subway) (3)					
Bus (4)					
1.3. Bicycle/ebicycle (5)					
1.4. Walking (6)					

Q2.7 To what extent are the following important to you when choosing your travel mode? For each, indicate the degree of importance.

	Very unimportant (1)	Somewhat unimportant (2)	Neither unimportant nor important (3)	Somewhat important (4)	Very important (5)
Is cheap (1)					
1.5. Is comfortable (2)					
1.6. Saves time (3)					
1.7. Is flexible (4)					
1.8. Is mentally relaxing (5)					
1.9. Is physically relaxing (6)					
1.10. Is enjoyable (7)					
1.11. Impresses people (8)					
1.12. Offers privacy (9)					
1.13. Benefits my health (10)					
1.14. Reduces environmental impact (11)					
1.15. Provides safety from traffic (12)					
1.16. Provides safety from crime (13)					
1.17. Suits my lifestyle (14)					
Prevents from air pollution(15)					

Q3 Questions about your most recent commute to work

Q3. 1 For your most recent commute to work, please select your primary mode of transportation:

Drove alone (1)

Carpooled with another person (could be a family member) (2)

Walked (3)

Rode a worker (shuttle) bus(4)

Rode a car by company(5)

Rode a bicycle(6)

Rode a E-bicycle (7)

Rode a subway (8)

Rode a bus (9)

Other (please specify) (10) ____________________

Answer Q3.2 to Q3.7 If For your most recent commute to work, shuttle bus/subway/bus is Selected

Q3.2 How did you get from home to the shuttle stop/ bus stop/rail station?

Walked (1)

Rode a bicycle (2)

Rode a bus (3)

Carpooled (4)

Drove alone (5)

Other (6) ____________________

Q3.3 How crowded was the shuttle bus/bus/subway?

Not at all crowded (1)

Somewhat crowded (2)

Very crowded (3)

Q3.4 How did you get from the stop/ bus stop/ rail station to work?

Walked (1)

Rode a bicycle (2)

Streetcar (3)

Carpooled (4)

Drove alone (5)

Other (6) ____________________

Q3.5 How crowded was the shuttle bus/ bus/subway?

Not at all crowded (1)

Somewhat crowded (2)

Very crowded (3)

Q3.6 Did you have to make any transfers?

Yes (1) how many times____________

No (2)

Q3.7 How congested were the streets?

Not at all congested (1)

Somewhat congested (2)

Very congested (3)

Q3.8 How long did the total trip take, from the time you left home to the time you arrived at work (in minutes)?

Minutes (1)

Answer Q3.9 and Q3.10 If For your most recent commute to work, other ways expect shuttle bus/subway/bus is Selected

Q3.9 How congested were the streets?

Not at all congested (1)

Somewhat congested (2)

Very congested (3)

Q3.10 How long did the total trip take, from the time you left home to the time you arrived at work (in minutes)?

Minutes (1)

Q3.11 Please select the box that best corresponds to your experience during the trip. For example, if you were very tense, select the box for -3. If you were neither tense nor relaxed, select the box for 0.

	-3 (1)	-2 (2)	-1 (3)	0 (4)	1 (5)	2 (6)	3 (7)
Tense (-3) to Relaxed (3) (1)							
1.18. Worried that you would arrive on time (-3) to Confident that you would arrive on time(3) (2)							
1.19. Bored (-3) to Enthusiastic (3) (3)							
1.20. My trip was the worst I can imagine (-3) to My trip was the best I can imagine (3) (5)							
1.21. Tired (-3) to Excited (3) (4)							
1.22. Not enjoyable (-3) to Enjoyable (3) (7)							
1.23. My trip went poorly (-3) to My trip went smoothly (3) (6)							

Q3.12How long did the total trip take, from the time you left home to the time you arrived at work (in minutes)?

Minutes (1)

Q3.123 Which of the following things did you do during the commute? Pick as many as apply.

Working/studying (1)

Reading for leisure (2)

Listening to music/radio (3)

Used Internet for leisure (4)

Sleeping/resting (5)

Email/Text messaging/Phone (6)

Gaming (7)

Talking to other travelers (8)

Windowgazing/people watching (9)

Other (10) ____________________

None of the above (11)

Q3.13 How satisfied were you with your commute from home to work on this particular day?

Very Dissatisfied (1)

Somewhat Dissatisfied (2)

Neither satisfied nor dissatisfied (3)

Somewhat Satisfied (4)

Very Satisfied (5)

Q4 The following questions ask about your satisfaction with your job, home, and life in general

Q4.1 Please indicate your agreement with each item by selecting one of the options[6].

	Strongly Disagree (1)	Disagree (2)	Slightly disagree (3)	Neither Agree nor Disagree (4)	Slightly agree (5)	Agree (6)	Strongly Agree (7)
In most ways my life is close to my ideal. (1)							
1.24. The conditions of my life are excellent. (2)							
1.25. I am satisfied with my life. (3)							
1.26. So far I have gotten the important things I want in life. (4)							
1.27. If I could live my life over, I would change almost nothing. (5)							

[6] Satisfaction with Life Scale (SWLS)

Q4.2 Please indicate your agreement with each item by selecting one of the options[7].

"The following questions ask how satisfied you feel, on a scale from zero to 10. Zero means you feel completely dissatisfied. 10 means you feel completely satisfied. And the middle of the scale is 5, which means you feel neutral, neither satisfied nor dissatisfied."

(1) How satisfied are you **with your standard of living?**

Completely Dissatisfied					Neutral					Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

(2) How satisfied are you **with your health?**

Completely Dissatisfied					Neutral					Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

(3) How satisfied are you **with what you are achieving in life?**

Completely Dissatisfied					Neutral					Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

(4) How satisfied are you **with your personal relationships?**

Completely Dissatisfied					Neutral					Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

(5) How satisfied are you **with how safe you feel?**

Completely Dissatisfied					Neutral					Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

(6) How satisfied are you **with feeling part of your community?**

[7] Personal well-being indes (PWI), International well-being group (2005)

Completely Dissatisfied					Neutral					Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

(7) How satisfied are you **with your future security?**

Completely Dissatisfied					Neutral					Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

(8) How satisfied are you **with your spirituality or religion?**

Completely Dissatisfied					Neutral					Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q4.2 Please score the following items[8].

(1) Overall, how satisfied are you with your life nowadays?

Not at all					Neutral					Completely
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

(2) Overall, to what extent do you feel the things you do in your life are worthwhile?

Not at all					Neutral					Completely
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

(3) Overall, how happy did you feel yesterday?

Not at all					Neutral					Completely
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

(4) Overall, how anxious did you feel yesterday?

Not at all					Neutral					Completely
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q4.3 Please indicate your agreement with each item by selecting one of the options.

[8] Personal well-being indes (PWI), International well-being group (2005)

Do you have physical limitation in use

	YES(1)	NO(2)
Driving? (1)	❍	❍
1.28. Bicycle? (2)	❍	❍
1.29. Public Transport? (3)	❍	❍
1.30. Walk? (4)	❍	❍

Q5.1 is there anything else you would like to add or explain?

Thank you for taking this survey! Your responses are appreciated!

Appendix B

	Car	Rail	Walk	Bike	E-bike	Worker bus	Crowd	Transfer	Congestion	Travel Satisfaction	Life Satisfaction (SWB)
Travel characteristics											
Car										0.165 ***	0.031
Rail										0.043	0.008
Walk										0.206 ***	-0.014
Bike										0.215 ***	0.004
E-bike										-0.157 **	-0.054
Worker bus										0.044	0.028
Crowd										-0.225 **	-0.089
Transfer										-0.126 **	-0.027
Congestion										-0.197 ***	0.060
Socio-demographics											
Age	0.119 ***	-0.025	-0.109 ***	0.062 **	-0.024	0.096 ***				0.058 **	0.139 ***
Female	-0.044	-0.024	-0.043	-0.068 **	-0.049 *	0.022				0.018	0.104 ***
Education	0.055 **	0.018	-0.077 **	0.019	-0.096 ***	0.059 *				-0.025	-0.002
Income	0.231 ***	-0.021	-0.079 **	-0.036	-0.009	0.012				0.027	0.118 ***
Health	0.044	0.040	-0.025	-0.058 **	-0.03	0.029				0.142 ***	0.142 ***
Built-environment											
AccessTransit_H	-0.100 ***	0.127 ***	0.011	0.019	0.015	0.112 ***	-0.023	0.052	-0.056	0.008	-0.027
Suburb_H	-0.012	-0.040	0.038	0.109 ***	0.088 **	-0.042	0.095 **	0.07	-0.012	0.000	0.023
CloseGreen_H	0.073 **	-0.085 **	0.004	0.033	-0.002	0.033	-0.006	-0.051	-0.075 **	0.048	0.038
AccessTransit_J	0.078 **	0.051	-0.045	-0.042	-0.040	-0.055	-0.012	-0.133 **	0.026	-0.014	0.060
Suburb_J	0.003	0.049	0.063 *	0.051	0.005	-0.005	0.068	-0.094 *	-0.116 ***	0.020	-0.024
CloseGreen_J	0.027	-0.098 ***	-0.031	-0.048	-0.027	0.036	0.094 **	0.012	0.089 **	-0.035	-0.004
Distance from home to job	0.108 ***	0.110 **	-0.316 ***	-0.100 **	-0.057	-0.078 *	-0.013	0.261 ***	0.244 ***	0.030	0.031
Attitudes											
Fuel Efficiency	0.008	0.002	-0.068 **	-0.01	-0.007	-0.094 ***				-0.032	-0.047
Pro Bike	-0.049 *	-0.002	0.035	0.168 ***	0.124 ***	-0.055				0.010	0.031
Car Safer	0.209 ***	0.034	-0.053	-0.107 ***	-0.065 **	-0.015				0.011	0.146 ***
Pro-transit	-0.109 ***	0.094 ***	0.082 **	-0.021	-0.035	-0.008				0.074 **	0.062 *
Pro-walk	-0.051	-0.002	0.161 ***	-0.068 **	0.027	-0.083 **				0.096 ***	-0.022
Pro-driving	0.015	-0.093 ***	0.036	0.048	0.022	0.015				0.102 ***	0.012
Pro-environment	-0.184 ***	-0.024	0.020	0.058 *	0.037	0.04				0.055	0.027
Positive Travel	0.079 **	-0.023	0.108 ***	0.048	-0.015	-0.058				0.211 ***	0.033
Travel satisfaction											0.368 ***

*p<.1; **p<.05; ***p<.01