

1                   **INFLUENCES OF NORM AND EXCITEMENT ON BIKE USE BEHAVIOR OF**  
2                   **HIGH-INCOME PEOPLE IN CHINA**

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**1 ABSTRACT**

2           In China, the bicycle had a high relevance in the past. Some decades ago, it was the major  
3 mode for most Chinese people. This situation changed with growing wealth and increasing car  
4 ownership. Today, as cities are traffic-crowded, the bicycle seems to be an alternative again. At  
5 the same time, the government as well as private equity, invest in public bike systems. Previous  
6 research indicates that especially people with high-income are less likely to use the bicycle as a  
7 mode of transport. The question arises whether the bike is used by high-income people that usually  
8 have a car as an alternative. What are the influencing factors to use bicycles? To investigate these  
9 aspects, we present results of a study conducted in 8 Chinese cities. The data is analyzed using a  
10 structural equation model to investigate influences on bike use behavior of high-income people.  
11 This study provides no contribution in the research of psychological characteristics of users or the  
12 routes used. Rather, it is intended to provide understanding to ecological norm and excitement  
13 regarding usage. The results provides insights into the complex interrelationships of  
14 sociodemographic and psychological aspects as well as the modernity of the cities in the context  
15 of bike usage. Mainly car ownership and the place of residence show significant effects on the  
16 attitudes and norms of people and thus influence the use of bicycles. Our results help to understand  
17 the interrelationships between sociodemographic characteristics, spatial characteristics and the  
18 attitudes of people while making mobility decisions.

19 **Keywords:** China, ecological norm, bicycle excitement, bike use behavior

## 1 INTRODUCTION

2 For Chinese people, using the bicycle as a mode of transport was popular and common until the  
3 end of the last century. Nowadays, in the context of public bike systems and traffic-crowded cities,  
4 the mode may revive. Nevertheless, it is unclear whether the status of the bike may have changed.  
5 Is it a modern and reasonable mode of transport? In this paper, we investigate interdependencies  
6 between people's attitudes, spatial and sociodemographic characteristics and their effective usage.

### 7 *The role of cycling in China*

8 In the 70s and 80s cycling has been a major mode of transport in China. The majority of the  
9 population was living in so-called danwei compounds, where living and working was put together  
10 closely. This resulted in mainly short trips and hence a high level of bike use (1). Over time and in  
11 the context of urbanization, commuting distances and thus distances traveled increased but also  
12 household income and the ownership and use of cars (2; 3). At the same time the ownership of  
13 private bikes in whole China decreased during the last decades (4; 5). Both longer distances and  
14 higher importance of the automobile weakened the status of the bicycle. Many cities registered a  
15 lower level of bike use during the last decade, regarding both everyday mobility and commuting  
16 trips (2). Nowadays, a lot of dense urban areas exist where cycling would have great potential.  
17 Congestion often leads to low driving speeds (6) and the government invests in public bike  
18 systems. Many cities support the implementation of such systems and subsidize the companies  
19 running the service. However, cycling infrastructure in cities mostly still has a low quality and  
20 cycling in China is insecure as cyclists are comparatively vulnerable because of heavy traffic (4).  
21 In addition, bike systems in cities differ in the quality of implementation shown by varying service  
22 quality and acceptance (5). In 2015 already 300 systems with 1 million public bikes existed (7). In  
23 China, public bike systems are mainly seen as "last-mile" feeders. Some use the public bikes as a  
24 substitute for their private bicycle as the maintenance costs and theft risks are lower (5). In a city  
25 district of Shanghai, the service was mainly used by low- and medium-income people and  
26 increasing household income correlates with decreasing ride frequency (7). At the same time,  
27 public bike systems grow in dense city areas where mostly high-income residents live (2). Public  
28 bike systems are seen as a complementary mode of transport for public transportation having daily  
29 commuters, city dwellers, and tourists as main user groups. In contrast to other population groups,  
30 people with high incomes have the opportunity to afford and use a car. This effect is increasing by  
31 a rising standard of living. Car ownership itself has a considerable influence on the travel behavior:  
32 it usually goes along with a lower percentage of bike and public transportation trips. The bicycle  
33 ownership decreases with higher income. The sample of a study conducted in four urban quarters  
34 of Shanghai (8) showed for three cases a decline from 40.6 % owning a bicycle on the lowest  
35 income level to 31.7 % on the highest income level. In addition, Pan et al. (8) registered a small  
36 significant effect of higher income on the likeliness to use motorized vehicles. The share of trips  
37 done by bicycle in bigger cities like Beijing, Guangzhou and Wuhan decreased from over 35 % in  
38 the 1980s to under 15 % in 2005 (4).

### 39 *Applied Methods from literature*

40 In order to investigate the influence of sociodemographic characteristics and psychological factors  
41 there are different approaches in the literature. According to the Theory of Planned Behavior,  
42 attitudes influence eco-friendly and sustainable travel behavior substantially (9). The reciprocal  
43 relationship between attitudes towards cycling and bike use behavior was investigated by Thigpen  
44 et al. (10). To describe the relationship between the use of different modes and attitudinal,

1 sociodemographic as well as spatial characteristics, Structural Equation Models (SEM) and Hybrid  
2 Choice Models (HCM) are possible applications (11). For our study, SEM was chosen since the  
3 modeling of discrete choice decisions is not required. Li et al. (12) used SEM to describe the  
4 relationship of various attitudinal factors on the perception towards bicycling as well as on the  
5 willingness to use a bicycle. The results show environmental awareness being most positively  
6 related with the perception to use bicycles. The perception itself shows a considerable effect on  
7 the willingness to cycle. Another application investigating attitudes and behavior is given by Zhao  
8 (13), who used SEM to analyze the relationship between attitudes, behavior, and intention to  
9 explain car dependence. After the identification of relevant variables with an Anova, Zhao  
10 specified three different SEMs. Sociodemographic characteristics, land use, and public  
11 transportation access, as well as components of the socioeconomic status, served as exogenous  
12 variables. Attitudinal items and travel indicators displayed the latent variables in the model. With  
13 the application of SEM, Zhao was able to show the correlations between *Car Dependence*, *Car*  
14 *Use* and the *Intent to Reduce Car Use*. Next to the investigation of mode use, there are also  
15 applications of SEM that deal with influences on travel behavior in general. Van Acker et al. (14)  
16 included variables of three different dimensions – socio-economic, personal and spatial dimension  
17 – in their SEM to analyze the largest effects on travel behavior. Bagley and Mokhtarian (15)  
18 examined the influences of residential neighborhood type, attitudes, lifestyle and demographic  
19 characteristics on travel demand. A detailed overview of SEM and common areas of application  
20 in travel behavior research is given by Golob (16).

### 21 *Scope of the study*

22 In our study, we analyze the bicycle use of a survey conducted among high-income people from 8  
23 Chinese cities. Based on the data, we applied a SEM to investigate influences on bike use behavior  
24 of people. However, it must be emphasized that we try to examine the factors between different  
25 types of cities concerning their modernity on a more abstract level. This implies that we do not  
26 examine physical characteristics of people. We also do not analyze which specific routes they  
27 cycle and what the topography is. Rather, we want to observe how attitudes influence this use. The  
28 other factors are considered by sociodemographic characteristics such as age (sportiness) or the  
29 modernity of the city type. The paper is structured as follows: First, we describe the data used and  
30 the methodology of our analyzes. Second, we present results of the structural equation model and  
31 interpret resulting factors that influence bike usage in China. Finally, we draw a conclusion,  
32 discuss the limits of our approach and refer to further work.

### 33 **DATA**

34 The research presented in this paper is based on a unique data collection approach, especially in  
35 terms of capturing comprehensive information related to individual attitudes and travel behavior.  
36 The survey collected information on activities and mode choices using the concept of a travel  
37 skeleton (17; 18). This concept focuses on the collection of typical travel behavior elements. The  
38 skeleton provides a reasonable compromise between the level of detail needed and the required  
39 effort to survey travel behavior. The idea of using a skeleton to identify routines and typical  
40 behavior is common in travel behavior research (19–22). In addition, we used a standardized  
41 psychological item set to investigate respondents' attitudes towards different modes of transport  
42 including bicycles (18; 23). The item set also contains questions about personal and social norms

1 concerning travel behavior. Previous research showed a substantial influence of norms on travel  
2 behavior (24). Table 1 shows the used items.

### 3 **Data collection**

4 In our study, we use data collected through a survey in 8 Chinese cities. The surveyed cities were  
5 selected according to the categorization of cities into first-, second- and third-tier cities (25). Based  
6 on the selection of cities from different categories, the survey took place in Shanghai, Beijing,  
7 Chongqing, Shenyang, Wuhan, Kunming, Urumqi and Zhuhai between May-2017 and July-2017.  
8 The survey primarily focussed on capturing travel behavior and psychological factors of people in  
9 higher income classes in urban and high dense areas. To generate a comparable dataset from each  
10 city, we used a standardized survey approach based on a computer assisted personal interview  
11 (CAPI). The survey was carried out by a professional Chinese market research firm. The full  
12 sample size was 5,192 individuals with more than 550 respondents from each city.

### 13 **Data preparation**

14 The dataset used for this papers' analyzes is a subsample with employed people only. Multivariate  
15 statistical analyzes often face the issue of handling observations with missing data. Since the  
16 relationships between variables in complex models, such as structural equation models, can only  
17 be analyzed if all used variables show values, observations with missing data need to be excluded  
18 (26). First, we screened the data and deleted respondents with a high amount of missing values  
19 ( $\geq 20\%$ ). Second, to include respondents with a low number of missing values we applied the  
20 machine learning algorithm missForest (27; 28). This method is a non-parametric missing value  
21 imputation for mixed-type data using random forest and can cope with continuous and categorical  
22 variables simultaneously. Existing literature recommend this imputation method because of lower  
23 out-of-bag error estimates by mixed-type data in contrast to multivariate imputation methods (27;  
24 28). After the imputation, the data consisted of 4,807 complete observations.

## 25 **ANALYZING ATTITUDES AND BIKE USE**

26 In this section, we investigate bike use, norms, and attitudes towards bicycles of respondents in  
27 our dataset. First, we look at responses on attitudes and individual bike use frequencies. Second,  
28 we analyze bicycle related attitudes based on different characteristics. Finally, we used an  
29 explorative method to find unobservable latent variables for our structural equation model. In the  
30 following, we use the terms bike and bicycle synonymously. There is no inclusion of E-bikes and  
31 electric scooters.

### 32 **Descriptive analysis**

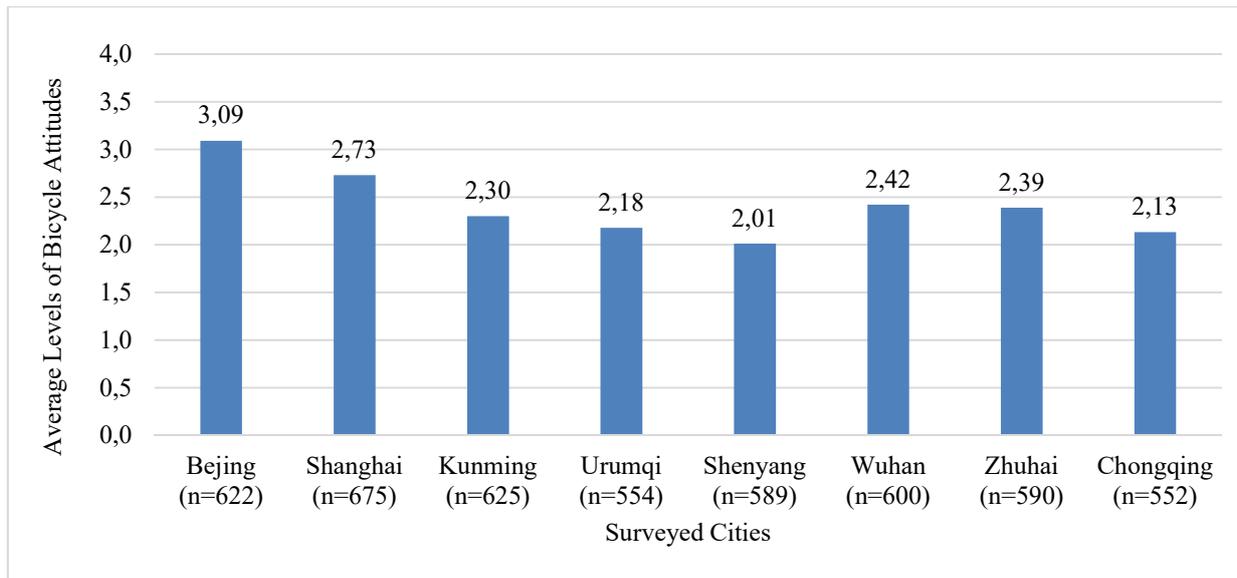
33 Table 1 shows the results of our descriptive analysis and codings for the items investigated. The  
34 majority (53.71%) of the investigated sample does not want to ride bicycles when the weather is  
35 bad. A positive respondent's behavior is visible in the indicator *BO2*. People use the bicycle  
36 because they can relax during the usage. Considering the usage, 40% of the respondents cycle at  
37 least once a month and 21.8% at least once a week. The frequency of bike usage includes the use  
38 of private bikes as well as bikes from public bike systems. In our study, 34.4% own a private  
39 bicycle. This value is comparable to bicycle ownership in Zhang et al. (5).

1 **Table 1 Descriptive analysis of attributes and bike use in Chinese cities**

<b>A. Distribution of selected attributes</b>		<b>N= 4,807</b>				
<i>Category</i>		<i>Does not apply (1)</i>	<i>Rather does not apply (2)</i>	<i>Applies in part (3)</i>	<i>Rather applies (4)</i>	<i>Applies (5)</i>
<i>Bicycle Orientation</i>						
I like to be out and about by bike.	BO1	24.92%	26.32%	25.40%	14.81%	8.55%
I can relax well when riding a bike.	BO2	23.30%	24.90%	24.07%	17.41%	10.32%
I ride a bicycle because I enjoy the exercise.	BO3	24.73%	23.30%	24.05%	15.77%	12.15%
<i>Weather Resistance</i>						
I also ride my bike when the weather is bad.	WR1	53.71%	25.71%	12.00%	5.47%	3.10%
<i>Personal Norm</i>						
Due to my principles, I feel personally obligated to use eco-friendly means of transportation for the things I do in everyday life.	PN1	3.39%	10.26%	30.58%	29.31%	26.46%
<i>Social Norm</i>						
People who are important to me think it is good if I would use public transportation instead of a car for things I do in everyday life.	SN1	12.46%	26.67%	31.72%	20.20%	8.95%
<b>B. Distribution of bike use</b>		<b>N= 4,807</b>				
<i>Frequency</i>		<i>Minimum once a week</i>	<i>Minimum once a month</i>	<i>Less often than once a month</i>	<i>Never</i>	
Bike or public bike usage		21.80%	20.16%	8.76%	49.28%	

2 **Analysis of bicycle related attitudes**

3 We further investigated bicycle related attitudes according to different characteristics of the  
4 dataset. Therefore, we calculated the mean of *BO1*, *BO2*, *BO3*, and *WR1* (see Table 1) for each  
5 person. Figure 1 illustrates the different levels of the average bicycle attitudes according to the  
6 surveyed cities. The highest values belong to Shanghai (3.09) and Beijing (2.73). Shenyang (2.01),  
7 Urumqi (2.18) and Chongqing (2.13) have the lowest average scores.



1

## 2 **Figure 1 Average levels of bicycle attitudes in different Chinese cities**

3 We further used an city-level index from a study by AutoNavi (29). The *Delay Index* describes  
 4 the state of congestion in the respective city, judged by travel time delay (travel time under  
 5 traffic congestion / travel time under free flow) from low to high (i.e., three categories). Average  
 6 bicycle attitudes have the highest average value (2.54) in cities with a high *Delay Index*, namely  
 7 Beijing, Shanghai, Shenyang and Chongqing. There is only a slight difference between low  
 8 (2.40) and middle (2.32) *Delay Index* cities. Table 2 displays the different levels of the average  
 9 bicycle attitudes according to different groups of people. We see high differences concerning car  
 10 and bike availability as well as differences in age. The comparison of age groups shows  
 11 differences between younger and older respondents. In our study, young people (< 30 years) are  
 12 more excited about bicycles than older people. In addition, people with no car in their household  
 13 are more excited. By looking at education, we see a slightly higher excitement of high educated  
 14 people (minimum bachelor degree).

1 **Table 2 Average levels concerning bicycle attitudes**

<b>Average levels of bicycle attitudes</b>					<b>N= 4,807</b>
<i>Variables (Attributes of respondents analyzed)</i>	<i>N</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>95% confidence interval for mean</i>	
<i>Personal level</i>					
Female	1,814	2.40	1.02	2.35	2.45
Male	2,993	2.43	1.04	2.40	2.47
Car available	1,731	2.59	0.99	2.55	2.64
No car available	3,076	2.32	1.05	2.29	2.36
< 30 years	1,231	2.60	1.00	2.55	2.66
> 29 years	3,576	2.36	1.04	2.32	2.39
High educated	3,789	2.45	1.02	2.42	2.48
Not high educated	1,018	2.31	1.06	2.24	2.37
Own bicycle	1,249	3.24	0.81	3.19	3.28
No bicycle	3,558	2.13	0.95	2.10	2.16
<i>Household level - Person in ...</i>					
... single household	420	2.53	0.94	2.44	2.62
... two-person household	1,239	2.45	1.03	2.40	2.51
... three-person household	2,657	2.35	1.02	2.31	2.39
... households with more than four	491	2.64	1.18	2.54	2.75
<i>Person</i>					
... household with no car	1,601	2.64	0.98	2.59	2.69
... household with one car	2,988	2.32	1.03	2.28	2.36
... household with more than one car	218	2.20	1.18	2.05	2.36
... household with children	2,068	2.32	1.03	2.27	2.36
... household without children	2,739	2.50	1.03	2.46	2.54

2 To investigate the significance of the characteristics concerning average bicycle attitudes,  
3 we used a One Way Anova. Table 3 shows the results of the One Way Anova. When specifying a  
4 structural equation model, the decision on what variables to include is crucial. Kline (30) points  
5 out that the model specification should rely on literature as well as on researchers' judgment.  
6 Besides the identification of significant variables from literature (e.g., 12; 14; 15), we decided with  
7 the help of the One Way Anova, which exogenous variables help to explain cycling related  
8 attitudes in our model. We analyzed attributes on the personal and household level as well as on  
9 the city level. For cycling related attitudes a significant difference between male and female is not  
10 observable. Analyzing the differences between age groups, we see a significant difference between  
11 people under and over 30 years.

1 **Table 3 One Way Anova of average bicycle attitudes**

<b>One Way Anova of bicycle attitudes</b>						<b>N= 4,807</b>
<i>Variables</i>		<i>DF</i>	<i>Sum of squares</i>	<i>Mean square</i>	<i>F value</i>	<i>Pr &gt; F</i>
<i>Personal level</i>						
Male	Between groups	1	1.34	1.34	1.25	0.26
	Within groups	4,805	5,155.01	1.07		
	Total	4,806	5,156.36			
High Educated	Between groups	1	17.25	17.25	16.13	<.0001
	Within groups	4,805	5139,11			
	Total	4,805	5,156.36			
Under 30 Years	Between groups	1	55.57	55.57	52.35	<.0001
	Within groups	4,805	5,100.79	1.06		
	Total	4,806	5,156.36			
<i>Household level</i>						
Household Size	Between groups	3	44.54	14.85	13.95	<.0001
	Within groups	4,803	5,111.82	1.06		
	Total	4,806	5,156.36			
Number of Cars	Between groups	2	116.48	58.24	55.52	<.0001
	Within groups	4,804	5,039.88	1.05		
	Total	4,806	5,156.36			
<i>City level</i>						
City	Between groups	7	530.89	75.84	78.69	<.0001
	Within groups	4,799	4,625.47	0.96		
	Total	4,806	5,156.36			
Delay Index	Between groups	2	43.90	21.95	20.62	<.0001
	Within groups	4,804	5,112.46	1.06		
	Total	4,806	5,156.36			

2 **Explorative analysis**

3 Attitudes towards modes of transport are visible in individuals' response behavior on  
4 psychological questions. Therefore, researchers use the construct of unobservable latent variables.  
5 To identify these latent variables, exploratory factor analysis is applicable (12). We performed a  
6 Principal Axes Factor Analysis (PFA) with six items about attitudes towards bicycles and  
7 ecological norms as input. Based on the Scree Plot and the Kaiser's Criterion, we obtained two  
8 factors: *Bicycle Excitement* (factor 1) and *Norm* (factor 2). All PFA results are shown in Table 4.

1 **Table 4 Factor analysis**

<b>A. Principal Factor Analysis (PFA) - Rotated factor pattern</b>			<b>N= 4,807</b>
<i>Used items in PFA</i>	<i>Factor 1</i>	<i>Factor 2</i>	
Bicycle Orientation 1 (BO1)	0.724		
Bicycle Orientation 2 (BO2)	0.694		
Bicycle Orientation 3 (BO3)	0.689		
Weather Resistance (WR1)	0.473		
Social Norm (SN1)		0.929	
Personal Norm (PN1)		0.408	
<b>B. Criteria of extraction and quality for PFA</b>			<b>N= 4,807</b>
<i>Criteria of extraction</i>	<i>Number of factors</i>		
Kaiser Criterion	2		
Scree Test	2		
<i>Criteria of quality</i>	<i>Value</i>	<i>Pr &gt; Chi-Square</i>	
Kaiser's Measure of Sampling Adequacy (MSA)	0.83		
Bartlett's Test of Sphericity	$\chi^2 (4,807) = 11,882.94$	<.0001	

2 **STRUCTURAL EQUATION MODEL**

3 The application of SEM is useful to describe multiple relationships of observed and latent variables  
4 in a specified model. Therefore, it combines factor analysis and multiple regression. In addition,  
5 SEM allows analyzing the relations of latent variables amongst each other (15; 26). In general,  
6 SEM are used in confirmatory analyzes (25) to verify theory-based assumptions. In our study, we  
7 assume an influence of both sociodemographic and psychological characteristics on the travel  
8 behavior of individuals.

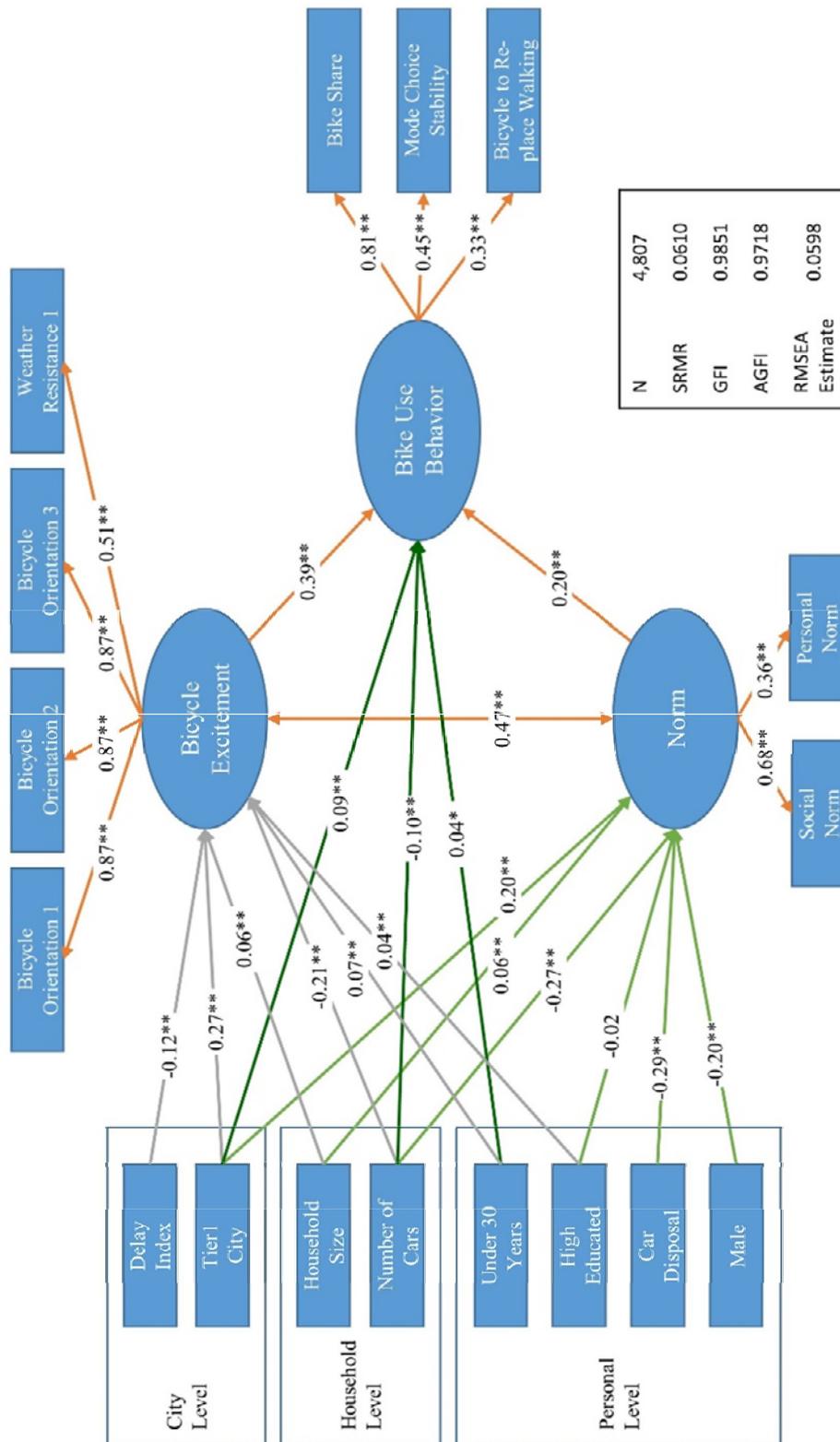
9 **Development**

10 To investigate the influences of psychological as well as sociodemographic and spatial  
11 characteristics on bike use in China, we specified a SEM with the software SAS. First, we included  
12 the two latent variables *Norm* and *Bicycle Excitement*, which are based on the factor analysis,  
13 presented in the previous section. We extended the model and added the latent variable *Bike Use*  
14 *Behavior*. This is based on three indicators: *Bike Share*, *Mode Choice Stability*, and *Bicycle to*  
15 *Replace Walking*. The indicator *Bike Share* includes the relative private bike and public bike usage  
16 over all other modes according to the typical travel behavior. *Mode Choice Stability* ranges from  
17 0 to 1 and contains the information if a person uses only one mode (monomodal) or multiple modes  
18 (multimodal) in daily travel behavior. Monomodal people have a value near 1 and multimodal  
19 people near 0. Thus they are very stable in their mode choice behavior. The indicator is adapted  
20 from Mallig and Vortisch (31). The last indicator *Bicycle to Replace Walking* describes if people  
21 use a bicycle to replace trips they walked before. The specified model thus consists of observed  
22 variables (squares) and three latent variables: *Bicycle Excitement*, *Norm*, and *Bike Use Behavior*,  
23 which are shown in ovals (see Figure 2).

24 When specifying a SEM, a differentiation between the structural model component and the  
25 measurement model component exists. The latter describes the connections of the observed and

1 the latent variables. More precisely, observed variables help to define latent structures. The  
2 structural model component identifies the effects of the latent variables on each other (26). During  
3 an iterative modeling process, we ex- and included variables step-by-step to see whether the model  
4 fittings improve. Sociodemographic variables that were identified in the One Way Anova are  
5 included in the measurement model component as exogenous variables (see left side of Figure 2).  
6 For example, having access to a car and being male show significant negative effects on the latent  
7 variable *Norm*. It should be noted that some other variables may not be specified in the model  
8 because they did not provide a significant explanation. Next to attributes on the personal and  
9 household level we included the variable *Tier1 City* to describe spatial characteristics on the city  
10 level. The dummy variable *Tier1 City* describes if the city of residence is Beijing or Shanghai (i.e.,  
11 the only first-tier cities of our sample). This classification according to tier cities is intended, since  
12 a consideration at city level would make the model extremely unclear. In addition, we would like  
13 to measure in particular the influence of the modernity of the city on the *Bicycle Excitement* and  
14 the *Norm* in China. Attitudinal items were included in the model as well. They display the latent  
15 variables and are used as endogenous variables. The psychological items are assigned to the latent  
16 variables according to their maximum factor loadings from the PFA carried out previously.

17 Figure 2 shows the setting of our SEM and the included variables and relationships within  
18 the single components. The standardized parameter estimates are indicated in the relationship-  
19 arrows: One-directional arrows indicate the causal effect of one variable on the other. Bi-  
20 directional arrows indicate the non-causal correlation between two latent variables. The SEM  
21 illustrates the relations between latent variables and independent observed variables from three  
22 categories: *City*, *Household*, and *Personal Level*. There are several indicators to describe the model  
23 fit. Most often used are RMSEA and SRMR which show values of 0.06 in our model and thus  
24 confirm a good fit. Based on the value of RMSEA we can conclude a relatively good fit between  
25 the observed data and the hypothesized model, according to classifications by Hu and Bentler (32).  
26 In addition, GFI and AGFI are over 0.9, which also indicate a well-fitting model (33).



1

2 **Figure 2 Structural equation model of bike use behavior in China**

## 1 Results

2 The advantage of SEM as a tool to investigate multiple influences becomes clear when examining  
3 the exogenous variables: *Tier1 City*, *Number of Cars*, *Household Size*, *Under 30 Years* as well as  
4 *High Educated* show effects on multiple latent variables. Not surprising, the number of cars has a  
5 negative effect on all three latent variables. As expected, car ownership plays a major role in the  
6 use of bicycles (see Figure 2). However, the *Bicycle Excitement* is less strongly influenced than  
7 the *Norm*. The highest negative influence on the *Norm* is via car ownership. People with a car  
8 (*Number of Cars*: -0.27) that they can use in the household (*Car Disposal*: -0.29) have the lowest  
9 norm. They do not care about the environmental friendliness of the chosen mode. The effect is  
10 intensified in men. Interestingly, the level of education does not appear to be contrary. It does not  
11 play a role in all three latent variables. We would expect people with a higher level of education  
12 to be more concerned with the sustainability of their everyday travel. Besides, we don't see any  
13 age effect. The expectation is that younger people could develop a higher norm, because they're  
14 experiencing a different socialization. However, this effect is not visible in high-income earners  
15 with regard to environmentally friendly means of transport.

16 In contrast, we can observe a positive influence on the *Norm* (0.20) through the *Tier 1 City*.  
17 These cities are among the most modern in China and this is also reflected in the norm of the  
18 people. Nevertheless, the positive influence is smaller than the negative influence on car  
19 ownership. The direct effect on *Bike Use Behavior* cannot be observed. When considering the  
20 influences on the *Bicycle Excitement*, the negative influence of the *Delay Index* is surprising.  
21 People from cities with high traffic congestion have a low bicycle excitement. One would expect  
22 people to switch to the bicycle alternative here. This effect is corrected by Tier 1 City At the other  
23 two cities Shenyang and Chongqing with much congestion it is not compensated. People from  
24 these cities have a lower *Bicycle Excitement*. We also see in our model a correlation between *Norm*  
25 and *Bicycle Excitement*, which was to be expected.

26 The application of SEM to examine the interrelations of variables allows the distinction  
27 between direct, indirect and total effects (14; 15). The total effects of endogenous and exogenous  
28 variables on *Bike Use Behavior* are given in Table 5. In our model, *Bicycle Excitement* and *Norm*  
29 influence *Bike Use Behavior* directly. Additionally, both latent variables have also a non-causal  
30 correlative effect on *Bike Use Behavior*. The correlation of *Bicycle Excitement* on *Bike Use*  
31 *Behavior* is the combination of direct causal and non-causal effects. *Bicycle Excitement* (0.39) and  
32 *Norm* (0.20) have a positive direct effect on *Bike Use Behavior* (see Table 5). Moreover, the non-  
33 causal correlative effect (bi-directional arrow) of *Bicycle Excitement* has a value of 0.09  
34 (0.47\*0.20). *Norm* has a higher value of 0.18 (0.47\*0.39) (see Figure 2).

1 **Table 5 Standardized effects on bike use behavior**

<i>Effects</i>	Bike Use Behavior		
	Total	Direct	Indirect
<i>Endogenous variables</i>			
Bike Excitement	0.39	0.39	0.00
Norm	0.20	0.20	0.00
<i>Exogenous variables</i>			
Delay Index	-0.05	0.00	-0.05
Tier 1 City	0.24	0.09	0.15
Household Size	0.03	0.00	0.03
Number of Cars	-0.23	-0.10	-0.14
Under 30 Years	0.07	0.04	0.03
High Educated	0.01	0.00	0.01
Car Disposal	-0.06	0.00	-0.06
Male	-0.04	0.00	-0.04

2 The results indicate a significant influence of both latent variables - *Bicycle Excitement* and  
3 *Norm* - on *Bike Use Behavior*. *Bicycle Excitement* has the more decisive impact on *Bike Use*  
4 *Behavior* compared to *Norm*. Looking at total effects on *Bike Use Behavior* of exogenous  
5 variables, *Tier 1 City* and *Number of Cars* have the highest total effects and explain most besides  
6 the psychological factors. We see a higher indirect effect of *Tier 1 City* and *Number of Cars* than  
7 a direct effect. Summarizing the strongest effects, young females from *Tier 1 City* without a car  
8 with a high norm and high bicycle excitement are most likely to use a bicycle. The specified SEM  
9 confirms the assumption that both sociodemographic characteristics and attitudes influence  
10 behavior.

## 11 CONCLUSIONS

12 Our study investigated influences on bike use behavior of high-income people in China. Given a  
13 specific dataset of people from 8 different cities in China, we used a structural equation model to  
14 investigate relevant influencing factors.

15 Our results indicate complex interrelations between sociodemographic characteristics,  
16 psychological attitudes and spatial aspects with respect to travel behavior. The inclusion of latent  
17 variables, based on attitudinal items, allowed us to investigate the motivation of bike use of high-  
18 income people in Chinese cities. Both factors *Norm* and *Bicycle Excitement* (determined by a  
19 Principal Axes Factor Analysis) show direct and indirect effects on *Bike Use Behavior*.  
20 Additionally, we identified decisive effects of characteristics at the personal, household and city  
21 level. In our study we were able to show that a high level of education and age has a low influence  
22 on the *Norm* and the *Bicycle Excitement* in the observed cities. This was definitely not to be  
23 expected, as there are differences in socialization, particularly in contrast to the generations of the  
24 elderly. Possibly this change is still in the process of being reinforced by a higher public bike  
25 system offer in the cities. But we also see that modern Chinese cities have higher *Norms* and higher  
26 *Bicycle Excitement*. This could be a sign for a positive development regarding the bicycle. Results  
27 of the total effects have shown that the use of the bicycle is most influenced by the modernity of  
28 the city and the availability of the car among the exogenous variables. *Tier1 City* can also be seen

1 as a substitute for other aspects not covered by our dataset. People living in the *Tier 1 Cities* of our  
2 sample, i.e., Shanghai and Beijing, are rather people who tend to cultivate a modern lifestyle. In  
3 these cities, opportunities for the usage of public transportation are available, the traffic is often  
4 crowded, and public bike systems are well-developed. Thus conditions for cycling are given. Our  
5 SEM reflects this situation as living in these area has a high positive influence on *Bike Use*  
6 *Behavior*. At the same time, the need for a car decreases when living in these areas. On the one  
7 hand, infrastructural development decreases the need, and on the other hand, car ownership is also  
8 regulated and restricted by governmental policies (e.g., license plate lotteries). Thus, the effects on  
9 *Bike Use Behavior*, indicated by the variable *Number of Cars* are plausible.

10 Although we cannot capture all pieces of societies' development in China with our SEM,  
11 we see significant effects towards the usage of bicycles. As the Chinese economy is still thriving,  
12 infrastructural development is fast and public bike systems are emerging, we can assume a  
13 prospering development and an increasing importance of the bicycle in other Chinese cities in the  
14 near future. Especially if they reach a level of development such as Shanghai or Beijing (Tier 1  
15 City). Obviously our model has limitations regarding the use of bicycles. Based on the data, we  
16 could not consider the physiological condition of the respondents. However, an interesting  
17 extension would be the splitting of the different cities according to topography and climate. A  
18 disadvantage would be a further increase in complexity, which would endanger the model's  
19 manageability.

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## 23 AUTHOR CONTRIBUTION

24 The authors confirm contribution to the paper as follows: literature review: Miriam Magdolen,  
25 Tim Wörle; data preparation: Sascha von Behren, Miriam Magdolen; data analysis: Sascha von  
26 Behren, Miriam Magdolen, Tim Wörle, Tim Hilgert; interpretation of results: Sascha von Behren,  
27 Miriam Magdolen, Tim Wörle, Tim Hilgert; draft manuscript preparation: Miriam Magdolen, Tim  
28 Hilgert. All authors reviewed the results and approved the final version of the manuscript.

## 29 REFERENCES

- 30 1. Yang, J., J. Chen, M. Zhou, and Z. Wang. *Major issues for biking revival in urban China*.  
31 *Habitat International*, Vol. 47, 2015, pp. 176–182,  
32 <http://dx.doi.org/10.1016/j.habitatint.2015.01.022>.
- 33 2. Yang, J. *Spatial and Social Characteristics of Urban Transportation in Beijing*.  
34 *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2193,  
35 2010, pp. 59–67, <http://dx.doi.org/10.3141/2193-08>.
- 36 3. National Bureau of Statistics of China. *Statistical Yearbook*, 2017.  
37 <http://www.stats.gov.cn/tjsj/ndsj/2017/indexeh.htm>.

- 1 4. Frame, G., A. Ardila-Gomez, and Y. Chen. *The kingdom of the bicycle - what Wuhan can*  
2 *learn from Amsterdam. Transportation Research Procedia*, Vol. 25, 2017, pp. 5040–5058,  
3 <http://dx.doi.org/10.1016/j.trpro.2017.05.203>.
- 4 5. Zhang, L., J. Zhang, Z.-y. Duan, and D. Bryde. *Sustainable bike-sharing systems:*  
5 *characteristics and commonalities across cases in urban China. Journal of Cleaner*  
6 *Production*, Vol. 97, 2015, pp. 124–133, <http://dx.doi.org/10.1016/j.jclepro.2014.04.006>.
- 7 6. Yang, J., Q. Shen, J. Shen, and C. He. *Transport Impacts of Clustered Development*  
8 *in Beijing: Compact Development versus Overconcentration. Urban Studies*, Vol. 49, No. 6,  
9 2012, pp. 1315–1331.
- 10 7. Tang, Y., H. Pan, and Y. Fei. *Research on Users' Frequency of Ride in Shanghai Minhang*  
11 *Bike-sharing System. Transportation Research Procedia*, Vol. 25, 2017, pp. 4979–4987,  
12 <http://dx.doi.org/10.1016/j.trpro.2017.05.376>.
- 13 8. Pan, H., Q. Shen, and M. Zhang. *Influence of Urban Form on Travel Behaviour in Four*  
14 *Neighbourhoods of Shanghai. Urban Studies*, Vol. 46, No. 2, 2009, pp. 275–294,  
15 <http://dx.doi.org/10.1177/0042098008099355>.
- 16 9. Ajzen, I. *The theory of planned behavior. Organizational Behavior and Human Decision*  
17 *Processes*, Vol. 50, No. 2, 1991, pp. 179–211, [http://dx.doi.org/10.1016/0749-](http://dx.doi.org/10.1016/0749-5978(91)90020-T)  
18 [5978\(91\)90020-T](http://dx.doi.org/10.1016/0749-5978(91)90020-T).
- 19 10. Thigpen, C., M. Kroesen, and S. Handy. *An exploration of the reciprocal relationships*  
20 *between bicycling attitudes, skills, and behavior on a college campus, Santa Barbara,*  
21 *18.07.2018.*
- 22 11. Kim, J., S. Rasouli, and H. Timmermans. *Hybrid Choice Models: Principles and Recent*  
23 *Progress Incorporating Social Influence and Nonlinear Utility Functions. Procedia*  
24 *Environmental Sciences*, Vol. 22, 2014, pp. 20–34,  
25 <http://dx.doi.org/10.1016/j.proenv.2014.11.003>.
- 26 12. Li, Z., W. Wang, C. Yang, and D. R. Ragland. *Bicycle commuting market analysis using*  
27 *attitudinal market segmentation approach. Transportation Research Part A: Policy and*  
28 *Practice*, Vol. 47, 2013, pp. 56–68, <http://dx.doi.org/10.1016/j.tra.2012.10.017>.
- 29 13. Zhao, J. *Subjective Measure of Car Dependence. Transportation Research Record: Journal*  
30 *of the Transportation Research Board*, Vol. 2231, 2011, pp. 44–52,  
31 <http://dx.doi.org/10.3141/2231-06>.
- 32 14. van Acker, V., F. Witlox, and B. van Wee. *The Effects of the Land Use System on Travel*  
33 *Behavior: A Structural Equation Modeling Approach. Transportation Planning and*  
34 *Technology*, Vol. 30, No. 4, 2007, pp. 331–353,  
35 <http://dx.doi.org/10.1080/03081060701461675>.
- 36 15. Bagley, M. N., and P. L. Mokhtarian. *The impact of residential neighborhood type on travel*  
37 *behavior: A structural equations modeling approach. The Annals of Regional Science*,  
38 Vol. 36, No. 2, 2002, pp. 279–297, <http://dx.doi.org/10.1007/s001680200083>.
- 39 16. Golob, T. F. *Structural equation modeling for travel behavior research. Transportation*  
40 *Research Part B: Methodological*, Vol. 37, No. 1, 2003, pp. 1–25,  
41 [http://dx.doi.org/10.1016/S0191-2615\(01\)00046-7](http://dx.doi.org/10.1016/S0191-2615(01)00046-7).
- 42 17. von Behren, S., C. Minster, J. Esch, M. Hunecke, and B. Chlond. *Assessing Car*  
43 *Dependence: Development of a Comprehensive Survey Approach Based on the Concept of a*

- 1        *Travel Skeleton. 11th International Conference on Transport Survey Methods*, Esterel,  
2        Canada, September 24-29, 2017, 2017.
- 3 18. von Behren, S., C. Minster, M. Magdolen, B. Chlond, M. Hunecke, and P. Vortisch.  
4        *Bringing travel behavior and attitudes together: An integrated survey approach for*  
5        *clustering urban mobility types. TRB 97th Annual Meeting Compendium of Papers*,  
6        Washington, D.C., 2018.
- 7 19. Doherty, S. T., E. J. Miller, K. W. Axhausen, and T. Gärling. *A Conceptual Model Of The*  
8        *Weekly Household Activity-Travel Scheduling Process*, 2002.
- 9 20. Joh, C.-H., T. A. Arentze, and H. Timmermans. *Identifying Skeletal Information of Activity*  
10        *Patterns by Multidimensional Sequence Alignment. Transportation Research Record:*  
11        *Journal of the Transportation Research Board*, No. 2021, 2007, pp. 81–88.
- 12 21. Saneinejad, S., and M. Roorda. *Application of sequence alignment methods in clustering and*  
13        *analysis of routine weekly activity schedules. Transportation Letters: The International*  
14        *Journal of Transportation Research*, Vol. 1, No. 3, 2009, pp. 197–211,  
15        <http://dx.doi.org/10.3328/TL.2009.01.03.197-211>.
- 16 22. Dianat, L., K. N. Habib, E. J. Miller, and Transportation Research Board. *Modeling Non-*  
17        *Work/School Activity Patterns in a Week-Long Activity-Based Model Using Skeleton*  
18        *Schedule Constraints. TRB 96th Annual Meeting Compendium of Papers*, Washington, D.C.,  
19        2017.
- 20 23. Hunecke, M., S. Haustein, S. Böhler, and S. Grischkat. *Attitude-Based Target Groups to*  
21        *Reduce the Ecological Impact of Daily Mobility Behavior. Environment and Behavior*,  
22        Vol. 42, No. 1, 2010, pp. 3–43, <http://dx.doi.org/10.1177/0013916508319587>.
- 23 24. Hunecke, M., S. Haustein, S. Grischkat, and S. Böhler. *Psychological, sociodemographic,*  
24        *and infrastructural factors as determinants of ecological impact caused by mobility*  
25        *behavior. Journal of Environmental Psychology*, Vol. 27, 2007, pp. 277–292,  
26        <http://dx.doi.org/10.1016/j.jenvp.2007.08.001>.
- 27 25. The World Bank, and Development Research Center of the State Council. *Urban China.*  
28        *Toward Efficient, Inclusive, and Sustainable Urbanization*. The World Bank, Washington,  
29        D.C, 2014, <http://dx.doi.org/10.1596/978-1-4648-0206-5>.
- 30 26. Schreiber, J. B., A. Nora, F. K. Stage, E. A. Barlow, and J. King. *Reporting Structural*  
31        *Equation Modeling and Confirmatory Factor Analysis Results: A Review. The Journal of*  
32        *Educational Research*, Vol. 99, No. 6, 2006, pp. 323–338,  
33        <http://dx.doi.org/10.3200/JOER.99.6.323-338>.
- 34 27. Doove, L. L., S. van Buuren, and E. Dusseldorp. *Recursive partitioning for missing data*  
35        *imputation in the presence of interaction effects. Computational Statistics & Data Analysis*,  
36        Vol. 72, 2014, pp. 92–104, <http://dx.doi.org/10.1016/J.CSDA.2013.10.025>.
- 37 28. Stekhoven, D. J., and P. Bühlmann. *MissForest--non-parametric missing value imputation*  
38        *for mixed-type data. Bioinformatics (Oxford, England)*, Vol. 28, No. 1, 2012, pp. 112–118,  
39        <http://dx.doi.org/10.1093/bioinformatics/btr597>.
- 40 29. AutoNavi Software Co., L. *Traffic Analysis Report of Major Cities in China*, 2018.  
41        <http://report.amap.com/>.
- 42 30. Kline, R. B. *Principles and practice of structural equation modeling*. Guilford Press, New  
43        York, 2011.

- 1 31. Mallig, N., and P. Vortisch. *Measuring Stability of Mode Choice Behavior. Transportation*  
2 *Research Record, No. 2664*, 2017, pp. 1–10, <http://dx.doi.org/10.3141/2664-01>.
- 3 32. Hu, L.-t., and P. M. Bentler. *Cutoff criteria for fit indexes in covariance structure analysis:*  
4 *Conventional criteria versus new alternatives. Structural Equation Modeling: A*  
5 *Multidisciplinary Journal*, Vol. 6, No. 1, 1999, pp. 1–55,  
6 <http://dx.doi.org/10.1080/10705519909540118>.
- 7 33. Hooper, D., J. Coughlan, and M. R. Mullen. *Structural Equation Modelling: Guidelines for*  
8 *Determining Model Fit. Electronic Journal of Business Research Methods (ECRM)*,  
9 Vol. 2008, Volume 6, 2008, pp. 53–60.