Research on Influencing Factors of Orderly Charging Decision of Battery Electric Vehicle Consumers Based on Structural Equation Model

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Abstract: With the continuous increase in the number of BEV (Battery Electric Vehicles), more and BEV are integrated into the grid, and the promotion of orderly charging strategy is an effective means to reduce the pressure on the grid. But in actual operation, there are many factors influencing consumers on whether accepting orderly charging. Based on the "Howard-Sheth" model, this paper constructs a consumer orderly charging decision-making factor model, and uses the structural equation model to analyze the survey questionnaire data to obtain the final decision model, and calculate weight of each factor.

1. Introduction

Since the 21st century, with the promotion and popularization of new energy vehicles, orderly charging strategy has gradually entered the field of vision of many scholars. Correspondingly, many researches on orderly charging strategies of electric vehicles have been proposed. In general, the currently known orderly charging strategies can be roughly divided into two types. One is to directly control the level of the grid load through the charging station. When the grid load is too high, it is directly regulated. Chen Yan [1] and Huang Run [2] took private cars as the research object and considered multiple realistic factors to analyze the effects of direct load control strategies under different strategies. Luo Zhuowei [3] proposed to model according to the different needs of different types of electric vehicles, and the potential for overall regulation is greater. The second is to guide users to accept an orderly charging strategy through real-time electricity price regulation. This strategy starts from the consumer's point of view and considers price factors to guide consumers to accept an orderly charging strategy. Song Junhe [4] studied the issue of electric vehicle charging price setting, and established an optimization model for charging electricity price setting in the community with the goal of maximizing the benefit of community charging piles, minimizing user charging costs and stable grid load.

When a consumer’s BEV has insufficient power and needs to be supplemented with electricity, the consumer needs to decide whether to use slow charging or fast charging, private or public pile charging, and whether to use orderly charging mode. The above several options, Consumers are required to pay a certain amount to obtain electric energy, and the price varies according to the convenience that consumers obtain. Therefore, the essence of which charging method consumers choose is still a purchase decision behavior. The study of consumers' orderly charging decision-making mode has two advantages. First, it helps to better meet consumer needs, and helps consumers make judgments and support the products that are most suitable for their needs. Secondly, it can improve the effectiveness of related enterprise marketing work, help enterprises in product positioning, and supplemented by supporting publicity.

2. Model construction and questionnaire design of factors affecting orderly charging

2.1 Howard-Sheth buying behavior theory model

Buyer behavior theory expounds the reasons why consumers buy a certain product from four perspectives: external factor, stimulus or input factor, internal factor, response or output factors. The external factors refer to some objective conditions that consumers have. Stimulus or input factors include three indicators, namely social stimulus, product symbolic stimulus, and product physical stimulus. Internal factors are the most important and most critical intermediary factors in the entire model. They refer to the process of a series of changes in the psychological state of consumers after they receive the influence of external factors and stimulus or input factors. The last is response or output factor, which is the process by which consumers judge and choose various product schemes through the influence of internal factors, and finally produce purchase behavior.

The purchasing behavior theory's estimation formula for consumers' actual purchasing behavior is:

$$B \approx IN = \omega_1 EX + \omega_2 SO + \omega_3 SI + \omega_4 FA \quad (1)$$

Among them:
B: Response or output factor
IN: Internal Factor
EX: External Factor
SO: Social stimulus
SI: Product symbolic stimulus
FA: Product physical stimulus
$\omega_1,\ \omega_2,\ \omega_3,\ \omega_4$: Regression coefficients

2.2 Construction of orderly charging decision model and selection of influencing factors

Internal factors are the most critical intermediary variables in consumer purchase theory. The study of this paper contains three factors, namely familiarity, satisfaction and demand. External factors include the consumer's personality, the culture, and the consumer's time sufficiency and financial status. In this paper, they represent whether consumers are willing to accept new things, whether they are willing to contribute to the collective, whether they have free and sufficient charging time, and the degree of financial pressure. Social stimulus refers to the recommendation of products by other people in society other than the seller and other stakeholders, such as OEMs, Electricity Company or charging operator. For orderly charging, the actual stimulation of its products refers more to low charging costs, because under the strategy of real-time electricity prices, once consumers choose to accept orderly charging, the charging time must be at a relatively low price, so the charging cost is lower. Service is also a key factor affecting consumers' acceptance of orderly charging. The services involved in a charging mode mainly include charging stability, ease of operation, easy understanding of information, and after-sales solution capabilities. Based on the above analysis, establish an orderly charging decision model and related assumptions for BEV consumers, as shown in Figure 1.

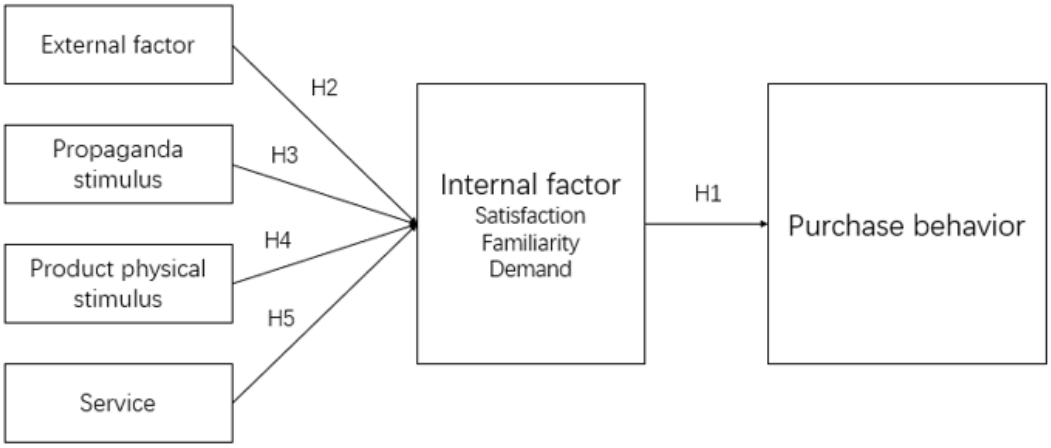

Figure 1. Structural equation model and hypotheses.

The hypotheses are shown as follows:

H1: Internal factors significantly positively affect consumers' orderly charging behavior.

H2: External factors significantly negatively affect the orderly charging behavior of consumers.

H3: Propaganda stimulus significantly positively affects consumers' orderly charging behavior.

H4: Product physical stimulus significantly positively affects the orderly charging behavior of consumers.

H5: Service significantly positively affects the orderly charging behavior of consumers.

2.3 Design of Index Scale for Influencing Factors of Orderly Charge

In order to ensure that the reliability and validity analysis of the questionnaire is within a reasonable range, this article mainly refers to the verified scales in domestic and foreign literature. In addition to the research content, teachers in the field of research and product managers from the SAIC charging department are invited. See the Table 1 for the structure of the scale after finishing.

Table 1. An indicator scale of influencing factors of electric vehicle owners' acceptance of orderly charging behavior

Measured Varible	Specific Operational Quantitative Indicators
External factor (EX)	EX1. My personal funds are tight, financial pressure is great, and I still need to work hard
	EX2. My current work intensity and time pressure are not great, and I have some discretionary time
	EX3. I am more patient in doing things, and think that as long as the problem is solved within the stipulated time, it is better not to rush to complete it immediately
	EX4. I am more curious and I am more willing to experience and try new things
	EX5. I have a strong sense of group, and I am very willing to make my own contribution to the group
	EX6. I usually pay attention to some social hot spots, and I can't understand the waste of social resources
Propaganda stimulus (SO)	SO1. When a government or other official department or organization appeals to the public to use a new product/feature, I will use this product/feature
	SO2. When my relatives and friends recommend a new product/feature for me, I will use this product/feature
	SO3. When the mobile app I use frequently recommends a new product/feature for me, I will use this product/feature
	SO4. When I see an advertisement for a product/feature on a website or on a street billboard, I will use the product/feature
Product physical stimulus (FA)	FA1. I pay much attention to cost performance. For products that can meet my same needs, I will choose the more cost-effective product
	FA2. I am usually frugal, and I will often buy it when there are discounts on the product
	FA3. I only pay attention to the practicability of the product when I buy things, and I don't like the premium measures such as additional services and experiences that the merchant

	adds to the product
	FA4. For products that can meet my same needs, I prefer to choose energy-saving and environmentally friendly products
Service (SE)	SE1. When I charge the car, I will choose a charging mode with higher charging stability and less fluctuation
	SE2. When I charge the car, I will choose a charging mode with a simpler and more convenient charging process
	SE3. When I charge the car, I will choose the charging mode that I am familiar with and understand the information prompted
	SE4. When I charge the car, I will choose the model with quick after-sales response and better service
Internal factor (IN)	IN1. I agree with the orderly charging mode and I am very satisfied with it
	IN2. I think the orderly charging mode is very valuable for both individuals and society
	IN3. I use the car more frequently and need to charge my electric car frequently
	IN4. I already know the orderly charging mode very well, know its principle and the value it can bring to me
Purchasing behavior (BU)	BU1. If the orderly charging mode enters daily life in the future, I will try to use it.
	BU2. If orderly charging mode enters daily life in the future, I will give priority to orderly charging mode for charging every time I charge.
	BU3. If the orderly charging mode enters daily life in the future, I will not only use this mode by myself, but also recommend it to relatives and friends.

After the questionnaire design was completed, the author released a total of 500 questionnaires, and finally recovered 476 valid samples.

3. Model relationship verification and analysis

3.1 Reliability Analysis and Validity Analysis

Since most of the questions designed in this questionnaire and the research and analysis process are abstract, the reliability of the questionnaire must be measured before analysis. The Cronbach α coefficient of each factor obtained by SPSS all exceed 0.7, so the reliability is good. Validity, also known as validity, is to determine whether the questionnaire is effective to achieve the purpose of the investigation through certain measurement tools or means. This paper uses a combination of exploratory factor analysis and confirmatory factor analysis. The former uses SPSS software to determine whether the KMO value and Bartlett value of each index meet the requirements, and conducts principal component analysis to determine the variance contribution rate of each item. The latter uses AMOS structural equation software to fit the measured variables of each latent variable, and judges whether it meets the requirements by the value of the fitting index. After testing, the exploratory factor analysis and confirmatory factor analysis of each indicator are qualified and can be used for follow-up research.

3.2 Model Structure Verification

The relevant data is loaded into the AMOS model for calculation, and the final empirical model and fitness index are shown in Figure 2 and Table 2. It can be seen that the model fitting index is within the acceptable range, and the above assumptions are all established.

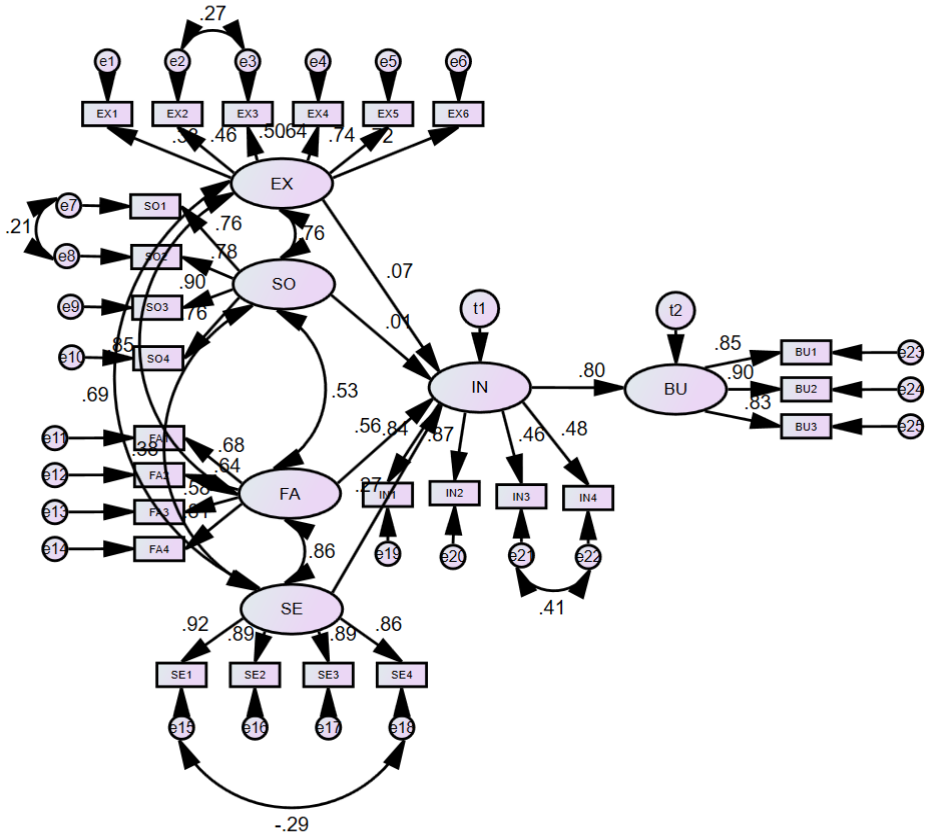

Figure 2. The structural relationship between all influencing factors and buying behavior.

Table 2. All influencing factors and the fit index of the structural relationship model of buying behavior.

Standard	x^2	df	x^2/df	**GFI**	**AGFI**	**NFI**	**CFI**	**RMR**	**RMSEA**
	/	/	<3	>0.9	>0.8	>0.9	>0.9	<0.05	<0.08
AM1.1	629.172	260	2.420	0.924	0.881	0.950	0.905	0.077	0.076

3.3 Model Weight Calculation

External factors (EX), propaganda stimulus (SO), product physical stimulus (FA), and service (SE) are research variables, and internal factors (IN) are intermediary variables. The factors that influence the acceptance of orderly charging strategies by electric vehicle owners Evaluation, the weight value of each indicator is calculated as Table 3.

Table 3. Model weight of factors.

Factor	$\mathbf{W_i}$
EX	0.069
SO	0.111
FA	0.552
SE	0.268

4. Conclusions

In this paper, the "Howard-Sheth" buyer behavior theory is used as the basis, combined with the actual status of orderly charging, to construct the influencing factor model of consumers' orderly charging decision, and the latent variable factors in the model are quantified. Using SPSS and AMOS to analyze the reliability and validity of the questionnaire indicators, the results are good after verification. Finally, AMOS is used to fit the model and calculate the weight value. The results

show that external factor, propaganda stimulus, product physical factor, and service all significantly positively affect consumers' internal factors, while internal factors significantly positively affect consumers purchase behavior.

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