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Understanding customers' battery electric vehicle sharing adoption based on hybrid choice model

Fanglei Jin [a], Enjian Yao [a, *], Kun An [b, c, **]

[a] Key Laboratory of Transport Industry of Big Data Application Technologies for Comprehensive Transport, Beijing Jiaotong University, Beijing, China
[b] College of Transportation Engineering, Tongji University, Shanghai, China
[c] Institute of Transport Studies, Department of Civil Engineering, Monash University, VIC, Australia

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ABSTRACT

Carsharing as a sustainable mode faces many difficulties such as low market share and acceptance rate in developing and developed countries. In order to develop effective promotion strategies, this study provides insights on the effects of the key factors, including customers' attitude, level of service, and vehicle restriction policies, on the adoption of battery electric vehicle sharing service. The hybrid choice model framework is incorporated to quantify unobserved attitudinal variables and their effects. In the framework, factor analysis methods are used to construct the factor structure for latent attitudinal variables, a multiple-indicator multiple-cause model is incorporated to capture the relationship between observed variables and latent variables, and a multinomial logit model is used to comprehensively investigate the effects of the key factors on carsharing choice. Results indicate that Beijing permanent residency, demand for private cars, travel pattern, and home-work area have the most significant effects on the attitude towards carsharing. Attitudes such as environmental consciousness, social benefits, satisfaction with transport system, and reliability significantly affect the adoption of battery electric vehicle sharing. Vehicle cruising range and free-floating availability are two crucial factors that hinder the adoption of battery electric vehicle sharing against conventional gasoline vehicle sharing. Results also indicate that the quota scheme on private car plate registration improves the adoption intention of carsharing while restrictions on vehicle use owing to license plates significantly affects the adoption of battery electric vehicle sharing. The findings act as a reference for policy-making, promotion strategy, and operation management of carsharing.

1. Introduction

1.1. Backgrounds

Many metropolises face serious congestion and air pollution problems due to growing car ownership and quick urbanization, especially in Beijing, China, which is the most populated city in China. By the end of 2018, the population and total number of private cars in Beijing reached 21.73 million and 5.94 million, respectively. In 2016, severe congestion was observed for 75 days and moderate congestion in the evening peak hours was observed for 154 days (Beijing Transportation Research Center, 2016). Along with traffic congestion, 168 days were associated with unhealthy air quality based on the Beijing Municipal Environmental Protection Bureau (Beijing Municipal Environmental Protection Bureau, 2016).

Substantial efforts are devoted to addressing these issues, including transportation demand management, public transport priority strategies, and incentives to use sustainable alternative modes instead of driving private vehicles, and parking management programs (Yoon et al., 2019). Carsharing can serve as a sustainable alternative that provides an on-demand car rental service (Kim, 2015). Carsharing is more attractive in individuals' daily trips due to significant advantages in terms of booking convenience, lesser parking hassles, and transferring fixed cost of vehicle purchase into pay-as-you-go. It is also considered that carsharing is beneficial in protecting the environment and reducing private vehicle ownership and vehicle miles traveled especially if electric vehicles are used (Stasko et al., 2013; Martin et al., 2010; Cervero

* Corresponding author.
** Corresponding author. College of Transportation Engineering, Tongji University, Shanghai, China.
E-mail addresses: 15114232@bjtu.edu.cn (F. Jin), enjyao@bjtu.edu.cn (E. Yao), kunan@tongji.edu.cn (K. An).

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et al., 2004). Recently launched carsharing systems typically provide a one-way service with or without stations, namely station-based carsharing and free-floating carsharing (Shaheen et al., 2015), which allow users to return vehicles at any available parking spaces. The costs include membership fee (or deposit) and rental fee charged based on time (i.e., minute, hour, or day) and/or distance traveled.

1.2. Motivations

Despite the aforementioned benefits and years of operation in China, the general public is still not familiar with this new transport mode, thus carsharing is experiencing low market share. Furthermore, a few issues are reported such as long distance to access the vehicle and difficulty in finding available vehicles. Hence, governments and operators are struggling with carsharing development and attempting to propose effective promotion strategies. Theoretically, understanding customers' adoption of carsharing is crucial in predicting demand and making policies to better guide the development of carsharing systems especially in its early stage in the market.

However, relevant studies that target developing countries such as China or India are still rare while most existing studies are based on the developed world such as America, Europe, and Japan (Shaheen et al., 2003; Firnkorn and Müller, 2011; Ohta et al., 2013). China distinguishes itself with high population density, complex culture, and unique policy environment. Additionally, there is a paucity of studies on customers' attitude and adoption intention based on survey data in China. The reason for tailored research of carsharing in China is that Chinese market exhibits three distinguishing features:

First, Chinese individuals weigh vehicles significantly more when compared to developed countries. Vehicles satisfy individuals' daily travel demand and also have symbolic meanings beyond the vehicle itself (Burgess et al., 2013). A survey conducted in 2009 reveals that 46% of the Chinese university students consider that a "private car is a symbol of success", and 42% consider cars as a symbol of modern life (Zhu et al., 2012). Behind these figures, it is the individuals' attitude that affects the choices. Under the effect of self-identity with respect to private cars, an open question remains as to customers' attitudes to carsharing and how well Chinese individuals accept the concept of a shared vehicle is still an open question, especially when carsharing becomes a new choice in urban transport market.

Second, China has adopted a series of unique policies on transport management. For example, Beijing has a license plate lottery system where last-digit license plate vehicles use restrictions on weekdays and odd/even plate vehicles use restrictions on extreme weather days. The regulations on the use of private cars influence the decision-making process with respect to carsharing adoption differently from that in other countries.

Third, a significant proportion of shared vehicles in operation include battery electric vehicles (BEV) due to national promotions with respect to environmental-friendly vehicles. Based on "Beijing electric vehicle promotion and application action plan for 2014–2017", the Beijing government considers BEV sharing as one of the key demonstration projects in the public transport sector, which is considered as an efficient method to educate the public on advantages of BEVs and hopefully aid in the private BEV market penetration. In selecting travel mode, users should consider the BEV features including the state of charge, driving range, and charging opportunity (Egbue and Long, 2012) in the case when BEVs are not unable to complete the trip. Thus, shared BEV and shared conventional gasoline vehicle (CGV) could lead to significant differences in customers' attitude and intention analysis. However, the effects of BEV features are not well examined in the context of BEV sharing.

1.3. Research objectives and contributions

As the distinguishing issues in China market mentioned above, it is essential to develop a compatible modeling method to comprehensively analyze the adoption intention. The objective of the study is to answer these questions:

(1) What are customers' attitudes to BEV sharing in China and how do attitudes affect the BEV sharing adoption?
(2) How do vehicle restriction policies affect BEV sharing adoption?
(3) To consider different features against CGVs, e.g. cruising range and state of charge, what are customers' preferences for BEV in the carsharing system?
(4) How to develop the model that is capable of dealing with all the issues above simultaneously with few biases?

Thus, this study analyzes the effects of the key factors including customers' attitude, level of service, and vehicle restriction policies on the adoption of BEV sharing in the context of China, and further to provide references for policy-making to promote BEV sharing. To make it well-targeted at the research issues, a hybrid choice model is proposed, which combines the advantages of structural equation model and discrete choice model, and is capable of handling latent variables in choice utility. It is aimed to measure the latent variables that reflect customers' attitude to BEV sharing via the factor analysis approach and explore how various observed variables affect customers' attitude via the multiple-indicator multiple-cause (MIMIC) model. Simultaneously, a multinomial logit model is incorporated to investigate how attitude affects adoption intention of BEV sharing using the survey data. Additionally, level of service variables, such as the state of charge of BEV and policy scenario variables, in relation to the three vehicle restriction regulations implemented in Beijing are investigated to analyze their effects on BEV sharing adoption.

Regarding the main contributions of this study, from the perspective of methodology, the theory of planned behavior and the theory of random utility are combined in the form of a hybrid choice model. The concept of attitude from the theory of planned behavior reflecting individuals' psychology is linked with individuals' BEV sharing choice utility. In the modeling, to the best of our knowledge, this study is the first one that presents elaborate information to determine the attitudinal latent variables related to BEV sharing in China, and provides the survey design and reliable factor structures. In the model estimation, in contrast with some studies that estimated the measurement of latent variables and choice model in a separated way (in contrast with Peng et al., 2017), this study succeeds in the integrated estimation of both parts. The attitudinal latent variables are treated as endogenous variables instead of exogenous variables so that some biases can be avoided for a better model accuracy. From the perspective of the explanatory power of the model, detailed information covering personal attributes, vehicle ownership, travel pattern, level of service, policy scenarios, etc. is considered in the model to dig more relationships among variables. Particularly, some variables with Chinese characteristics such as Beijing permanent residency and vehicle restrictions are incorporated to reveal how these policy-related factors affect adoption intention of BEV sharing. Also, not only in private BEV market, this study discusses customers' preferences for BEV features in the carsharing system, which enlarges the understanding of BEV features.

The rest of the study is organized as follows. Section 2 details the literature review on BEV sharing attitude analysis and identifies the research gaps. Section 3 states methods including survey, attitude structure, and hybrid choice model framework. Section 4 presents the attitude statistical analysis, factor structure for latent variables, and hybrid choice model results and discussions with respect to the impact of attitudes, level of service, and restriction policies on BEV sharing adoption. Section 5 summarizes the concluding remarks and proposes policy implications related to BEV sharing promotion.

2. Literature review

Carsharing is extensively examined based on different aspects, namely sociodemographic factors (Luca and Pace, 2015; Prieto et al., 2017; Millard-Ball et al., 2005), mode share analysis (Catalano et al., 2008), station planning and relocation problem (Bruglieri et al., 2014; Huang et al., 2018), and effect of carsharing on other travel modes (Stasko et al., 2013; Martin and Shaheen, 2011; Kim et al., 2015). Among the factors, customers' adoption intention reveals the demand for carsharing, and this is decisive in terms of strategic or operational decisions on carsharing system planning.

Some studies consider users' attitude as a crucial factor in estimating transport mode choice (Temme et al., 2008) or electric vehicle market share (Larson et al., 2014; Liu et al., 2015). With respect to the attitude analysis of BEV sharing, Kim et al. (2017a) indicated that the relationship between the latent attitudes of individuals and intention to use carsharing is not well examined to date. The study designed 11 indicators using 7-point Likert scale, such as "It is my responsibility to take action to be environmentally friendly", "I limit my auto travel to help improve congestion and air quality", "My car shows who and what I am", "I prefer a private mode because I like to be on my own", and "I like driving myself better than others driving me". By investigating the indicators, the study proposed four latent attitudes including Intrinsic preference for driving, Pro-environmental attitudes, Symbolic value of car, and Privacy-seeking. They further tested the effects of the four attitudes on the carsharing utility. The results indicated that the Pro-environment attitude negatively impacts private car and shared-car uses while the Symbolic value of cars negatively impacts shared-car alone. Thus, individuals consider themselves as environmentalists who dislike using cars irrespective of whether they are shared with others or family owned. However, the model only considered gender, age, education, and income in the attitude analysis, and this is not comprehensive. Kim et al. (2017b) measured individuals' attitudes of satisfaction using a 7-point Likert-scale, the questions are such as "what do you think of the travel time of public transport". The respondents are asked to answer "extremely dissatisfied", "very dissatisfied", "dissatisfied", "neutral", "satisfied", "very satisfied", and "extremely satisfied". Kim et al. (2015) asked respondents about "EV sharing reduce concerns such as maintenance", "EV sharing has less environmental concerns", "using EV sharing makes a positive impression on others", etc. Efthymiou (2013, 2016) analyzed travelers' satisfaction degree on their current travel patterns and tested the effect of environmental consciousness on their intention to join in both bike-sharing and car-sharing systems using an Ordered Logit model. In the study, four latent variables were extracted including Safety, Cost, Environment/parking, and Convenience to capture customers' latent attitudes on the new travel mode. However, the authors failed to investigate the effect of level of service variables, such as cost, vehicle feature, and vehicle accessibility, on carsharing adoption. With respect to carsharing attitudes under the China context, Peng et al. (2017) developed a technology acceptance model to investigate the effect of latent variables on transport mode choice via using age, occupation, income, education, and vehicle ownership as observed variables. However, sequential estimation is the method that is used in the study, which implies that the structural equation model and discrete choice model are separately estimated. This leads to inconsistent and biased estimates for the random utility part and imperfection in testing behavioral theories (Walker and Ben-Akiva, 2002). In summary, there is a paucity of studies related to customers' attitudes to BEV sharing. The concerns about carsharing are not comprehensively covered in the existing indicator design, such as safety, reliability, access/egress distance, deposit, and development in the future. Thus it is necessary to outline a better construction of latent variables reflecting attitudes, and emphasize the impact of attitudes and level of service variables on BEV sharing based on hybrid choice model. The simultaneous estimation method should also be implemented as opposed to sequential estimation.

In addition to attitudes, policies can also influence BEV sharing adoption. To control the rapid growth of private car ownership, Beijing first launched a public lottery system in January 2011 to distribute a limited number of new license plates annually. Although the concept of license plate registration control is not new, Beijing is unique in its use of a lottery for this purpose as opposed to an auction system (Yang et al., 2014; Zhang et al., 2018). The lottery is held six times per year, and only qualified applicants can participate in the same. Based on the temporary regulations on the number of passenger cars in Beijing, the quota for CGV in 2018 shrunk from 90,000 to 40,000 although there are 3 million efficient applicants on the list. The low success rate of 0.05% can aid in transferring some demand for private cars to carsharing and especially from those with urgent demand for private vehicles. In addition to the restriction on plate registration, Beijing exhibits implemented administrative regulations to restrict the use of vehicles for approximately 10 years. Based on the last digit of the license plate number, a CGV is not allowed to run within Beijing Fifth Ring Roads for a period from 7:00 to 20:00 for one weekday each week. Additionally, given the frequent occurrence of extreme hazy weather since 2014, the government also implements even- or odd-numbered plate restriction (only 50% of vehicles are allowed on road) when an air pollution Red Alert is in effect. However, BEVs are an exception that are not affected by any of the aforementioned restrictions since the aim of the Beijing government involves promoting BEV adoption via the privileges. Shared BEVs exhibit significant potential as an alternative mode that can provide similar user convenience as private cars while they are not affected by various restrictions. An example is the success of Company Bee started in 2013 in the city of Naples, Italy due to vehicle availability in restricted traffic areas in the city center and in preferential lanes (Ferrero et al., 2015). Hence, it is reasonable to assume that the license plate restriction policy affects customers' attitude and adoption intention for carsharing. However, only a few studies addressed the effect of vehicle restriction policies on intention to adopt carsharing.

3. Method

3.1. Survey

In the first part of the survey, personal and household information of the respondents is collected including gender, age, personal monthly income, education, occupation, Beijing permanent residency, household annual income, living area, and working area. It is noted that living and working areas are divided into 6 rings by the circular expressways. The area with ring number one represents the city center while ring number six represents the location farthest away from the city center. The Beijing permanent residency is also known as Hukou (Chan and Buckingham, 2008) and provides

Table 1
Level specification of considered attributes.

	CGV sharing	BEV sharing
Generic attributes		
Deposit	350 CNY, 699 CNY, 1000 CNY, 1500 CNY	
Trip cost per km	1.0 CNY/km, 1.5 CNY/km, 1.88 CNY/km, 2.3 CNY/km,	
Trip cost per min	0.1 CNY/min, 0.2 CNY/min, 0.28 CNY/min, 0.4 CNY/min,	
Number of vehicles	1000, 2000, 3000, 4000, 5000	
Specific attributes		
Cruising range	500 km	100 km, 300 km, 500 km
Free-floating	Available, Not available	Not available

Note: Based on vehicles operated by TOGO which is a CGV sharing operator, the deposit is 1500 CNY, 1.88 CNY/km, and 0.28 CNY/km for trip cost and allowing users to return vehicles outside the station area (free-floating). Conversely, for BEV sharing operated by GOFUN, the deposit is 699 CNY, 1.5 CNY/km, and 0.1 CNY/km. Their vehicle cruising range in operation concentrates at 100 km; few of them are 300 km vehicles. Users must return vehicles to the stations.

information if the household is registered in Beijing. An individual who does not hold a Beijing permanent residency is not qualified to purchase vehicles registered in Beijing, and vehicles not registered in Beijing include many additional limitations on the road. For example, they are not allowed to use expressways within the 5th ring road in peak hours (7 a.m.—9 am and 5 p.m.—8 pm).

The second part involves the status of vehicle ownership including the number and type of private cars. The information on driving license status, skilled driving level, and stated vehicle purchase demand are collected. In the question of stated vehicle purchase demand, 3 options: “Not at all”, “Not now, but I would like to join the lottery system for future needs”, and “Yes, I want to have a vehicle registered in Beijing” are designed, which describe the increasing urgency level of needs for private cars.

The third part is related to the travel pattern. Respondents are asked about their daily travel distance and mode choice on both weekdays and weekends.

The fourth part investigates individuals’ revealed attitude to BEV sharing. Referring to the form of designing the indicators stated in Section 2 literature review, 37 statements are designed using a 5-point Likert scale. It is noted that the statements are conceptualized based on existing literature, media comments, and government reports with respect to pro-environment, satisfaction level with the current transport system, and concerns on shared vehicle availability, access distance, reliability, safety, etc. The aim is to cover as many aspects as possible that can affect an individual’s attitudes to BEV sharing. Thus, a comprehensive analysis is developed to determine the latent variables behind the responses.

The fifth part investigates the adoption intention of carsharing. The choice cases incorporate both BEV sharing and CGV sharing in the choice set to investigate the preference difference. After weighing various level of service variable combinations and policy factors, respondents are asked to sect a statement among “I prefer to become a BEV sharing member,” “I prefer to become a CGV sharing member,” and “I don’t feel like using any of them.” With respect to level of service variables, deposit (or regarded as membership fee), trip cost per km, trip cost per min, cruising range, free-floating operation, and number of vehicles in operation area are considered. In order to gain insights into the trade-offs among level of service variables, a fractional factorial design is adopted to cover as much level of service combinations as possible. Table 1 specifies the values used for generic attributes and mode specific attributes in carsharing. Given that most BEVs have less cruising range comparing to CGVs, the cruising range of CGVs is fixed at 500 km, which is capable of running in a free-floating mode, while BEVs exhibit different cruising ranges that run in a station-based mode. Two rows are added to Table 1 to distinguish those differences.

To investigate the effects of vehicle restriction regulations on respondents’ adoption intention, hypothetical scenarios are also designed. Four policy scenarios are constructed as follows: no restriction (base), vehicle registration restriction, vehicle use restriction in normal days, and vehicle use restriction under extreme weather. The last two vehicle use restrictions are applied to CGV only. One policy scenario is randomly allocated to each respondent to avoid correlation between adjacent scenarios.

The stated preference survey was conducted in July—August 2018 in the form of a paper questionnaire. Simultaneously, in order to obtain sufficient samples in the factor analysis, an online survey was conducted only for the fourth part. In the end, 536 questionnaires were collected, and 513 valid samples are used after the data cleaning, which are used in the hybrid choice model; and 512 valid samples from the internet are obtained, which are used in the Explanatory Factor Analysis.

3.2. Basic theories

The theory of planned behavior was proposed by Ajzen in 1985 based on the theory of reasoned action. It provides a framework about how behavior is made. In the theory, behavior is influenced directly by intention and behavior control, and intention is further influenced by individuals’ attitude and subjective norm. Attitude indicates individuals’ positive or negative evaluation of performing the behavior, or reflects what kind of people they are in nature. Subjective norm is the perception of social pressure put on individuals to or not to perform the behavior, reflecting the expectation from the society. Behavior control indicates that, behavior is not only to consider the intention to behavior, but also to consider the degree of control over behavior. Thus, attitude is considered as an important determinant of performing intention, and intention directly affects actual choice behavior. The intention to try is stronger when an individual ’s attitude towards attempting to perform a behavior is more favorable (Ajzen, 1985).

The theory of random utility stems from psychology and consumer theory of micro-economics, which is the basic theory of discrete choice modeling. It uses the principle of utility maximization, which assumes that the decision-maker’s preference for an alternative is captured by a value, called utility, and the decision-maker tends to choose the alternative that makes them obtain maximum utility (Hall, 2012). To reflect the complexity of human behavior as well as different information situations, the decision is treated as a probabilistic dimension. The utility therefore consists of two parts, the deterministic part which can be calculated by attributes, and the random term which captures the uncertainty. When the random term yields to the Normal distribution, then the model is developed into Probit model; if the random term yields to the Gambel distribution, then the model is Logit model (Ben-Akiva et al., 1985).

However, these two theories are usually solely developed in behavioral analysis. In this study, to investigate the effect of attitudinal variable on utility, the two theories are combined together, thus, a hybrid choice model is developed. Regarding the model specification and model estimation, please see Section 3.4 and Fig. 1 in Section 4.3. Therefore, the theories adopted in the study cover social psychology and consumer economics, and are further adapted in the analysis regarding sustainable productions in transport sector.

3.3. Attitudinal constructs

To model how attitude affects the adoption, it is not appropriate to directly treat all attitude indicators (investigated in the fourth part of the survey) as explanatory variables, because there may

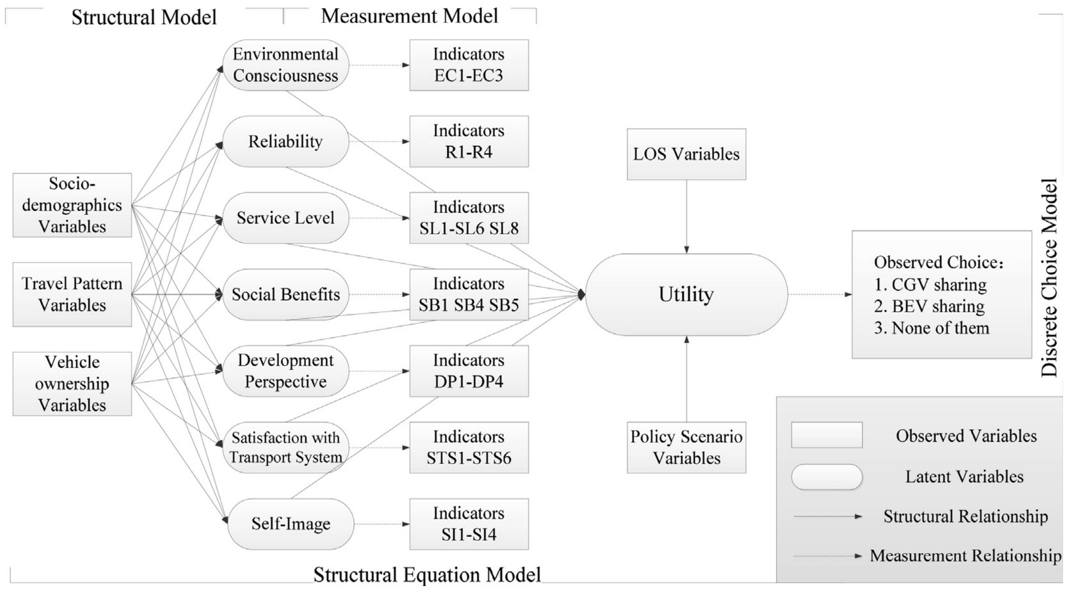

Fig. 1. Hybrid choice model framework.

exist correlations among the indicators. Among correlated indicators, it is assumed to have a common factor that is believed to be the main cause beyond these indicators. By the measurement of these factors, the dimensions of indicators can be reduced as well as the explanatory ability in the choice model can be improved.

Prior to developing the hybrid choice model, unobservable latent variables (which are attitude variables in the study) must be defined properly. The main challenge is that there is no existing factorial structure that connects the observed attitudinal responses to the underlying unobservable latent variables. Thus, Exploratory factor analysis is applied to determine the factorial structure of latent variables (Comrey and Lee, 1992). Exploratory factor analysis extracts unobserved factors from indicators without specifying the number of factors or fixing the assignment of the factors to the indicators. Conversely, factors are defined after they are extracted. Subsequently, Confirmatory factor analysis is used to examine the performance of the generated factorial structure. The factorial structure is modified until a satisfying performance is obtained.

3.4. Hybrid choice model specification

Hybrid choice models are largely applied to investigate the effects of attitudes and perceptions via incorporating latent variables. The multiple-indicator multiple-cause (MIMIC) model is a member of the Structural Equation model family and is applied to understand customers' attitudes to BEV sharing. To model the adoption intention, a multinomial logit model is incorporated. The relationship between latent variables and socio-demographic, travel pattern variables, and vehicle ownership variables are specified by the structural equations. The relationship between latent variables and indicators is specified by measurement equations; and the relationship between utility and level of service variables, latent variables, and policy scenario variables is identified by utility functions. The parts are estimated simultaneously to capture the effects of latent variables and other explanatory variables on choice preferences.

3.4.1. MIMIC model

The MIMIC models are typically employed to assess the effects of unobservable latent variables on a set of indicators when causes of the latent variables are observed. For simplification purposes, a linear form is adopted to describe the path of the indicators onto the latent variables, thereby leading to the following measurement equation:

$$y_n = \Lambda \eta_n + \varepsilon_n \tag{1}$$

where η_n denotes the vector of seven latent variables of individual n, y_n denotes the vector of indicators obtained from the attitudinal survey, Λ denotes the matrix of factor loadings, and ε_n denotes the vector of measurement error terms which is assumed to be independent and identically distributed in the form of multivariate normal.

The structural model for the latent variables is given in Equation (2):

$$\eta_n = \Gamma x_n + \zeta_n \tag{2}$$

where x_n denotes the observed variables including socio-demographic variables, vehicle ownership variables, and travel pattern variables, Γ denotes the unknown regression coefficients to be estimated, and ζ_n denotes the vector of measurement error terms that is assumed as independent and identically distributed multivariate normal.

3.4.2. Choice model

With respect to the choice part of the hybrid choice model, the multinomial logit model is adopted. The utility function is given below:

$$U_{ni} = V(x_{ni}, \eta_{ni}) + \nu_{ni} \tag{3}$$

where U_{ni} denotes the utility of the alternative i perceived by individual n, x_{ni} and η_{ni} denote the observed variables and latent variables of alternative i, ν_{ni} denotes the stochastic utility component. Thus, the effects of both observed variables and latent variables are simultaneously considered in the deterministic part of the utility function V_{ni}. A linear function that is typically used in choice modeling is specified as follows:

$$V_{ni} = \beta_x x_{ni} + \beta_\eta \eta_{ni} + C \quad (4)$$

where β_x denote the parameters of observed variables, β_η denote the parameters of latent variables, and C denotes the constant to be estimated. Thus, the probability that individual n chooses alternative i is expressed as follows:

$$P_{ni} = \frac{\exp(V_{ni})}{\sum_j \exp(V_{nj})} \quad (5)$$

In the study, there are three alternatives including "become a member of CGV sharing", "become a member of BEV sharing", and "none of them." The reason not to consider "become members of both services" is because the deposit corresponds to considerably significant sunk cost, and thus respondents are assumed not to consider both at the same time. With respect to level of service variables, deposit (Thousand CNY), trip cost per km (CNY), and trip cost per min (CNY) are considered to investigate the impact of monetary factors. Cruising range (Hundred km) of BEVs is incorporated to test users' perception of different vehicle types against CGVs, which is fixed to 500 km. Whether CGV sharing can be used in a free-floating way is also considered as a 0−1 variable to measure users' preference relative to BEV sharing which is assumed only to be station-based. The number of vehicles is considered as an indicator to reveal the vehicle availability and accessibility. If the number of vehicles is high, then it is assumed that vehicles are well-distributed and that users would have more opportunities to access shared vehicles. With respect to policy scenario variables, three 0−1 variables are considered, namely, vehicle registration restriction, vehicle use restriction on weekdays, and vehicle use restriction under extreme weather. It is expected to observed that the restriction policies have positive effects on BEV sharing adoption.

The MIMIC model and the discrete choice model are estimated simultaneously via Mplus. More than 3 latent variables enter the utility function, and thus computational complexity rises exponentially (Temme et al., 2008). To solve the problem, Monte Carlo integration is adopted instead of a numerical integration such as Gaussian.

4. Results

4.1. Attitudinal indicator statistical analysis

Table 2 elaborates the indicators and their corresponding descriptions in the customers' attitude survey and their statistics. The names of indicators are designed and categorized based on the meanings of corresponding statements including Awareness (A1-A2), Environmental Consciousness (EC1-EC4), Reliability (R1-R4), Service Level (SL1-SL8), Social Benefits (SB1-SB5), Development Perspective (DP1-DP4), Satisfaction with Transport System (STS1-STS6), and Self-Image (SI1−SI4).

The low mean value of A1 and A2 demonstrates that the respondents do not possess significant knowledge on BEV sharing service yet, and only 39.7% of them exhibit interest in BEV sharing. With respect to the attitude to environment-related statements, the respondents in general are positive about the pro-environment feature of BEV sharing. The low scores of R1−R4 reveal that individuals exhibit concerns about the BEV range, state of charge, reliability, and safety especially comparing with CGV sharing. Furthermore, the lowest mean scores occur in SL4 and SL6. The respondents are most concerned about "I am afraid to have no available vehicles at the nearest station" and "I feel inconvenient to return shared BEV to stations near the destination", thereby revealing that the main barrier to BEV sharing is vehicle availability at both origins and destinations. Conversely, the deposit is well accepted. Based on the scores of SB1−SB5, respondents agree with the potential benefits of BEV sharing in urban mobility enhancement. However, they exhibit a negative attitude on the congestion and parking problem relief based on the low average scores in SB2 and SB3. Although many analytical studies suggested congestion mitigation via shared cars (Martin et al., 2010; Cervero and Tasi, 2004), the public is doubtful on the two benefits. This can be because the newly launched service in Beijing is not well known to users or is not well organized yet. With respect to the satisfaction level of the current transport system, respondents exhibit a high level of satisfaction. However, the respondents consider privacy is the worst in all aspects. That is, BEV sharing exhibits the potential of providing a more private service in the public transport system. It is observed that low scores in the statements of SI1−SI4 with respect to the respondents view of BEV sharing. Generally, they consider BEV sharing as not a cool or fashion thing, probably because using it reveals that one does not own a vehicle.

4.2. Factor analysis

Based on the responses of the 5-point Likert-scale survey, an Exploratory factor analysis test is performed to identify the latent variables that most significantly affect dependent indicators and to match the indicators with each identified latent variable. Maximum likelihood estimation is used as the extraction method and Varimax with Kaiser normalization is adopted as the rotation method. The sample collected from the online survey with a size of 512 is used in the analysis. Please recall the meanings of the indicators in Table 2.

Table 3 shows the exploratory factor analysis results. A 5-factor structure is first obtained. The values in a row represent the factor loadings of each indicator on the 5 latent variables, which imply the degree of relevance of the indicator to the five factors. The highest values in each row are retained to represent the most influential indicators while values below 0.4 are omitted. Based on the results, 6 indicators including A1, A2, SB2, SB3, SL7, and EC4 are removed due to their low factor loadings on every latent variable. The remaining 31 indicators are used in the test. The value of Kaiser-Meyer-Olkin (which describes the appropriateness of data in factor analysis) is 0.885 for the study, thereby indicating that the 31 indicators are suitable for the factor analysis. The values of Cronbach α are calculated to test the reliability wherein the identified group of indicators should match each latent variable. All the values of α corresponding to the five factors exceed 0.7, representing acceptable reliability.

In order to test whether the obtained 5-factor structure is rational, a Confirmatory factor analysis test is conducted using the sample collected via a paper questionnaire with the size of 513 to verify structure validation using Mplus software.

The Modification Indices in Table 4 reflect the decrease in model chi-square statistic with one degree of freedom, thereby indicating whether a particular parameter is freed from a constraint in the preceding model (Wang and Wang, 2012). Based on the table, the Modification Indices value between EC1 and EC2 correspond to an extremely high value of 164.594, which is potentially because the indicators are affected by Factor 1 and also other latent variables. Most of the indicators with high Modification Indices values are related to Factor 1. Therefore, it is split into more factors to obtain better model performance via Confirmatory factor analysis trails (Browne, 2001).

A 6-factor model and a 7-factor model are tested in which only EC1-EC3 are separated as the 6th factor, and EC1−EC3 and DP1−DP4 are separated as the 6th and 7th factors, respectively. Table 5 presents the 5 metrics of model fitness, namely Chi-Square,

Table 2
Indicator Description and Statistic (the 4th part of the survey).

Initial category	Indicator abbreviation	Description	Mean	Standard error	Percentage (%)				
					1	2	3	4	5
Awareness	A1	I know clearly about BEV sharing service.	2.72	1.237	20.5	22.2	33.3	13.1	10.9
	A2	I am interested in BEV sharing service.	3.15	1.241	10.7	21.1	28.5	22.4	17.3
Environmental Consciousness	EC1	BEV sharing will benefit energy conservation and emission reduction.	3.82	1.276	7.6	9.6	17.3	23.8	41.7
	EC2	BEV is pro-environmental.	3.81	1.252	7.0	10.3	16.2	27.3	39.2
	EC3	I care about the environment problem.	3.98	1.149	5.3	6.4	16.0	29.6	42.7
	EC4	Transport sector is a big source of air pollution.	3.44	1.281	9.6	14.2	25.3	24.2	26.7
Reliability	R1	The State of Charge is accurate in shared BEV.	3.03	1.085	8.6	20.9	40.4	19.5	10.7
	R2	The cruising range is enough for daily trips.	2.99	1.107	9.7	22.0	37.4	20.7	10.1
	R3	BEV sharing is more reliable than conventional car sharing.	2.71	1.167	17.2	26.3	33.1	14.8	8.6
	R4	It is safe to drive shared BEVs.	3.19	1.031	5.7	17.5	40.0	25.9	10.9
Service Level	SL1	It will be easy to deal with traffic accidents if happened when using BEV sharing.	2.47	1.181	25.1	27.3	29.6	10.9	7.0
	SL2	The distance between stations and my origin or destination is acceptable.	2.54	1.157	23.8	23.4	32.7	14.8	5.3
	SL3	The BEV sharing deposit is affordable to me.	2.79	1.161	17.9	19.1	36.8	18.7	7.4
	SL4	There will always be available vehicles at the nearest station.	2.14	1.110	33.5	36.5	17.3	8.0	4.7
	SL5	The internal environment of shared BEVs is tidy.	2.29	1.163	30.0	32.9	21.1	10.3	5.7
	SL6	It is convenient to return shared BEVs to stations near the destination.	2.17	1.098	32.0	35.9	19.3	8.8	4.1
	SL7	Vehicles in operation are beautifully designed.	2.82	1.173	16.8	19.5	37.8	16.6	9.4
	SL8	My deposit is safe with the operator and I can get it back anytime.	2.58	1.190	21.8	28.3	27.3	15.6	7.0
Social Benefits	SB1	BEV sharing enriches urban transport supply.	3.90	1.144	5.5	7.2	16.6	33.7	37.0
	SB2	BEV sharing will relieve the congestion problem.	2.95	1.304	16.8	22.4	25.3	20.5	15.0
	SB3	BEV sharing will relieve the parking problem.	2.96	1.264	16.0	20.5	28.1	22.2	13.3
	SB4	BEV sharing enhances the convenience of daily trips.	3.66	1.058	3.9	9.2	27.9	35.3	23.8
	SB5	BEV sharing will provide more mobility.	3.61	1.046	4.3	9.2	28.8	37.0	20.7
Development Perspective	DP1	The government gives strong support to BEV sharing.	3.58	1.165	5.1	13.6	26.1	28.5	26.7
	DP2	BEV sharing is of significant significance to the society.	3.67	1.145	5.5	9.9	25.0	31.6	28.1
	DP3	The future development of BEV sharing is optimistic.	3.57	1.157	6.0	10.7	29.4	28.1	25.7
	DP4	BEV sharing is the future direction of urban mobility.	3.50	1.129	5.8	11.7	30.6	30.0	21.8
Satisfaction with Transport System	STS1	I am satisfied with the convenience of current transport modes.	3.68	1.052	4.3	8.0	26.3	37.8	23.6
	STS2	I am satisfied with the comfort level of current transport modes.	3.36	1.120	6.2	15.4	31.8	29.6	17.0
	STS3	I am satisfied with the timeliness of current transport modes.	3.50	1.101	5.1	12.9	28.7	33.5	19.9
	STS4	I am satisfied with the fee for current transport modes.	3.65	1.020	2.7	9.7	29.8	35.1	22.6
	STS5	I am satisfied with the privacy of current transport modes.	3.22	1.173	7.6	20.1	32.2	23.0	17.2
	STS6	I am satisfied with the safety of current transport modes.	3.64	1.088	3.7	12.3	24.2	35.7	24.2
Self-Image	SI1	Using BEV sharing reveals a better personal image.	2.90	1.114	11.1	23.6	39.6	15.4	10.3
	SI2	My friends who use BEV sharing are cool.	2.76	1.131	16.4	21.4	39.4	15.0	7.8
	SI3	Individuals who use BEV sharing are fashionable.	2.78	1.096	14.4	23.4	38.0	17.7	6.4
	SI4	Individuals using BEV sharing have better personal images than individuals using private vehicles.	2.27	1.165	33.3	25.3	27.7	8.2	5.5

Note: Score 1–5 represent “Strongly disagree”, “Disagree”, “Neutral”, “Agree”, and “Strongly agree” respectively.

Degree of Freedom (DF), Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Error Residual (SRMR). Among them, CFI is the most common index to measure the model fitness irrespective of the sample size and it exhibits a good performance and especially in modeling a small sample (Fan et al., 1999). Only the 7-factor structure passes the required criteria.

Therefore, the 7-factor structure is adopted, thereby that revealing customers' attitudes to BEV sharing are identified as Environmental Consciousness, Development Perspective, Social Benefits, Satisfaction with Transport System, Self-Image, Service Level, and Reliability. Environmental Consciousness represents the customers' perception of the environmental protection feature of BEV sharing or one's self-cognition about pro-environment. Development Perspective measures customers' opinion on the future development of BEV sharing as affected by government policies. Social Benefits captures the potential benefits of BEV sharing to the urban transport system such as mobility enhancement. Satisfaction with Transport System represents the satisfaction of the current transport system. Self-Image measures how an individual evaluate themselves or his/her friends who use the transport mode. Service Level is related to the walking accessibility of shared BEVs, vehicle availability, and deposit affordability. Reliability indicates BEV sharing reliability relative to safety, breakdown, and charging or range problem.

4.3. Model results

Fig. 1 presents the framework of hybrid choice model in the study. Dashed lines represent the measurement model shown in Equation (1) where the latent variables are measured by the indicators obtained from the survey and a matrix of factor loading calculated by the confirmatory factor analysis method. Solid lines represent the structure model shown in Equation (2), which indicates the regression relationship between socio-demographic variables, travel pattern variables, vehicle ownership variables, and latent variables. Following the factor analysis, seven latent variables extracted in Section 4.2 are involved.

The results in relation to the MIMIC model and the choice model are presented below. The sample size is 513. The initial log likelihood is −25694.108. The final log likelihood is −21667.210, Akaike Information Criteria is 43690.419, and Sample-Size Adjusted Bayesian Information Criteria is 43880.187.

4.3.1. MIMIC model

Table 6 shows the estimated coefficients of the MIMIC model that reflect the relationship between the observed variables and the 7 latent variables. With respect to the impact analysis, only the structural model part in the MIMIC model is provided to examine the impact of the socio-demographic, travel pattern variables, and vehicle ownership variables on attitudinal variables. The t-values

Table 3
Exploratory factor analysis results.

	Factor Index				
Indicator	1	2	3	4	5
DP2	.859				
DP3	.842				
DP1	.727				
SB1	.711				
DP4	.702				
SB4	.690				
SB5	.670				
EC1	.630				
EC2	.577				
EC3	.519				
STS1		.797			
STS2		.775			
STS3		.754			
STS5		.620			
STS4		.562			
STS6		.516			
SI2			.887		
SI3			.838		
SI4			.664		
SI1			.634		
SL4				.686	
SL6				.646	
SL5				.600	
SL3				.497	
SL2				.456	
SL8				.429	
SL1				.406	
R2					.688
R3					.672
R1					.665
R4					.461
Cronbach α	0.916	0.759	0.764	0.857	0.875

for most of the observed variables are over 1.648, thereby indicating that the quantified estimates are statistically significant at a confidence level of 90%.

In the column of Environmental Consciousness, the coefficient of Number of BEVs (0.314) is positive. Individuals who own BEVs should exhibits a better knowledge of BEV, thereby resulting in a positive attitude to Environment Consciousness. The coefficient of Nonlocal (0.302) is positive, thereby indicating that individuals without Beijing permanent residency are more positive with respect to the pro-environment feature of BEV sharing and are more likely to use it. Individuals who traveled considerably on weekdays exhibit a negative attitude to Environment Consciousness (−0.080). This is potentially because the commuting trips on weekdays make individuals care more about travel time and reliability as opposed to the environment. With respect to Annual Household Income, individuals whose annual household income is below 300 k exhibit a stronger pro-environmental attitude. It is interesting to note that the coefficient of BEV sharing experience is negative (−0.320), thereby indicating that individuals with BEV sharing experience doubt the environmental protection feature of BEV sharing, which is counter-intuitive. This probably reveals that the vehicles in operation now in Beijing fail to convince the users of

Table 4
Part of the Modification Indices information for the 5-factor model.

Indicators	Modification Indices value	Indicators	Modification Indices value
EC1 and EC2	164.594	DP2 and EC1	10.872
EC1 and EC3	27.521	DP2 and EC2	11.093
EC2 and EC3	58.444	DP2 and EC3	19.848
SB4 and EC1	11.992	DP3 and EC1	30.311
SB4 and EC2	13.485	DP3 and EC2	33.526
SB4 and SB1	14.761	DP3 and DP2	55.366
SB4 and SB5	27.841	DP4 and DP3	19.068

Table 5
Test result comparison among Confirmatory factor analysis models.

	Chi-Square	DF	CFI	RMSEA	SRMR	Factor Specification
5-factor	1673.009	424	0.839	0.076	0.078	Base
6-factor	1373.671	416	0.877	0.067	0.073	EC1-EC3 are separated as a new factor
7-factor	1174.144	409	0.902	0.060	0.071	EC1-EC3 and DP1-DP4 are separated as 2 new factors
Acceptable level	Chi-Square/DF < 3		>0.9	<0.06	<0.08	

Table 6
Estimations of the MIMIC model part (t-values in parentheses).

Observed Variables	Environmental Consciousness	Reliability	Service Level	Social Benefits	Development Perspective	Satisfaction with Transport System	Self-Image
Gender							
Male					−0.143 (−1.855)		
Age							
26−35					−0.155 (−1.880)		
Income (CNY)							
4.5−6.0 k				0.277 (2.417)			
6.0−8.0 k						−0.220 (−2.370)	
10.0−15.0 k				0.274 (2.301)			−0.148 (−1.580)
>15.0 k			−0.147 (−2.173)				
Occupation							
Business & Services					−0.348 (−2.725)		
Students				0.401 (3.462)			
Beijing Permanent Residency							
Nonlocal	0.302 (2.291)				0.184 (2.023)		
Annual Household Income (CNY)							
<100k	0.260 (1.737)						
200−300 k	0.333 (2.415)	0.229 (2.543)					
300−500 k		0.251 (2.486)	0.132 (1.970)				0.178 (2.190)
500−700 k			0.221 (2.244)			−0.288 (−2.270)	
Trip Distance_weekday							
>40 km				−0.231 (−1.837)			
Trip Distance_weekend							
*10−*20 km							−0.120 (−1.593)
*20−*40 km		0.185 (1.823)	0.148 (2.178)			−0.148 (−1.529)	
>60 km							−0.276 (−2.554)
Main Mode_weekday							
Private vehicle		0.180 (1.819)	0.121 (1.577)	−0.217 (−1.684)			
Bike			−0.117 (−1.777)				−0.339 (−2.692)
Main Mode_weekend							
Private vehicle	0.354 (2.566)		−0.247 (−3.723)	0.340 (2.410)	0.297 (3.398)	0.428 (5.071)	
Travel Frequency weekday	−0.080 (−2.196)						
Travel Frequency weekend				−0.067 (−2.029)			
Living Area							−0.074 (−2.540)
Working Area							0.095 (3.115)
Vehicle Ownership				0.208 (1.529)			
Driving License						−0.212 (−1.746)	
Skilled Driving						0.317 (3.671)	
Number of BEVs	0.314 (1.971)	0.312 (2.280)	−0.111 (−1.422)		0.221 (1.758)		
Number of CGV Applicants		−0.155 (−3.364)			−0.168 (−2.837)		
Number of BEV Applicants				0.237 (2.607)	0.335 (3.618)		
Vehicle Purchase Demand					−0.123 (−1.709)	−0.139 (−1.713)	−0.174 (−3.732)
CGV sharing experience			0.121 (1.773)				0.150 (1.431)
BEV sharing experience	−0.320 (−1.653)				0.134 (1.098)		

Note: When DF is more than 1000, the absolute critical value for *t*-test is 1.646 (at 10% confidence level), 1.962 (at 5% confidence level).

its pro-environment feature.

With respect to Reliability in the second column, the coefficient of Number of BEVs (0.312) is positive, thereby indicating that individuals with private BEV exhibit more confidence in Reliability. The coefficient of CGV Applicants (−0.155) is negative, thereby indicating that individuals who have urgent demand for CGV tend to show distrust on the reliability of BEV sharing. Individuals with Annual Household Income in the range of 200−500 k exhibit positive attitude to BEV sharing Reliability when compared to low or high Annual Household Income. Individuals who typically travel 20−40 km on the weekend are more positive with respect to BEV sharing Reliability (0.185). It indicates that BEV is potentially more attractive to individuals who travel 20−40 km on weekend. The results also indicate that individuals who typically use private vehicles on weekday trust the reliability of BEV sharing when compared to individuals using other transport modes. Intuitively, individuals typically using cars are not willing to use BEV sharing and exhibit a negative attitude to Reliability when compared to using their own vehicles. A potential explanation is that private car users are used to driving cars as opposed to using other public transport modes. Hence, they exhibit a more optimistic attitude to BEV sharing on Reliability. Moreover, they can also consider BEV sharing as an alternative to their own vehicle under the vehicle plate restrictions in Beijing, which potentially results in an open attitude to BEV sharing Reliability.

The third column is related to the latent variable of Service level. A negative effect of Number of BEVs (−0.111) on Service level is found. This can cause individuals to be sensitive to the Service Level such as inconvenience when compared to owning a BEV. Individuals with an income exceeding 15.0 k CNY exhibit the most negative attitude towards the side effects of BEV sharing, and this potentially because they can afford other transport modes that are more comfortable and convenient. For transport mode typically used on weekdays, individuals who typically use private vehicle potentially exhibit a positive attitude (0.121) while individuals who typically use bike exhibit a negative attitude towards Service Level of BEV sharing (−0.117). Individuals exhibit a negative attitude towards BEV sharing if they typically use private vehicles on weekends (−0.247). This is due to the different travel purpose on weekdays and weekends. On weekdays, the trip purpose typically corresponds to commuting where individuals care more about travel time while on weekends typically corresponds to a leisure trip where individuals care more about comfort. Therefore, it is rational that individuals feel more frustrated to use BEV sharing

Table 7
Results of the multinomial logit model.

Variables	Estimates	t value	Marginal rate of substitution
Common level of service variables			
Deposit	−1.781	−5.514	1.000
Trip cost per km	−2.934	−6.653	1.647
Trip cost per min	−2.616	−1.746	1.469
Cruising range	0.500	2.935	−0.281
Free-floating	1.771	5.865	−0.994
Number of vehicles	1.845	6.589	−1.036
Variables on BEV sharing			
Intercept	4.461	4.285	
Environment Consciousness	0.298	1.704	
Reliability	0.774	3.009	
Service level	0.399	1.020	
Social Benefit	0.607	1.713	
Development Perspective	0.109	0.377	
Satisfaction of Transport System	−0.784	−3.284	
Self-Image	0.249	1.169	
Vehicle use restriction on weekdays	0.805	2.572	
Vehicle use restriction under extreme weather	0.778	2.301	
Vehicle registration restriction	0.516	1.234	
Variables on CGV sharing			
Intercept	4.741	4.141	
Satisfaction of Transport System	−0.238	−1.168	
Vehicle use restriction on weekdays	−0.608	−1.942	
Vehicle use restriction under extreme weather	−1.095	−2.849	
Vehicle registration restriction	0.657	2.024	

due to access distance or other inconvenient processes on weekends. Individuals using bike are negative about carsharing, and this is potentially because free-floating bike share causes much trouble in the city and results in the distrust in BEV sharing. The positive coefficient of CGVSE (0.121) indicates that individuals with CGV sharing experience are likely to accept the shortcomings of BEV sharing. It is noted that the coefficient of BEV sharing experience is not statically significant. It is not clear as to whether the attitude changes with the BEV sharing experience.

With respect to Social Benefit in the fourth column, individuals owning vehicles unexpectedly agree with more of BEV sharing Social Benefit (0.208). Individuals who use private vehicles frequently on weekdays exhibit a negative attitude to Social Benefit (−0.217) albeit a stronger positive attitude on weekends (0.340). However, individuals who travel more than 40 km on weekday exhibit doubts about its Social Benefit.

In the fifth column for Development Perspective, males aged 26 to 35, engaged in Business/Services or Enterprises/Institutions and not locally registered exhibit significantly correlation with the attitude to Development Perspective. Men are more pessimistic than women (−0.143), young individuals aging from 26 to 35 show negative attitudes when compared with other ages (−0.155), and employees of enterprises and institutions exhibit a negative attitude to Development Perspective (−0.348). Furthermore, individuals without Beijing permanent residency exhibit an optimistic attitude (0.184) to the future of BEV sharing, and this potentially because they are not eligible to purchase private cars registered in Beijing. A positive coefficient of Number of BEVs (0.221) is observed, thereby indicating that individuals exhibit an optimistic attitude to BEV sharing future development. It is unexpected to observe that individuals who exhibit a urgent demand for vehicle tend to exhibit negative attitude to BEV sharing future development (−0.123). This is potentially because individuals who want a car urgently mostly prefer private vehicles and do not exhibit interest in shared BEVs. Conversely, individuals without the worry tend to be more optimistic about BEV sharing in the future. With respect to BEV sharing experience (0.134), the same reason applies as to why individuals with BEV sharing experience are more inclined to believe in the future development of BEV sharing. Finally, individuals typically drive on weekends appear to be more optimistic about BEV sharing.

In the sixth column for Satisfaction of Transport System, individuals owning driving licenses are unsatisfied with the current situation (−0.212). People who are capable of skilled driving is likely to feel more satisfaction with the current transport situation (0.317). It is easy to understand that individuals with urgent vehicle purchase demand tend to show a negative attitude to Satisfaction of Transport System (−0.139). Individuals who typically travel a long distance of 20−40 km on weekends are not satisfied with the current transport system due to uncomfortable long trips. However, individuals who typically travel by car on weekends are happy with the current system (0.428).

The last column is related to Self-Image. In the model, the coefficient of the Living Area (−0.074) and Working Area (0.095) are significant. When an individual works far from home, the effect of home-work location on Self-Image increases significantly, either positively or negatively. For example, if an individual lives in the 6th ring area and works in the 2nd ring area, a private vehicle is considerably much necessary to fulfill his/her daily travel demand. The individuals would deem BEV sharing as “not cool.” Furthermore, individuals with urgent vehicle purchase demand exhibit a negative attitude on Self-Image of BEV sharing (−0.174).

4.3.2. Choice model

Table 7 shows the estimated parameters for the choice model part. The t values are used to test the statistical significance of variables.

Among all 7 latent variables in the utility function, Satisfaction of Transport System affects users' adoption intention choice most with a coefficient of −0.784 in BEV sharing and −0.238 in CGV sharing. Its negative sign indicates that individuals who are satisfied with the current transport system are unlikely to become members of the carsharing service. By comparing the two parameters, the negative effect of Satisfaction of Transport System is more sensitive to BEV sharing utility than CGV sharing utility. Thus, individuals exhibit better acceptance of CGV sharing. When individuals are satisfied with the current transport system, they prefer CGV sharing as a supplementary mode than BEV sharing. The Reliability (0.774) and Social Benefit (0.607) rank as the second and third most important factors. They both exhibit a positive impact on the choice of BEV sharing membership. The positive value for the Reliability parameter shows that individuals who are confident about the range or safety of BEV sharing tend to perceive higher utility for BEV sharing. Furthermore, if individuals exhibit faith in the positive BEV sharing social benefit, they tend to become members. Environment Consciousness exhibits a positive effect on the utility, thereby indicating that individuals who care more about the environment and consider BEV sharing as pro-environment are inclined to become members. Finally, attitudes to Service level, Self-Image, and Development Perspective positively affect adoption. However, they do not satisfy statistical significance.

With respect to the level of service variables, all the parameters exhibit the expected signs. The deposit and trip costs (per km and min) reveal negative effects while cruising range, free-floating availability, and the number of vehicles exhibit positive effects on BEV sharing adoption. To perform an intuitional comparison, the Marginal rates of substitution are calculated to analyze the trade-offs between different variables. Specifically, the deposit is set as the base, and the other values indicate the increase in the amount of money if a unit of other variables increases. With respect to monetary variables, one unit of trip cost per km rise is equivalent to 1647 CNY (which is 1.12 times of the trip cost per min), and this indicates that individuals care trip cost per km more than trip cost per min. Irrespective of the expensive deposit, individuals care most about the cost in the future trips, and this is potentially because the deposit is affordable (see the result of SL3 in Table 2) and refundable. Cruising range is an important factor that affects the adoption intention of BEV sharing. Every 100 km of range decrease is equivalent to 281 CNY, thereby indicating that the cruising range is an obstacle in BEV sharing development. Free-floating availability performs as a significant factor that affects BEV sharing adoption when compared with CGV sharing. Ultimately, if the battery technology and charging condition improve, BEV sharing is feasible in terms to eliminating stations to become free-floating, and then BEV sharing is well adopted and more competitive when compared to CGV sharing. The number of vehicles is incorporated to simply represent vehicle availability and accessibility, which is verified positively affect adoption intention. More vehicles allocated in the service area represent better opportunities to access stations and vehicles close to users.

Policy variables are also found to significantly affect carsharing adoption. The positive parameter corresponding to the vehicle registration restriction policy indicates that individuals are likely to buy the membership due to the vehicle registration restriction. However, it is not statistically significant in terms of BEV sharing. As introduced in Section 2, Beijing applied the vehicle registration restriction of CGV for almost 10 years and commenced granting a limited quota of BEV for 4 years, thereby leading to a huge unfulfilled demand for private cars and especially with respect to CGVs. The demand for private vehicles also significantly affects the demand for vehicle uses, which is satisfied by carsharing. The vehicle registration restriction exhibits a direct effect on individuals with urgent demand for CGV. Thus, the demand shifts to CGV sharing yet not sensitive to BEV sharing. Under the vehicle use restriction on weekdays and vehicles use restriction under extreme weather day. It is interesting to observe a positive effect on BEV sharing utility (with parameter values of 0.805 and 0.778) albeit a negative effect on CGV sharing utility (with parameter values of -0.608 and -1.095). The two use restriction policies are important factors that make customers select BEV sharing. This is because vehicle use restrictions policies constrain the number of CGVs in operation while BEV is not affected by the policies due to zero-emission. Generally, vehicle availability of CGV sharing is reduced almost by 20% on weekdays and even 50% in some days under extreme weather. Thus, individuals are reluctant to become members of CGV sharing under vehicle use restriction policies. This implies that in the current policy environment in Beijing, BEV sharing exhibits potential in the market to fulfill the gap in private vehicle use.

5. Conclusion and policy implication

The study provides insights into Chinese customers' BEV sharing adoption. In a manner different from existing studies involving adoption behavior, attitudes are treated as explanatory variables. Based on survey data, a comprehensive factor structure is developed to measure latent variables and explore the relationship between various observed variables and latent variables. Various factors including customers' attitude, level of service, and vehicle restriction policies are considered, and customers' preferences for BEV sharing are deeply explored and discussed based on a hybrid choice model framework. Findings provide insights on customers' attitudes, and the effect of policy environment and BEV features on BEV sharing adoption. The study provides references on policy-making, promotion strategy, and operation management of BEV sharing.

From the statistical results of the Likert scale, respondents are not very familiar with BEV sharing nor feel interested in the new mode in the current stage in Beijing. Respondents exhibit a vague attitude on the benefits of congestion and parking due to BEV sharing. Although many studies indicate that carsharing is beneficial for urban traffic problem (Martin et al., 2010; Cervero and Tasi, 2004), respondents in the sample are doubtful with respect to the cognition of the two benefits.

The results of the attitude analysis indicate that many variables reflecting the China context, such as Beijing permanent residency, affect individual's attitude to BEV sharing. With respect to the relationship between attitude and adoption, it is verified that attitudes including Environmental Consciousness, Social Benefits, Satisfaction with Transport System, and Reliability significantly affect BEV sharing adoption. For example, individuals with high Environmental Consciousness are likely to use BEV sharing, which is consistent with the results of a study on BEV purchase by Liu et al (2015); and Satisfaction for the current transport system exhibits a negative effect on the adoption intention of BEV sharing, which is consistent with the study by Efthymiou and Antoniou (2016).

With respect to the level of service effects on BEV sharing adoption, individuals care about future trip cost more than the deposit. In the trip cost, individuals consider cost per km as the most important factor when compared with cost per min. The model results of vehicle cruising range and free-floating operation indicate the advantages of CGV sharing over BEV sharing. Additionally, the number of vehicles in operation exhibit a positive effect on adoption, thereby indicating that users care for the opportunity to use vehicles. The results of restriction policies suggest that the vehicle registration restriction increases the adoption intention for the CGV sharing service. However, vehicle use restrictions can shift the intention from CGV sharing to BEV sharing.

A few policy implications are as follow:

(1) Customers' attitudes significantly affect the BEV sharing adoption, and thus governments and operators can further promote the BEV sharing adoption via advertising a positive

image to the public. The strategies can focus on features, such as pro-environment, benefits to society, safety, and reliability in use, to improve positive attitudes. Based on the results in Table 6, the targeted groups who are more optimistic on the three attitudes can include individuals owning BEVs or applying for BEVs with nonlocal household registration working in the field of business and services, etc.

(2) Individuals who are more satisfied with the transport system are not likely to adopt BEV sharing. Operators can locate stations in the neighborhoods where the public transport is not well developed, and car ownership rate is low.

(3) Based on the effects of restrictions on vehicle registration and usage, the carsharing service exhibits potential in the Beijing case. Operators can consider other cities with similar restrictions. Furthermore, it also implies that a few privileges can be implemented to attract users (Ferrero et al., 2015) such as allowing shared vehicles to use bus lanes and reducing or exempting parking costs in other parking spaces additionally to carsharing stations.

(4) An optimal pricing strategy should be better implemented by operators to attract more members. For example, by comparing the choice preferences for both cost per km and cost per min, operators can increase the cost per min and reduce the cost per km to attract more users to achieve a higher profit. Furthermore, vehicle cruising range and free-floating availability are two crucial factors that hinder the adoption of BEV sharing relative to CGV sharing.

Credit author statement

Fanglei Jin: Investigation, Data curation, Formal analysis, Software, Writing - original draft. **Enjian Yao:** Methodology, Funding acquisition, Resources, Project administration, Supervision. **Kun An:** Conceptualization, Validation, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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