Transportation Research Part A 47 (2013) 56–68

Contents lists available at SciVerse ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Bicycle commuting market analysis using attitudinal market segmentation approach

Zhibin Li [a,b,1], Wei Wang [a,2], Chen Yang [c,*], David R. Ragland [b,3]

[a] School of Transportation, Southeast University, 2 Sipailou, Nanjing 210096, China
[b] Safe Transportation & Education Center, Institute of Transportation Studies, University of California, Berkeley, 2614 Dwight Way #7374, Berkeley, CA 94720-7374, United States
[c] Shanghai City Comprehensive Transportation Planning Institute, 331 Tongren Road, Shanghai 200040, China

ARTICLE INFO

Article history:
Received 2 November 2011
Received in revised form 1 September 2012
Accepted 8 October 2012

Keywords:
Bicycle
Commuting
Market segmentation
Attitude
Policy

ABSTRACT

The market segmentation analysis for bicycle commuting can help identify distinct bicycle market segments and develop specific policies or strategies for increasing the bicycle usage in each segment. This study aims to use the approach of attitudinal market segmentation for identifying the potential markets of bicycle commuting. To achieve the research objective, the household survey is conducted to obtain the travelers' attitudes towards their commuting travels. The factor analysis is used to explore the latent attitudes. The structural equation modeling (SEM) simultaneously estimates the correlations between the attitudinal factors. The *K*-means clustering is conducted to segment the bicycle commuting market into several submarkets. Finally, six segments of bicycle commuting market with distinct attitudes are identified by four dividing factors including the willingness to use bicycle, need for fixed schedule, desire for comfort, and environmental awareness. The attitudinal characteristics, socioeconomic features, and actual bicycle choices in each market segment are analyzed and compared. The policy implications that best serve the needs of each submarket are discussed to promote the bicycle commuting.

1. Introduction

Bicycle has been widely recognized as an environmentally friendly mode of transport. Numerous studies have been conducted to explore how to increase the bicycle usage for commuting trips (Martens, 2004; Meeusen et al., 2008; Pucher and Buehler, 2008; Su et al., 2010; Xing et al., 2010; Yang et al., 2010; Pucher and Buehler, 2011; Heinen et al., 2011). Previously, most bicycle-related policies generally focused on the whole population of travelers. However, heterogeneous travelers could response differently towards policies which sometimes makes the results of these policies be less effective. The market segmentation approach is helpful in distinguishing the bicycle commuting markets with distinct characteristics. More focused policies and strategies that best serve the needs of each submarket can be developed to promote the bicycle commuting. The effectiveness of these policies can be estimated more accurately.

The market segmentations traditionally used in the bicycle-related studies are commonly based on some intuitive socioeconomic characteristics, such as gender, age or income, or attribute of trips, such as trip length or purpose. But these segmentation methods fail to explain why individuals with similar socioeconomic or trip features make different decisions

* Corresponding author. Tel.: +86 21 62895912; fax: +86 25 83794101.
E-mail addresses: lizhibin@seu.edu.cn (Z. Li), wangwei@seu.edu.cn (W. Wang), yang0403@gmail.com (C. Yang), davidr@berkeley.edu (D.R. Ragland).
[1] Tel.: +86 13952097374; fax: +86 25 83794101.
[2] Tel.: +86 13905170160; fax: +86 25 83794101.
[3] Tel.: +1 510 642 0655; fax: +1 510 643 9922.

0965-8564/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.tra.2012.10.017

on the choice of bicycle for travels. In particular, inconsistent conclusions on the relationships between the bicycle usage and these factors are often found in different surveys (Pucher et al., 2009; Heinen et al., 2010) which indicates these relationships may not be well explored or understood. In recent years, the interest of using travelers' attitudes for the market segmentation analysis has drawn more attentions from transportation researchers. Studies have shown that the attitude-based market segmentation is useful in identifying potential transit markets and developing plans to increase the public transport ridership (Outwater et al., 2003; Shiftan et al., 2008). These studies motivate our thought of using the attitude-based segmentation for the bicycle commuting market analysis.

The primary objective of this study is to use the attitudinal market segmentation approach for identifying the potential submarkets of bicycle commuting. More specifically, this study includes the following tasks: (1) to identify the travelers' latent attitudes towards commuting travels and estimate the relationships between attithem; (2) to segment the bicycle commuting market into several distinct segments based on the attitudinal factors; and (3) to analyze the characteristics of these submarkets and develop policies to promote the bicycle usage in each segment. The findings of this study can help identify the travelers who could be persuaded to be bicycle commuters and those who might be enticed out of bicycle commuting.

The remainder of this paper is organized as follows. The following section reviews the existing work. Section 3 introduces the methodology for the market segmentation analysis. Section 4 gives the model estimation results and Section 5 discusses the findings and policy makings. The paper ends with concluding remarks and future work in Section 6.

2. Literature review

Previously, the market segmentation bas been used in the studies on travel behaviors (Badoe and Miller, 1998; Button and Hensher, 2001; Cambridge Systematics, 2001; Outwater et al., 2003; Elgar and Bekhor, 2004; Ryley, 2006). Travelers or travel activities with distinct characteristics can be identified as different submarkets. Previous studies have shown that the market segmentation analysis is a means of increasing the share of public transit modes. For example, a hand-book published by TRB provided detailed steps and procedures for implementing the market-segmentation plans to increase the transit use (Elmore, 1998). The market segmentation has also been found useful in developing strategies to best serve the various submarkets for increasing the public transport ridership (Guliano and Hayden, 2005; Shiftan et al., 2008).

Some simple and basic ideas on the market segmentation have been found in several bicycle-related studies. Deakin (1985) defined the potential bicycle commuting market as employed full-time, under 40 years old, travels less than 11.2 km one-way to work, drives alone during peak-period, and owns a bike suitable for commuting, and estimated the reasonably upper bound on the size of the market. Clark (1997) grouped the existing trips into several segments based on the trip length and trip purpose and estimated the potential transferring vehicle trips to bicycling and walking. Bergstrom and Magnusson (2003) clustered the bicycle travelers into winter cyclist, summer-only cyclist, infrequent cyclist, and never cyclist, and evaluated the number of bicycle trips potentially transferred to car trips in a winter season. Shan (2007) segmented travelers into several groups by the commuting trip length and developed separate mode choice mdoel for each group. Xing et al. (2010) grouped the bicycle trips into bicycling for transportation and recreation by the trip purpose and idnetified the factors associated with the miles of bicycling in each group. Heinen et al. (2011) segmented the commuting trips into three groups according to the trip length (<5 km, 5–10 km, and >10 km) and identified the attitudes related to the choice to cycle to work.

The above studies generally segment the bicycle travelers or trips based on some pre-defined socioeconomic characteristics or trip attributes. But these segmentation analyses do not consider the fact that individuals with similar socioeconomic or activity characteristics could make different decisions on the bicycle choice. In recent years, there has been an increasing interest in using the travelers' attitudes for the market segmentation analysis. This method is supported by significant works which have shown that the attitudinal factors are important in the mode choice sometimes even more than the instrumental variables (Steg et al., 2001; Anable and Gatersleben, 2005; Steg, 2005; Abraham and Gardner, 2007; Heinen et al., 2011).

Anable (2005) segmented the travel market based on multi-dimensional attitudinal statements to identify the degrees of mode switching potential. This study also indicated that the common segmentation method based on the socioeconomic variables or simple behavioral measures could oversimplify the structure of the market. Outwater et al. (2003) segmented the ferry-riding market into eight subsegments by three attitudinal factors which were the travelers' reaction to time saving, sensitivity to travel stress and desire to help environment. Shiftan et al. (2008) used the market segmentation approach to identify the potential transit markets. Travelers were clustered into eight groups by three attitudinal factors including the sensitivity to time, need for fixed schedule, and willingness to use public transit. Specific plans were developed to increase the transit ridership in each submarket.

The relationship between travelers' attitude and bicycle choice was reported in several previous studies. Davies et al. (1997) confirmed the significant impact of attitudinal factors on the willingness of bicycling. The attitude towards safety and convenience of bicycling was found significantly influenced the bicycle use (Noland and Kunreuther, 1995). A positive attitude towards bicycling increased the likelihood of bicycle commuting (Dill and Voros, 2007) while a negative perception towards car use simulated the bicycling (Stinson and Bhat, 2005). Gatersleben and Appleton (2007) examined the attitudes and perceptions in relation to the bicycling to work and found that the attitudes towards bicycling and the perception of barrier influenced travelers' decision on bicycle use. A recent study by Heinen et al. (2011) reported that the attitudes including the awareness, direct trip-based benefits and safety had relatively strong impacts on the choice to commute by bicycle.

The study also showed that the socio-demographics can only explain a limited extent of travelers' attitudes. The findings of above studies significantly support the work of the current study on the attitude-based market segmentation analysis for the bicycle commuting market.

Travelers' attitudes are often unobservable that cannot be directly measured. Previously, the structural equation modeling (SEM) method has been commonly used in identifying the latent attitudes towards travel behaviors from a series of attitudinal statements or questions (Golob and Hensher, 1998; Gärling et al., 2001; Golob, 2003; Outwater et al., 2003; Shiftan et al., 2008). For example, Outwater et al. (2003) reported that the SEM provided a significantly better performance for identifying the travelers' latent attitudes from the attitudinal statements as compared to the logistic regression model with factor analysis. Shiftan et al. (2008) used the SEM to simultaneously identify the relationships among travelers' attitudes, travel behaviors and socioeconomic profiles. The latent attitudinal factors in the SEM were further used for the transit market segmentation. Thus, the SEM was considered in the current study for the bicycle market segmentation analysis.

As for the market segmentation method, some studies intuitively divided the samples into subgroups according to some specified classification factors (Bergstrom and Magnusson, 2003; Clark, 1997; Elgar and Bekhor, 2004; Xing et al., 2010; Heinen et al., 2011). But the segmentations were based on researchers' subjective perceptions that may not well reflect the inherent attributes of dataset. Several studies evaluated the use of statistical cluster methods such as the *K*-means clustering to segment the travel market (Outwater et al., 2003; Anable, 2005; Ryley, 2006). These studies generally reported that the statistical cluster method can effectively extract the homogeneous travelers and generate distinct market segments. Thus, the *K*-means clustering method was used in this study for the bicycle commuting market segmentation.

3. Methodology

A comprehensive approach for the segmentation analysis of bicycle commuting market is presented in this section. The data resource is first introduced and the overall modeling framework including the factor analysis, SEM and *K*-means clustering is briefly introduced.

3.1. Data resource

The household survey was conducted in 2009 in the city of Nanjing, China to obtain the travelers' attitudes towards their commuting travels. Nanjing is one of the biggest cities in the southeast of China by the year of 2009 with a population of 6.9 million and an area of 598 km^2. The survey was conducted in multiple traffic analysis zones in the metropolitan district to reduce the share of homogeneous characteristics within each zone. The respondents were randomly selected in the household interview during the survey.

The attitude has various definitions in different studies (Shiftan et al., 2008; Heinen et al., 2010). In this study, the "attitude" generally indicates the psychological perception or preference of travelers towards commuting travels and bicycling. The attitudinal questions (or statements) are carefully designed in the questionnaire to reflect the travelers' attitudes that potentially impact the choice of bicycle. These attitudes have been found to be related to travelers' mode choice behaviors in several previous studies (Shiftan et al., 2008; Yang et al., 2010). The respondents are asked to provide their rating level of agreement or disagreement for each question using a five-point scale, which "1" means a strong disagreement while "5" means a strong agreement.

A pilot survey was conducted due to the complexity of questionnaire and several confusing questions were redesigned based on the feedbacks. The final questionnaire involved three parts: (1) the socioeconomic characteristics of respondents; (2) the attitudinal questions used to measure the respondents' attitudes towards commuting travels and bicycling; and (3) the information on respondents' daily commuting trips such as trip length and mode choice. Successive analysis is conducted based on the 639 valid recordings after excluding the samples with missing key information. Near 81.7% of individuals in the

Table 1
Statistics of socioeconomic characteristics of respondents.

Socioeconomic characteristics	Valid sample (N = 639)		Bicyclists (N = 148)		Non-bicyclists (N = 491)	
	Mean	Std.	Mean	Std.	Mean	Std.
Age (years)	34.34	0.47	33.72	1.11	34.53	0.52
Gender (female = 1)	0.56	0.02	0.55	0.04	0.57	0.02
Education (college and higher = 1)	0.48	0.02	0.52	0.04	0.46	0.02
Individual income (1000 yuan/year)	34.82	1.11	27.86	1.85	36.86	1.32
Household income (1000 yuan/year)	85.16	2.27	75.36	3.23	88.12	2.78
Marriage (yes = 1)	0.74	0.02	0.68	0.04	0.76	0.02
Child under 12 (yes = 1)	0.64	0.02	0.54	0.04	0.67	0.02
Bicycle available (yes = 1)	0.81	0.02	0.94	0.02	0.77	0.02
Automobile available (yes = 1)	0.26	0.02	0.09	0.02	0.32	0.02
Trip duration (min)	28.78	0.84	24.05	1.52	30.16	0.98

Table 2
Descriptive statistics of the attitudinal questions.

Question	Content	Mean	SD
Q1	I need to go shopping on the way to/from work/school	2.61	1.13
Q2	I usually have multiple trips on the way to/from work/school	2.31	1.52
Q3	I am usually in a hurry during a trip	3.23	1.18
Q4	If travel is delayed, I want to know delay length and cause	3.71	1.22
Q5	I prefer a travel option that has predictable travel time	4.05	0.94
Q6	I prefer going to/back from work/school on fixed schedule	3.72	1.03
Q7	I prefer a calm and uncrowded travel environment	3.95	1.10
Q8	I prefer car or bus than walk and bicycle in rainy days	3.38	1.46
Q9	I prefer travel modes with airconditioner in summer/winter	3.49	1.21
Q10	I prefer motor vehicle because it costs less physical energy	2.99	1.19
Q11	I don't mind paying more money to save my travel time	2.83	0.99
Q12	I don't mind paying more money to travel more comfortably	2.84	0.97
Q13	I don't care about the raise of bus ticket price	2.90	0.99
Q14	If taxi price rises by 10%, I will use it as usual	2.88	1.48
Q15	Private car is one major cause of air pollution in urban areas	3.44	1.21
Q16	I prefer changing travel mode if it is helpful for environment	3.47	1.05
Q17	I don't mind paying more for travel to help the environment	3.87	1.01
Q18	More public transport uses can improve air quality	3.98	1.00
Q19	Bicycling is helpful to environmental protection	4.49	0.82
Q20	Bicycling is good for the health	4.48	0.83
Q21	Bicycling is convenient for its flexible routing and parking	4.05	1.04
Q22	Bicycling can save my travel time	3.10	1.15
Q23	Bicycle is a safe travel mode	3.51	1.04
Q24	Bicycling can save my travel cost	4.28	0.89
Q25	Bicycle is a comfortable mode of transportation	3.08	1.07
Q26	I would like to bicycle more often if stolen bike rate goes down	3.69	1.11
Q27	I would like to bicycle if the weather is pleasant	3.86	1.13
Q28	I would like to bicycle more often if parking is more convenient	3.77	1.14
Q29	I would like to bicycle if I travel mostly during rush hours	3.87	1.14

survey own a bicycle and 23.2% of them use bicycle for daily commuting. The summary statistics of valid samples are shown in Table 1. The contents of questions and their descriptive statistics are shown in Table 2.

3.2. Attitude-based market segmentation approach

To support the market segmentation analysis for bicycle commuting, the latent attitudinal factors are extracted from a series of attitudinal statements. Then the target market is segmented by several selected factors. The overall framework of attitude-based market segmentation approach includes the following steps:

Step 1: Factor analysis to explore the latent attitudinal factors: This initial step aims to explore the structural relationship among the attitudinal statements in the questionnaire and extract several latent attitudinal factors from the statements. The factor analysis provides the information for determining the model structure in the SEM.
Step 2: SEM to estimate the coefficients of attitudinal factors: This step employs the SEM to estimate the coefficients between the latent attitudinal factors and the statement variables. The final set of attitudinal factors and factor scores are used as inputs to the cluster analysis. The SEM also simultaneously estimates the relationships between attitudinal factors which helps understand travelers' choice of bicycle for commuting.
Step 3: Cluster analysis to segment the bicycle commuting market: The *K*-means clustering method is used to group travelers into distinct segments. Individuals within the same segment share similar attitudes towards commuting trips while people in the different segments hold different attitudes. This step generates several distinct segments of bicycle commuting market used for further analysis.
Step 4: Cross-comparison to identify the characteristics of subsegments: This step examines and compares the characteristics of travelers' attitudes as well as the socioeconomic attributes in each submarket. The policy implications for increasing the bicycle commuting are developed based on the characteristics of each subsegment.

3.2.1. Factor analysis

Factor analysis is one of statistical methods for examining the underlying correlation structure among explanatory variables (Washington et al., 2010). The objective of performing the factor analysis in this study is to describe the attitudinal statement variables in the household survey in terms of a lower number of unobserved variables, named the latent attitudinal factors, while retaining the explanatory power of the original variables.

Two types of factor analysis, the exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), are conducted to extract the latent factors from the original variables. The EFA statistically estimates the correlation structure among the attitudinal statement variables and describes the content of resulting factors, without imposing any a priori hypothesis about the underlying structure of the data. Based on the prior information from EFA, the CFA evaluates the construct validity of latent factor structure of the data and provides a robust statistical estimation. The number of latent factors as well as the correlation structure between latent factors and original variables are determined by the CFA. Then these information are used to construct the model structure in the SEM.

3.2.2. SEM structure

SEM is a modeling technique that can handle a large number of endogenous and exogenous variables as well as latent variables specified as linear combinations of explanatory variables (Washington et al., 2010). The objective of employing the SEM in this study is to estimate the coefficients of latent attitudinal factors as functions of original statement variables and identify the relationships between attitudinal factors. The SEM is a confirmatory, rather than an exploratory method, since it requires constructing a model structure in terms of a system of unidirectional effects of one variable on another (Golob, 2003).

Fig. 1 outlines the schematic structure of SEM. The SEM used in this study includes two types of variables. One is the attitudinal statement variables (squares in Fig. 1) that are directly measured from the survey data, while the other is the latent attitudinal factors (ovals in Fig. 1) that are inferred by the correlations among the statement variables. Two models, which are the measurement model and the structural model, are simultaneously estimated in the SEM. The measurement model is used to specify the latent attitudinal factors as linear functions of the statement variables, according to the underlying correlation structure from the factor analysis. The structural model is developed to describe the causal relationships between the latent attitudinal factors.

The single-headed arrows in Fig. 1 represent the causal effects between variables and the SEM estimates all the path coefficients simultaneously. The SEM estimates are used to calculate the scores of attitudinal factors for each individual and the scores are then used in the cluster analysis. The relationship between attitudinal factors in the SEM estimates provides important information in understanding the travelers' considerations on the choice of bicycle for commuting.

3.2.3. K-means clustering

K-means clustering is a statistical method that has been widely used to determine a set of subgroups by several pre-specified dividing factors (Washington et al., 2010). The goal of the *K*-means clustering in the present study is to identify the groups of homogenous travelers by minimizing within-group distances while maximizing between-group distances according to the selected attitudinal factors. Based on a pre-specified number of cluster centers (*K*), the *K*-means clustering analysis allocates each sample to the cluster with the nearest center point. The cluster solution is obtained when all samples are allocated.

An optimal value of *K* may not always be obvious. The progress of distinctness of clusters as *K* gets larger or smaller can be useful in deciding where to draw the segmentation line. The size of clusters could be neither too large (which means clusters are too heterogeneous that cannot be statistically analyzed further) nor too small (which means clusters fail to distinguish

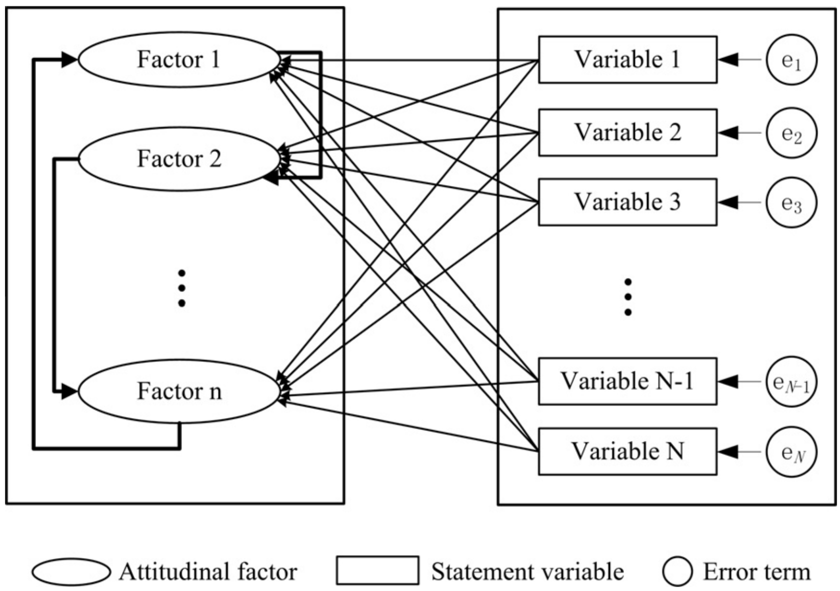

Fig. 1. Underlying structure of SEM model.

the travelers with distinct attitudes and do not subdivide the travelers well). Moreover, each cluster needs be reasonable and explicitly explainable.

4. Results

4.1. Identifying attitudinal factors using factor analysis

The EFA is first conducted to explore the proper groups of latent factors that explain all the original statement variables. The Cattell's Scree Plot method is used to decide the number of factors. A set of eight latent factors that are significant and all of whose loadings have the correct signs are chosen as latent attitudinal factors. Those latent factors account for 3.6% to 18.1% of the variance in the data, and the total variance explained by the EFA is 58.3%. Based on the preliminary EFA, eight latent attitudinal factors are extracted from 29 statement variables by the CFA using the AMOS 16.0. The goodness of fit index (GFI) of the CFA is 0.869, indicating that 86.9% of the co-variation in the data can be reproduced by the given model. The CFA shows the eight-dimension latent factor structure is appropriate for the data of this study.

Table 3 shows the eight latent attitudinal factors with the factor loading, standard error and *t*-statistics from the CFA. Each latent factor is a linear combination of several statement variables. For example, factor 1 includes two statement variables (Q1–Q2) related to the respondents' requirement of flexible trips. Thus, factor 1 reflects the need for flexibility. Other attitudinal factors can be interpreted in a similar way: factor 2 reflects the respondents' sensitivity to time (Q3–Q4), factor 3 is related to the need for fixed schedule (Q5–Q6), factor 4 is identified as the desire for comfort (Q7–Q10), factor 5 is the desire for economy (Q11–Q14), factor 6 reflects the people's environmental awareness (Q15–Q18), factor 7 is related to the respondents' perception towards bicycling (Q19–Q25), and factor 8 is a measurement of the travelers' willingness to use bicycle (Q26–Q29).

4.2. Estimating correlations between variables using SEM

Based on the prior information of the correlation structures from the CFA in this study and several literature (Anable, 2005; Dill and Voros, 2007; Shiftan et al., 2008), the model structure shown in Fig. 2 is specified in the SEM. The measure-

Table 3
Latent attitudinal factors in the CFA.

Latent factor	Statement variable	Coefficient	Std. error	*t*-Stat.
Factor 1: Need for flexibility	Q1	1		
	Q2	1.525	0.372	4.097
Factor 2: Sensitivity to time	Q3	1		
	Q4	1.335	0.229	5.840
Factor 3: Need for fixed schedule	Q5	1		
	Q6	0.458	0.135	3.395
Factor 4: Desire for comfort	Q7	1		
	Q8	2.723	0.395	6.896
	Q9	2.717	0.387	7.017
	Q10	1.720	0.267	6.450
Factor 5: Desire for economy	Q11	1		
	Q12	0.925	0.069	13.338
	Q13	0.452	0.056	8.046
	Q14	0.609	0.083	7.312
Factor 6: Environmental awareness	Q15	1		
	Q16	1.177	0.135	8.694
	Q17	1.250	0.142	8.774
	Q18	0.712	0.103	6.917
Factor 7: Perception towards bicycling	Q19	1		
	Q20	1.180	0.128	9.220
	Q21	1.831	0.179	10.21
	Q22	1.706	0.181	9.442
	Q23	1.613	0.167	9.656
	Q24	1.242	0.136	9.153
	Q25	1.446	0.161	8.986
Factor 8: Willingness to use bicycle	Q26	1		
	Q27	1.183	0.049	24.027
	Q28	1.225	0.050	24.619
	Q29	1.081	0.050	21.413

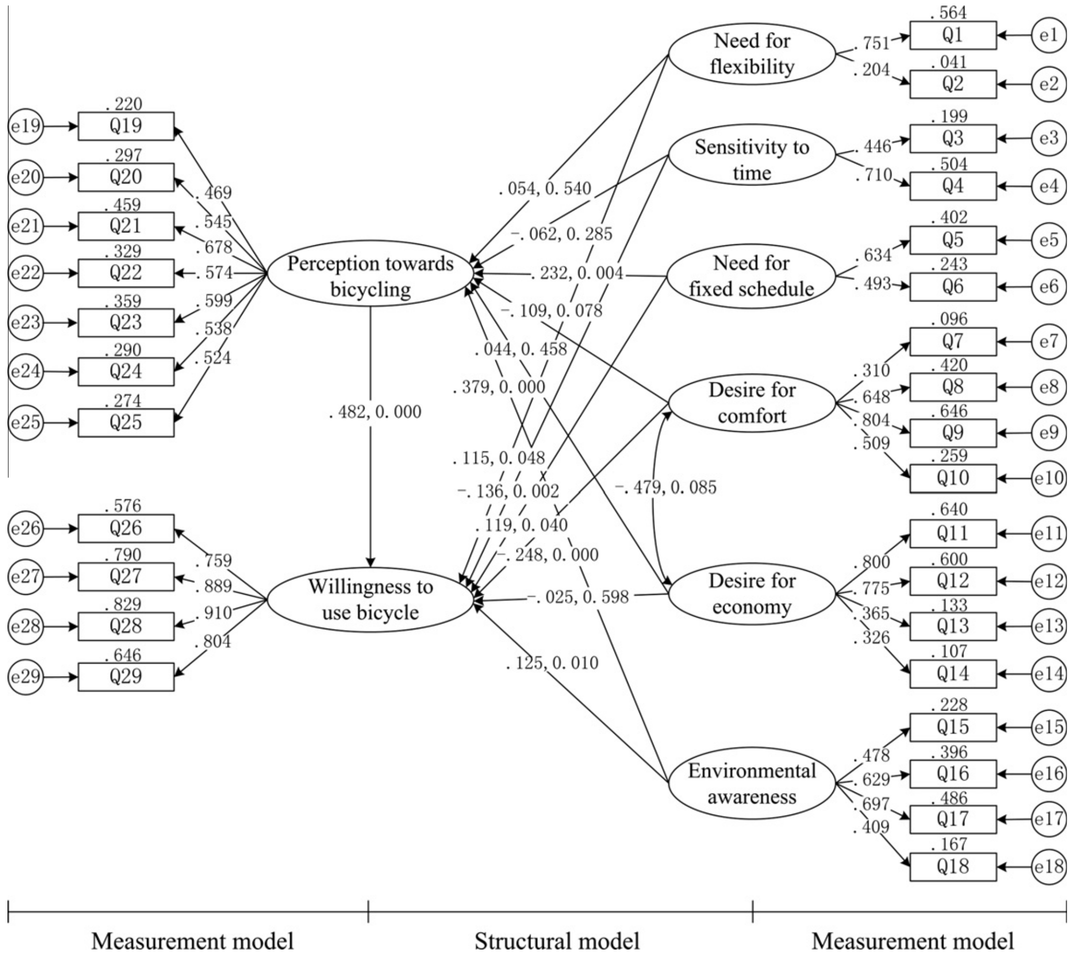

Fig. 2. Estimation results of SEM model.

ment model and structural model are simultaneously estimated. Fig. 2 also shows the model estimates including the factor loadings of statement variables on the latent factors and the coefficients of correlations between the latent factors.

The goodness of fit index (GFI) of the SEM is 0.93, the root mean square residual (RMR) is 0.080, and the root mean square error of approximation (RMSEA) is 0.050, indicating these measures meet the acceptable criteria. The incremental fit index (IFI) = 0.891 and comparative fit index (CFI) = 0.890 are close to the ideal value 0.9. The adjusted goodness of fit index (AGFI) = 0.882 is above the recommended value 0.8. These indices indicate that the final model of SEM in this study is a good fit.

The coefficients between latent factors and statement variables that estimated in the SEM (as shown in Fig. 2) are in general consistent with the results of CFA (as presented in Table 3). All the coefficients in the measurement model of SEM are significant at a 95% confidence level. Those coefficients are used to calculate the attitude scores for each respondent and are further used for the market segmentation analysis. The numbers on the top of rectangles indicate the equation R-squares.

The structural model of SEM estimates the relationship between attitudinal factors. As shown in Fig. 2, several attitudinal factors are significantly related to travelers' perception towards bicycling. The need for fixed schedule is positively related to the perception towards bicycling, which indicates bicycle is commonly viewed as a trip mode with a stable trip time. The desire for comfort has a negative impact on the perception towards bicycling, which means bicycle is less comfortable for commuting trips as compared to other travel modes. The environmental awareness is positively related to the perception towards bicycling, which suggests bicycle is well accepted as an environmentally friendly trip mode.

The travelers' perception towards bicycling has a significant positive impact on the willingness to use bicycle. Other attitudinal factors are also related to this willingness. The direct and indirect effects of attitudinal factors on the willingness to use bicycle are summarized in Table 4. The environmental awareness has a large positive impact on the bicycling willingness. It indicates travelers that tend to benefit the environment are more likely to use bicycle. Travelers who desire for high travel comforts are less willing to use bicycle for commuting, since bicycling consumes physical energies of travelers. The desire for flexibility as well as the need for fixed schedule increase the willingness to use bicycle, which suggests bicycle

Table 4
Direct and indirect effects between latent attitudinal factors.

Dependent	Independent[a]	Direct effect	Indirect effect	Total effect
Factor 8: Willingness to use bicycle	Factor 7: Perception towards bicycling	0.482	–	0.482
Factor 8: Willingness to use bicycle	Factor 6: Environmental awareness	0.125	0.183	0.308
Factor 8: Willingness to use bicycle	Factor 4: Desire for comfort	−0.248	−0.053	−0.301
Factor 8: Willingness to use bicycle	Factor 3: Need for fixed schedule	0.119	0.112	0.231
Factor 8: Willingness to use bicycle	Factor 2: Sensitivity to time	−0.136	/	−0.136
Factor 8: Willingness to use bicycle	Factor 1: Need for flexibility	0.115	/	0.115
Factor 8: Willingness to use bicycle	Factor 5: Desire for economy	/[b]	/	/

[a] Descending order by total effect.
[b] Insignificant at the 90% confidence level.

can either provide a flexible trip or provide a trip with fixed trip time. This may due to that bicycle does not have a fixed departure time (as bus), is easy for parking (compared to car), and is less likely to be delayed by traffic congestion. The sensitivity to time is negatively related to the bicycling willingness which indicates that bicycle generally has a slower speed and more travel time as compared to other travel modes.

The estimates of the structural model in the SEM indicates that bicycle has advantages in providing an flexible or schedulable trip and is beneficial for the environment, but has disadvantages in providing a comfortable and rapid travel. These findings help better understand travelers' decision on the choice of bicycle for commuting and provide useful information for developing strategies to increase the bicycling, which are discussed in detail in Section 5.

4.3. Bicycle commuting market segmentation using K-means clustering

Preliminary experiments are conducted to determine the attitudinal factors used for the market segmentation. The explanatory analysis shows that choosing the dividing factors that are highly intercorrelated could result in more heterogeneous subsegments (and more homogeneous characters within each subsegment) with a reasonable number of clusters. Using the dividing factors that are less correlated could significantly increase the number of clusters and may not capture the inherently homogeneous features of travelers. The clustering results are carefully examined to obtain an acceptable and reasonable segmentation manner.

In this study, four of the eight attitudinal factors are selected to perform the market segmentation for the bicycle commuting. These factors are the willingness to use bicycle, need for fixed schedule, desire for comfort, and environmental awareness. The four factors are chosen because they have the highest statistical reliabilities, as measured by the correlation coefficients and significance levels estimated in the SEM in Fig. 2. This segmentation manner results in obviously distinct characteristics of attitudes of travelers across clusters. The attitudinal factor scores of each respondent are normalized from their natural range to the values between 0 and 5. The original samples are finally clustered into six segments. Those segments of bicycle commuting are presented in Table 5. The attributes of attitudinal factors within each segment are summarized as follows:

Table 5
Segmentation results for bicycle commuting market.

Attitudinal factor	Level	Segments					
		S1 ($N = 36$)	S2 ($N = 125$)	S3 ($N = 83$)	S4 ($N = 127$)	S5 ($N = 148$)	S6 ($N = 120$)
Willingness to use bicycle	High					√(4.28)	√(4.55)
	Moderate			√(3.16)	√(3.46)		
	Low	√(1.48)	√(2.08)				
Need for fixed schedule	High		√(3.69)			√(4.21)	√(4.10)
	Moderate			√(3.47)	√(2.98)		
	Low	√(1.91)					
Desire for comfort	High	√(3.59)	√(3.75)				
	Moderate				√(2.95)	√(3.34)	
	Low			√(1.71)			√(1.49)
Environmental consciousness	High					√(3.72)	√(3.53)
	Moderate		√(2.74)		√(3.32)		
	Low	√(2.43)		√(1.77)			

Note: √ indicates the interval that cluster center belongs to; value in parentheses indicates cluster center in one dimension of attitudinal factor; high level: >3.5; moderate level: 2.5–3.5; low level: <2.5.

Segment 1 (S1) is a group with a low willingness to use bicycle. It also has a low need for fixed schedule and a low environmental awareness. It has a high desire for travel comfort.
Segment 2 (S2) is a group with a low willingness to use bicycle. It has high a need for fixed schedule and a moderate environmental awareness. It has a high desire for comfort.
Segment 3 (S3) is a group with a moderate willingness to use bicycle. It has a moderate need for fixed schedule, a low desire for helping the environment, and a low desire for comfort.
Segment 4 (S4) is a group with a moderate willingness to use bicycle. It has a moderate need for fixed schedule, a moderate environmental awareness, and a moderate desire for comfort.
Segment 5 (S5) is a group with a high willingness to use bicycle. It strongly needs a fixed schedule and has a high environmental awareness. The desire for comfort is moderate.
Segment 6 (S6) is a group with a high willingness to use bicycle. It strongly needs a fixed schedule and has a high environmental awareness. The desire for comfort is low.

Fig. 3 shows the relative position of samples within each market segment. The three axes in the figure represent the need for fixed schedule, desire for comfort, and environmental awareness. The difference of sample positions between market segments can be identified in those 3D figures. Similar figures can also be drawn for other combinations of attitudinal factors.

5. Discussion

5.1. Characteristics of market segments

The six subsegments of bicycle commuting have distinct attitudinal characteristics as presented in Section 4.3. The actual bicycle usage for commuting also presents different features in different segments, as shown in Fig. 4. It is identified that the actual bicycle usage is consistent with the willingness to use bicycle, i.e., the submarket with a lower score of willingness to use bicycle generally has a lower level of actual bicycle usage. The S1 has the lowest level of bicycle usage (with a percent of 2.8%) while the S6 has the highest level of bicycle usage (with a percent of 50.8%). In general, the percent of bicycle usage in the S1 and S2 are low, in the S3 and S4 are moderate, and in the S5 and S6 are high. Thus, the segments with similar level of bicycle usage are discussed together in this section.

Travelers in the S1 and S2 have low or moderate environmental awareness, and in the S1 have low needs for fixed schedule. These two aspects are the advantages of bicycle as a trip mode for commuting as discussed in Section 4.2. But travelers in the two segments have high desires for travel comfort which exactly are the disadvantage of bicycle. Consequently, these travelers have low willingness to use bicycle. In the S1 and S2, the bicycle has little competitive power as compared to the other types of trip modes. The bicycle usage in the S2 is a little higher than that in the S1 because travelers in the S2 have high needs for fixed schedule in which the bicycle has an advantage.

The S1 and S2 have the lowest willingness of using bicycle and actual bicycle usage. Individuals within the two segments can be considered as "firm non-bicycle travelers". The bicycle cannot fit the needs of travelers in their daily commuting travel activities. It could be hard to persuade these travelers to be bicycle commuters.

Travelers in the S5 and S6 have high needs for fixed schedule and high desires for helping environment, which are the advantages of bicycle trip mode. They have relatively low desires for travel comfort in which the bicycle does not perform well. As a consequence, the willingness to use bicycle for these travelers are high. Bicycle is quite an attractive and competitive commuting trip mode for the travelers in the two segments. The percent of bicycle commuting in the S6 is a little higher than that in the S5 due to the fact that travelers in the S6 have lower desires for travel comfort.

The S5 and S6 have the highest willingness of using bicycle and actual bicycle usage in commuting. Bicyclists in the two segments can be termed as "firm bicycle users" since the bicycle can well fit their needs in commuting trips. Other travelers in the S5 and S6 can be considered as "potential bicycle users" which means they could be easily persuaded to use a bicycle in their commuting trips.

Travelers in the S3 and S4 do not have any particular desires or needs towards travel activities since all the attitudinal preferences are not high. Thus, they do not present obvious willingness to use bicycle. These travelers are considered as "potential market switchers". If the travelers in the two segments switch to the S5 and S6, they will use a bicycle more frequently. If they switch to the S1 and S2, individuals who are currently using a bicycle could be enticed out of bicycling. Policies or strategies are required to instruct the market switching behaviors to keep the bicycle usage at a reasonable level.

We also analyzed the socioeconomic characteristics of travelers in each market segment as shown in Table 6. It is identified that most socioeconomic factors do not present obviously distinct characteristics between different segments. For example, highly educated people may either have low willingness to use bicycle (as in the S2) or high willingness to use bicycle (as in the S5). This finding is consistent with several previous studies which reported that the attitudes often cut across socioeconomic groups (Anable, 2005; Heinen et al., 2011). The present study suggests that the market segmentation by socioeconomic characteristics may not be able to reflect the difference of travelers' attitudes and capture the different behaviors in the bicycle commuting. However, particularly, there are some factors seem to be related to the segment features. The household income is generally lower in the S5 and S6 while travelers in the S1 and S2 have higher levels of automobile ownership. It indicates that there could be correlations between some socioeconomic factors and the attitudes towards bicycle commuting.

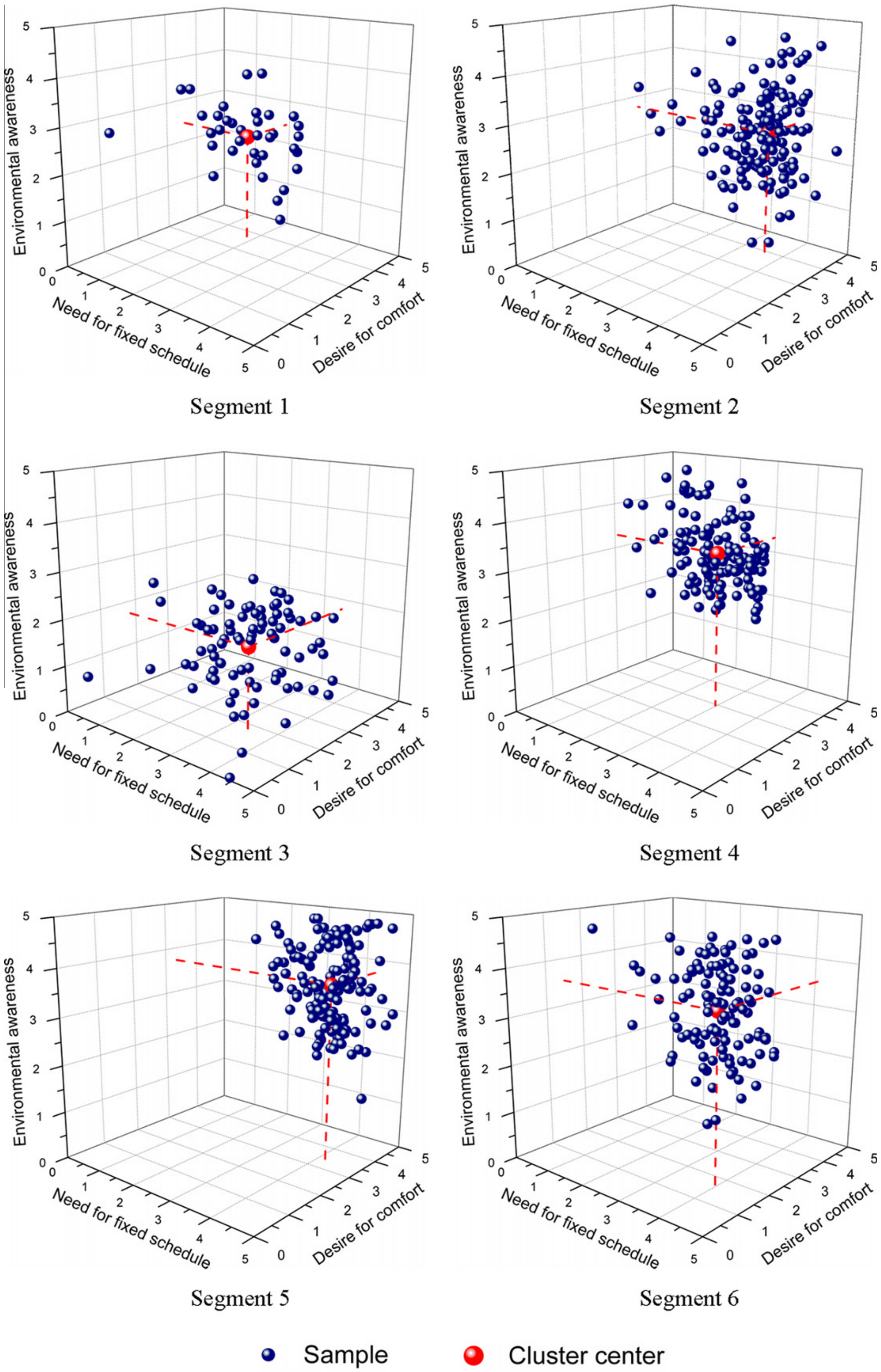

Fig. 3. Relative positions of samples in market segments.

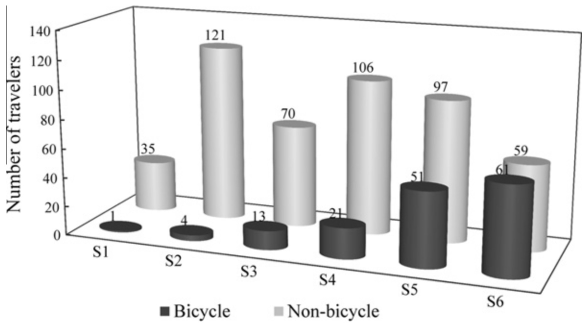

Fig. 4. Actual bicycle use for commuting in market segments.

Table 6
Socioeconomic characteristics in each market segment.

Socioeconomic characteristics	Statistics	Segments					
		S1	S2	S3	S4	S5	S6
Age (years)	Mean	30.639	34.760	31.952	34.567	34.331	36.467
	Std.	1.821	0.921	1.432	1.122	1.002	1.099
Gender (female = 1)	Mean	0.528	0.568	0.506	0.567	0.588	0.600
	Std.	0.084	0.044	0.055	0.044	0.041	0.045
Education (high educated = 1)	Mean	0.500	0.568	0.434	0.394	0.527	0.450
	Std.	0.085	0.044	0.055	0.044	0.041	0.046
Individual income (1000 yuan/year)	Mean	34.829	41.231	32.808	35.736	35.291	27.885
	Std.	3.966	2.641	3.811	2.843	2.017	1.777
Household income (1000 yuan/year)	Mean	101.282	97.538	80.074	88.976	82.536	70.192
	Std.	11.296	6.763	5.713	5.981	3.392	3.152
Marriage (yes = 1)	Mean	0.556	0.848	0.614	0.740	0.750	0.783
	Std.	0.084	0.032	0.054	0.039	0.036	0.038
Child under 12 (yes = 1)	Mean	0.556	0.752	0.590	0.622	0.723	0.517
	Std.	0.084	0.039	0.054	0.043	0.037	0.046
Automobile available (yes = 1)	Mean	0.444	0.528	0.253	0.213	0.209	0.075
	Std.	0.084	0.045	0.048	0.036	0.034	0.024

5.2. Policy implications for market segments

The market segmentation approach helps identify the travelers with homogeneous attitudes towards commuting travel activities. The travelers within each subsegment have particular desires or needs when making decision on choosing a bicycle or not. The market segmentation analysis can help transportation planners develop more focused policies or strategies that best serve the needs of different markets to promote the bicycle usage for commuting.

Since travelers in the S1 and S2 have high desires for travel comfort, building favorable and enjoyable cycling environments and improving the level of service of existing bicycle facilities could be effective ways to improve the competitive ability of bicycle. Travelers in the S2 have high needs for fixed travel schedule, which indicates designing well-equipped bicycle facilities that connect major work-related districts and residential distracts and providing more bicycle parking facilities in working areas could promote them to use bicycle more often. Besides, the public propaganda and education towards the environmental protection could improve the environmental awareness of travelers in the two segments. Some of them may realize the benefits of bicycle on the environment and choose the bicycle as the commuting tool.

Travelers in the S5 and S6 have high needs for fixed schedule with predictable trip time but have low needs for travel comfort. Thus, designing more continuous bicycle lanes or paths and increasing the connectivity of bicycle facilities as well as building convenient bicycle parking services could make the bicycling less likely to be impacted by traffic congestions and provide predictable trip times for bicycle travelers. These strategies could increase the bicycle usage in the two segments. Besides, the emphases on the harm of motor vehicle emissions and the benefit of bicycle on the environment could persuade some travelers to use bicycle more often, since the people in the two segments have high environmental awareness.

The above strategies in promoting bicycling may not be useful for travelers in the S3 and S4 as in the other segments. The reason is that travelers in the two segments do not have particular attitudinal preferences on the commuting activities and thus it is hard to find a way to make the bicycling better fits their preferences. However, particular strategies can be proposed to instruct the market switching behaviors in the two segments into the markets with higher level of bicycle usage. For example, the propaganda and education towards the environmental protection awareness can promote the travelers in the S3 and S4 switching to the S5 and S6 which have more bicycle commuting activities.

6. Conclusions and recommendations

This study evaluated the use of attitudinal market segmentation approach for the analysis of the bicycle commuting market. Individuals' attitudes towards commuting travels were extracted from the attitudinal questions in the household survey conducted in one city in China. The factor analysis and SEM were used to identify the latent attitudinal factors and capture the interrelationships between them. The *K*-means clustering method was then used to segment the bicycle commuting market into several submarkets by the selected attitudinal factors.

The results of this study showed that the approach of attitudinal market segmentation was useful in capturing the heterogeneity of bicycle commuting activities and identifying the potential bicycle commuters. In this study, the bicycle commuting market was segmented into six submarkets by four attitudinal factors which were the willingness to use bicycle, need for fixed schedule, desire for comfort, and environmental awareness. Different submarkets have distinct attitudinal features and actual bicycle usage. The findings of this study also suggested that most socioeconomic statuses do not present substantial characteristics among these submarkets.

According to the market segmentation results, travelers in the S1 and S2 have high desires for comfort, low environmental awareness, low willingness to use bicycle and less actual bicycle usage. These travelers are considered as firm non-bicycle travelers. Travelers in the S5 and S6 have low desires for comfort, high environmental awareness, high needs for fixed schedule, high willingness to use bicycle, and more actual bicycle usage. Thus, these travelers are considered as firm bicycle users and potential bicycle users. Individuals in the S3 and S4 do not have particular preferences towards commuting travelers and are considered as potential market switchers. The policies and strategies on promoting the bicycle commuting need to be developed specifically to well serve the needs of travelers in each market segment.

Due to the different culture and environment in travel activities between China and other countries, the bicycle commuting market segments identified in this study may not be directly transferrable to other parts of the word. But the attitudinal market segmentation approach presented in this study can be applied by local agencies or communities for identifying the distinct bicycle markets for local commuters. Then the policies can be proposed according to the particular characteristics of types of local bicycle commuting markets. This study provides grounds for communities to strive for better bicycling facilities, amenities, and supports.

Since the travelers' attitudes cannot be directly measured, future studies can be focused on exploring the connections between the latent attitudes and measurable variables such as socioeconomic statuses to make the attitude-based market segmentation analysis be more practicable. Besides, the selection of attitudinal factors used for the market segmentation is, to some extent, according to the researchers' subjectivity. Other types of attitudinal factors could be tested in the segmenting procedure to see if more homogenous and reasonable market segments can be generated. The authors recommend that future studies could focus on these issues.

Acknowledgements

This research is supported by the National Key Basic Research Program (NKBRP) of China (No. 2012CB725402), the National High-tech R&D Program of China (863 Program) (No. 2012AA112304), the Scientific Research Foundation of Graduate School of Southeast University (No. YBJJ1150), and the Fundamental Research Funds for the Central Universities and Foundation for Young Key Teachers of Southeast University are also appreciated. The authors would like to thank the senior students from Transportation School of Southeast University for their assistance in household interview and data reduction.

References

Abraham, C., Gardner, B., 2007. What drives car use? A grounded theory analysis of commuters' reasons for driving. Transportation Research, Part A 10, 187–200.

Anable, J., 2005. 'Complacent car addicts' or 'aspiring environmentalists'? Identifying travel behaviour segments using attitude theory. Transport Policy 12, 65–78.

Anable, J., Gatersleben, B., 2005. All work and no play? The role of instrumental and affective factors in work and leisure journeys by different travel modes. Transportation Research, Part A 39, 163–181.

Badoe, D.A., Miller, E.J., 1998. An automated segmentation procedure for studying variations in mode choice behavior. Journal of Advanced Transportation 32, 190–215.

Bergstrom, A., Magnusson, R., 2003. Potential of transferring car trips to bicycle during winter. Transportation Research, Part A 37, 649–666.

Button, K.J., Hensher, D.A., 2001. Modal diversion. In: Handbook of Transport Systems and Traffic Control. Pergamon Press, Oxford.

Clark, D.E., 1997. Estimating future bicycle and pedestrian trips from a travel demand forecasting model. In: 67th Annual Meeting, Institute of Transportation Engineers.

Cambridge Systematics, 2001. Market Research Approach for Transit Works Long-Range Strategy. Cambridge Systematics, Oakland, California.

Davies, D.G., Halliday, M.E., Mayes, M., Pockock, R.C., 1997. Attitudes to Cycling – A Qualitative Study and Conceptual Framework. Transport Research Laboratory, Ref. 266.

Deakin, Elizabeth A., 1985. Utilitarian Bicycling: A Case Study of the Bay Area and Assessment of the Market for Commute Bicycling. ITS Research Report. University of California, Berkeley.

Dill, J., Voros, K., 2007. Factors affecting bicycling demand – initial survey findings from the Portland, Oregon, Region. Transportation Research Record 2031, 9–17.

Elgar, A., Bekhor, S., 2004. Car rider segmentation according to riding status and investment in car mobility. Transportation Research Record 1894, 109–116.
Elmore, Y.R., 1998. A Handbook: Using Market Segmentation to Increase Transit Ridership. TCRP Report 36. Transportation Research Board, National Research Council, Washington, DC.
Gärling, T., Fujii, S., Boe, O., 2001. Empirical tests of a model of determinants of script-based driving choice. Transportation Research, Part F 4, 89–102.
Gatersleben, B., Appleton, K.M., 2007. Contemplating cycling to work: attitudes and perceptions in different stages of change. Transportation Research, Part A 41, 302–312.
Golob, T.F., 2003. Structural equation modeling for travel behavior research. Transportation Research, Part B 37, 1–25.
Golob, T.F., Hensher, D.A., 1998. Greenhouse gas emissions and Australian commuters' attitudes and behavior concerning abatement policies and personal involvement. Transportation Research, Part D 3, 1–18.
Guliano, G., Hayden, S., 2005. Marketing public transport. In: Hensher, D., Button, K.J. (Eds.), Handbook of Transportation. Pergamon Press, Oxford.
Heinen, E., van Wee, B., Maat, K., 2010. Commuting by bicycle: an overview of the literature. Transport Review 30, 59–96.
Heinen, E., Maat, K., Van Wee, B., 2011. The role of attitudes towards characteristics of bicycle commuting on the choice to cycle to work over various distances. Transportation Research, Part D 16, 102–109.
Martens, K., 2004. The bicycle as a feedering mode: experiences from three European countries. Transportation Research, Part D 9, 281–294.
Meeusen, R., de Geus, B., De Bourdeaudhuij, I., Jannes, C., 2008. Psychosocial and environmental factors associated with cycling for transport among a working population. Health Education Research 23, 697–708.
Noland, R.B., Kunreuther, H., 1995. Short-run and long-run policies for increasing bicycle transportation for daily commuter trips. Transport Policy 2, 67–79.
Outwater, M.L., Castleberry, S., Shiftan, Y., Ben-Akiva, M., Zhou, Y.S., Kuppam, A., 2003. Attitudinal market segmentation approach to mode choice and ridership forecasting – structural equation modeling. Transportation Research Record 1854, 32–42.
Pucher, J., Buehler, R., 2008. Making cycling irresistible: Lessons from the Netherlands, Denmark and Germany. Transport Review 28, 495–528.
Pucher, J., Buehler, R., 2011. Analysis of Bicycling Trends and Policies in Large North American Cities: Lessons for New York. Finial Report. University Transportation Research Center.
Pucher, J., Dill, J., Handy, S., 2009. Infrastructure, programs, and policies to increase bicycling: an international review. Preventive Medicine 50, S106–S125.
Ryley, T., 2006. Use of non-motorized modes and life stage in Edinburgh. Journal of Transport Geography 14, 367–375.
Shan, X., 2007. A Research on Urban Bicycle Transportation Rational Ridership and Road Resource Allocation. Ph.D. Thesis, Southeast University, China.
Shiftan, Y., Outwater, M.L., Zhou, Y.S., 2008. Transit market research using structural equation modeling and attitudinal market segmentation. Transport Policy 15, 186–195.
Steg, L., 2005. Car use: lust and must. Instrumental, symbolic and affective motives for car use. Transportation Research, Part A 39, 147–162.
Steg, L., Geurs, K., Ras, M., 2001. The effects of motivational factors on car use: a multidisciplinary modelling approach. Transportation Research, Part A 35, 789–806.
Stinson, M.A., Bhat, C.R., 2005. A comparison of the route preferences of experienced and inexperienced bicycle commuters. In: Proceedings of Presented at 84th Annual Meeting of the Transportation Research Board, Washington, DC.
Su, J.G., Winters, M., Nunes, M., Brauer, M., 2010. Designing a route planner to facilitate and promote cycling in Metro Vancouver, Canada. Transportation Research, Part A 44, 495–505.
Washington, S.P., Karlaftis, M.G., Mannering, F.L., 2010. Statistical and Econometric Methods for Transportation Data Analysis, second ed. Chapman Hall/CRC, Boca Raton, FL.
Xing, Y., Handy, S.L., Mokhtarian, P.L., 2010. Factors associated with proportions and miles of bicycling for transportation and recreation in six small US cities. Transportation Research, Part D 15, 73–81.
Yang, C., Wang, W., Shan, X., Jin, J., Lu, J., Li, Z., 2010. Effects of personal factors on bicycle commuting in developing countries. Transportation Research Record 2193, 96–104.