Manuscript details

Manuscript number TRD_2015_255

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

Article type Research Paper

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Keywords Commuting; Travel satisfaction; Built environment; Attitudes; China

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Submission files included in this PDF

File Type	**File Name**
Highlights	Highlights.docx
Response to reviewers	Response to reviewer_final.docx
Manuscript	TRD_R1Final.docx

Highlights

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- Active travel users have the highest level of commute satisfaction
- Travel attitudes have both direct and indirect effects on commute satisfaction
- The objectively measured built-environment only has indirect effects
- Congestion is strongly associated with poor commute satisfaction

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

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Abstract

Most of previous research that investigates the connections between the travel and satisfaction with travel has focused on the effect of the travel characteristics (e.g. travel mode choice, travel time, level of service, etc.) on satisfaction with travel. Little research has explored the role of the built environment or travel attitudes, two important factors for transport policies. Using data from a recent survey conducted in Xi'an, China, this study aims to quantitatively explore the relative effects of the built environment, travel attitudes, and travel characteristics on commute satisfaction. The data was analyzed using structural equation modeling. The model results suggest that commuting characteristics, including mode choice, congestion, and level of services of transit, all directly influence commute satisfaction. Attitudes have both direct and indirect effects on commute satisfaction, while the built environment only has indirect effects through influencing commuting characteristics.

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Introduction

Subjective wellbeing (SWB), as an alternative and enrichment to utility, has recently attracted significant attention from transportation researchers. SWB 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., 2007). A growing number of studies have investigated the connections between travel characteristics (e.g. travel mode choice, travel time, level of service, etc.) and satisfaction with travel (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). 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.

The built environment potentially influences travel satisfaction both directly and indirectly. First, travel characteristics, such as travel mode choice and travel time, are affected by the built environment (Ewing and Cervero, 2010). The "New urbanism" and related planning paradigms employing designs of higher density, mixed land use, and pedestrian-friendly design, for example, could shorten the time travelling from one location to various other locations, thereby improving travel satisfaction. Second, the built environment around one's home and job may directly influence the ease and comfort of one's commuting trip. A pedestrian friendly environment, for example, may make a walking trip go smoothly and with enjoyment. Similarly attitudes could also influence travel satisfaction in both direct and indirect ways. People's attitudes towards different modes may have a direct influence on their moods while commuting. 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. Attitudes could also indirectly affect travel satisfaction by influencing the travel mode choice. Travel behavior theory has long recognized the role of attitudes and preferences in influencing travel behavior. Even though attitudes are often included as control variables for self-selection, many studies have concluded that attitudes play a significant role in influencing travel behavior (Cao et al., 2009; Handy et al., 2005, 2006; Kitamura et al., 1997; Naess, 2005).

Using results from a recent survey conducted in Xi'an, China, this study 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. 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 increasing travel distances and worsening transportation conditions, 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. This highlights the importance of improving people's commuting experience and satisfaction.

Previous research on Chinese cities has primarily focused on Beijing, Shanghai, and Guangzhou, the mega cities of China, those 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.

Conceptual Model

Previous research linking the built environment and attitudes with travel behavior and travel satisfaction provides the conceptual basis of the analysis. First, a growing number of studies have linked travel behavior and travel satisfaction (Abou-Zeid, 2009; Cao and Ettema, 2014; De Vos et al., 2015; Ettema et al., 2011; Morris and Guerra, 2014; Olsson et al., 2013; St-Louis et al., 2014), and found a significant association between the two. For example, 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 is 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. Based on data from a web-based survey of university students in Hamilton, Canada, Paez and Whalen (2010) found that active travelers tend to be most satisfied with their commute, followed by those who travel in personal vehicles and transit users. Using the Hiawatha light rail transit (LRT) line in Minneapolis as a case, Cao (2013) found that the Hiawatha LRT positively influences satisfaction with travel and in turn satisfaction with life, but the size of the impacts were small. 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 commuting satisfaction was generally lower 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 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.

Second, the built environment could influence travel satisfaction through affecting travel behavior. The associations between the built environment and travel behavior 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). 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. Most of the empirical studies accounting for travel demand for a typical travel mode are conducted under this theoretical framework. Variables measuring the built environment can be classified into five dimensions (5D): density, diversity, design, destinations and distances to transit (Ewing and Cervero, 2010). In addition to the 5Ds, Alfonzo (2005) categorized the built environment elements based on the Maslow hierarchy of walking needs. 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.

Third, attitudes could also influence travel satisfaction through affecting travel behavior. 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, which is directly associated with travel satisfaction.

Meanwhile, the causality between the built environment and attitudes towards travel may exist in both directions. First, the self-selection hypothesis (Mokhtarian and Cao, 2008; Van Wee, 2009) contends that people choose home locations with built-environment characteristics that, at least to some extent, confirm 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. 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).

In addition to the indirect effects, both of the built environment and travel attitudes 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. 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.

Based on the above arguments, we constructed a conceptual model (Figure 1) that explains the structural relationships between the built environment, travel attitudes, travel characteristics, and travel satisfaction. As illustrated in Figure 1, most of the links between the variables are bi-directional. However, due to the limitation of cross-sectional design of this study, we could only test the associations rather than the causalities among variables.

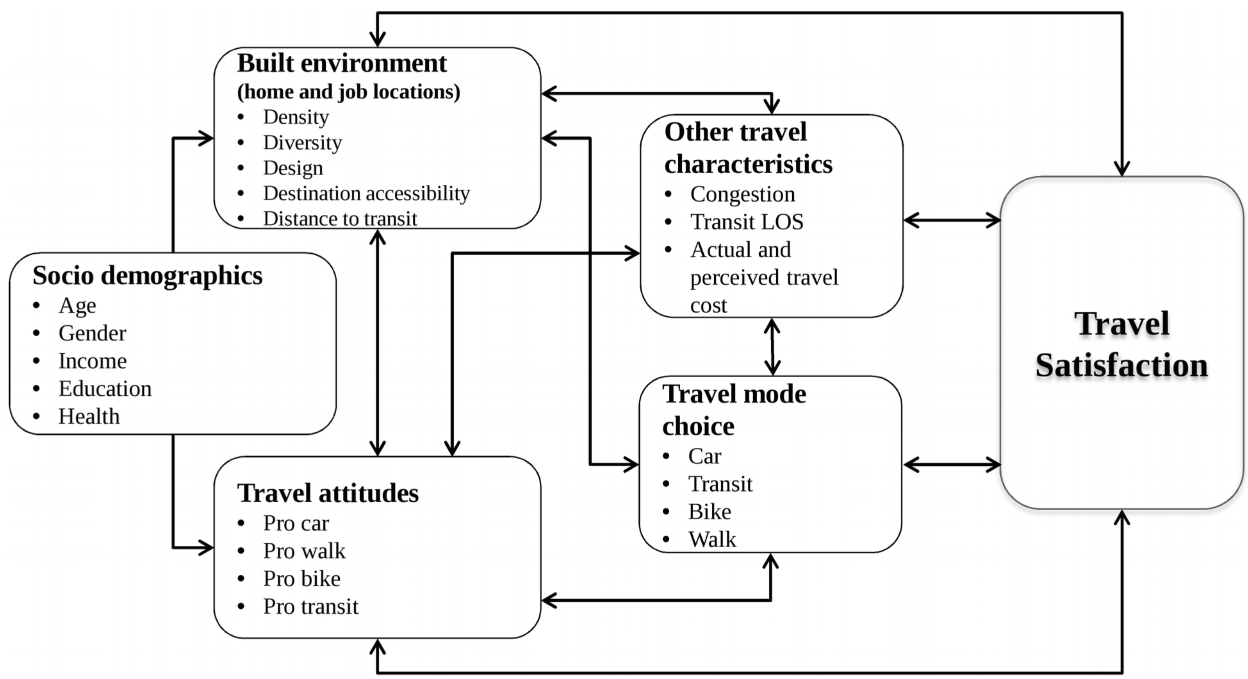

Figure 1 Conceptual Model

Data and Methods

The 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. 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 (Xi'an Bureau of Statistics, 2011); 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 was conducted between May 15th and June 30th 2013. 1364 valid surveys were collected, including 794 web-based surveys and 570 paper-based surveys. We compared answers of several survey questions that were conducted by paper and by internet, and we 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 survey collected data on the characteristics of the respondents' most recent commute, their satisfaction with various aspects of their most recent commute, their attitudes towards different modes and aspects of travel, their socio-demographic characteristics and their overall satisfaction with various non-travel aspects of their life.

Table 1 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 (Xi'an Bureau of Statistics, 2011). 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). However, this limitation is not expected to materially affect the analysis and results; this is because our focus is on investigating the relationships of various factors to travel satisfaction, rather than on describing the travel satisfaction of the city (Babbie, 2007).

All responses with a valid home and work address were geocoded in GIS. The spatial distribution of the home and job locations is presented in Figure 2. 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 Euclidean buffers were created around each home and job location. Due to a lack of precise GIS data on the street network, especially data on minor streets within residential neighborhoods, we decided not use a network buffer as the basis for calculating 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) distance to the nearest parks (*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) proportion of commercial land use within one quarter and one half mile (*diversity*); (7) proportion of green land use within one quarter and one half mile (*diversity*); (8) street nodes density within one quarter and one half mile (*design*). There are some inconsistencies between the 5Ds and the built environment measured in this study, but were limited to the GIS data we have.

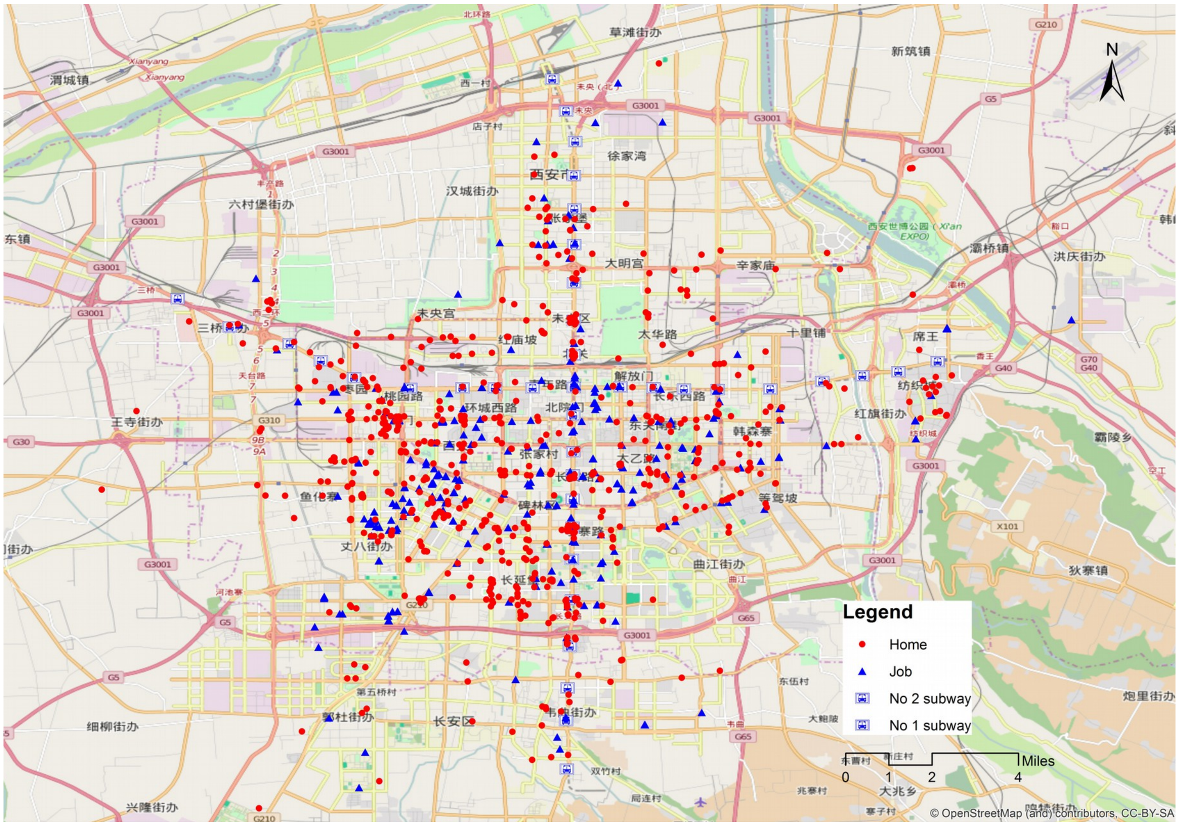

Figure 2 Distribution of home and job locations of the sampling employees

Table 1 Sample characteristics

Socio-demographics	Statistics
Average household numbers	3.5
% Having a drive license	56%
% Female	52%
Average age	34
# 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%
Widowed	0.3%
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%
Doctoral or professional degree	2%
Annual Income	
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%
Self-reported Health	
Poor	2%
Fair	9%
Good	37%
Very good	40%
Excellent	12%

Due to the collinearity of the individual built-environment variables, 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 home and job locations. Through the factor analysis (the Varimax rotation method was used) based on the nine indicators of home environment, three principal factors were extracted: (1) access to transit; (2) car dependence; and (3) close to greenery. The three factors for the home environment explained about 61% of the variance. Similarly, three principal factors were extracted for the job environment: (1) access to transit; (2) close to greenery; and (3) car dependence. The three factors for the job environment accounted for about 63% of the variance. The factor loadings of each individual built-environment variable are presented in Table 2 and Table 3.

Table 2 Factor analysis on indicators of home environment

	Access to Transit	Car Dependence	Close to Greenery
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.

Table 3 Factor analysis on indicators of job environment

	Access to Transit	Close to Greenery	Car Dependence
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.

Attitudes were measured based on 33 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 33 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. We chose the original eight factor solution, because of the 'leveling off' of eigenvalues on the scree plot 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 the Appendix.

Travel satisfaction was incorporated as a latent variable, which 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 -4 to 4 to assess each aspect of travel experiences. In this study only seven of the nine items were used because after the pilot study, we 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. The key reason we use seven items rather than nine is to reduce the burden of 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, we asked "for your most recent commute to work, how crowded was the bus?" as a measure of level of service of transit.

The data was analyzed using structural equation modeling (SEM). SEM was chosen because of its ability to solve simultaneous equations enabling the causal relationships between the independent, dependent and intermediate variables to be disentangled (Maruyama, 1997). SEM has been increasingly used in studying the travel behavior. 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.

Model Results

A model specified as in Figure 3, which is a simplified version of the conceptual model, was estimated. Correlation tests were conducted before creating the model. The model results, including model fits, standardized coefficients and significance, are provided in Table 4. 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.

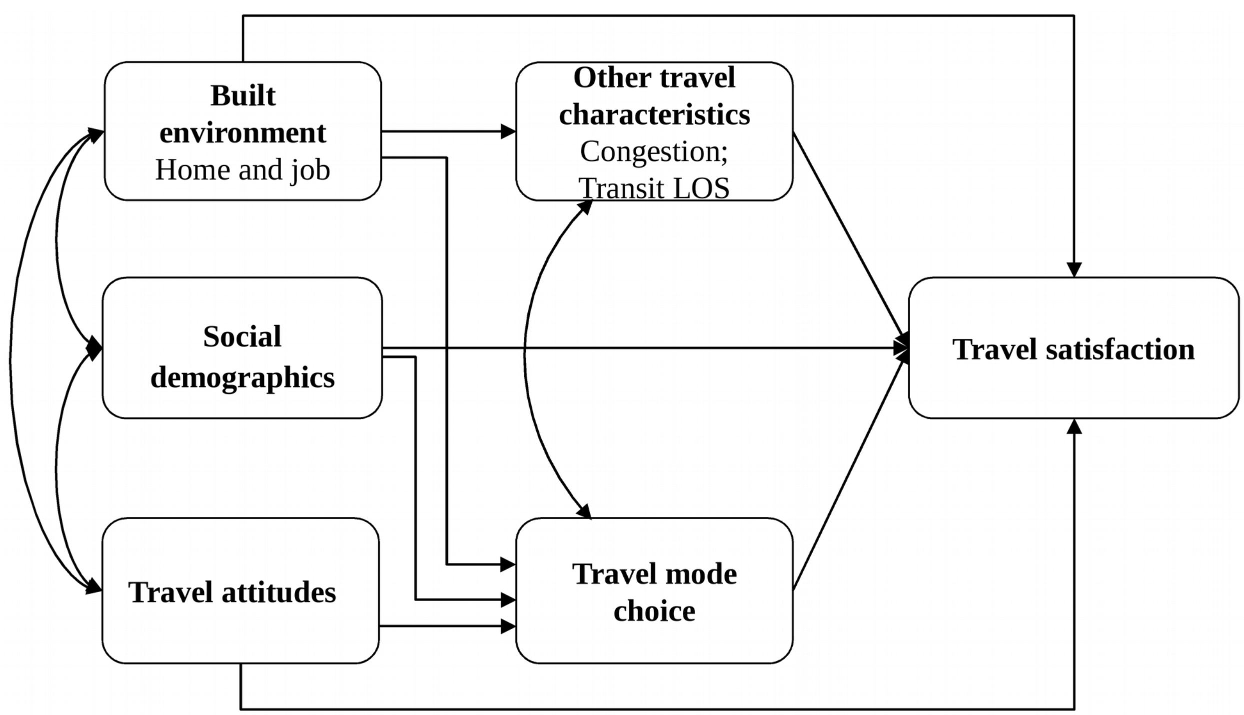

Figure 3 Model specification
Note: Curved line indicates a covariance between the two variables, and straight line represents the path from the causal variable toward the effect variable.

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 car-dependent environment (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 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 a car-dependent environment 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 our 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 4 Model results

	Car	Rail	Walk	Bike	E-bike	Worker bus	Crowd	Transfer	Congestion	Travel Satisfaction
Travel characteristics[1]										
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
Car dependent (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
Car dependent (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

1 Bus is the reference group for the travel mode choice Bus is the reference group for the travel mode choice

Conclusion

Studies linking travel and satisfaction with travel have recently received increasing attention in the field of transportation. This study contributes to the previous studies by further including the built environment and travel-related attitudes and by focusing on commuting, aiming to build a more comprehensive framework that helps to explain the complex relationships between the built environment, attitudes, travel, and travel satisfaction. By conducting surveys at selected employers in Xi'an, China, this study quantitatively tests the hypotheses embedded in the conceptual model using structural equation modeling. Model results suggest that the built environment has no direct effect on commute satisfaction, while it could indirectly affect commute satisfaction through the path of travel characteristics. 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. 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. 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. This may include adding routes and increasing frequency in suburban areas, where there are low-income population clusters, and providing more direct routes between major residential areas and job locations. This may also include preventing crime on transit, particularly theft and sexual harassment, which were the two most common criminal offenses reported by the participants in our study. 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. The e-bike is increasingly used as a travel mode in Xi'an and other Chinese cities, future research exploring the low level of travel satisfaction of e-bike users is needed. 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.

In terms of the built environment, 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. In addition, creating green spaces along the commuting route may help to moderate the negative effects of perceived congestion levels and long commuting times. 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.

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; (3) a car-dependent environment at the home location is associated with more bike and e-bike use for commuting, and a car-dependent environment at the job location is associated with more walking for commuting; (4) a car-dependent environment 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 less 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.

This study has several limitations. First, future research can improve this study by including more precise and complete measures of the built environment. Second, due to data limitations, we could only estimate a model that assumes the relationships between the variables are unidirectional, we recommend future research to explore the reverse direction of the relationships we proposed in the conceptual model. For example, how might travel satisfaction influence travel mode choice and home location choice? Third, 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

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.