Analysis of Factors Influencing EV Power Battery Recycling Channel Selection: A Study Based on TPB and Multi Class Logistic Regression

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Abstract: New energy electric vehicle (EV) have become the mainstream worldwide, and the power battery recycling industry is facing new opportunities and challenges. This article compares and analyzes the advantages and disadvantages of existing power battery recycling channels. Through a questionnaire survey, a multi class logistic regression model is used to study the impact and correlation of users' gender, age, occupational category, and education level on their choice of recycling channels. The results indicate that there is a positive correlation between education level and understanding of power battery channels. The higher the education level, the more concerned the group is about environmental protection compared to convenience. Finally, based on the TPB, the impact of seven factors on users' choice of recycling channels and corresponding measures were summarized to help the enterprises understand users' inner thoughts, facilitate the establishment of a more comprehensive recycling mechanism, and improve the revenue of power battery recycling.

Keywords: Power Battery; TPB; Multi Class Logistic Regression; Recycling Channel

1. Introduction

In recent years, the new energy vehicle industry has ushered in significant development opportunities, and the recycling of power battery as its core components has gradually become prominent. "Tiered utilization" and "recycling" are the main strategies for power battery recycling in China [1-2]. In the power battery recycling system, user participation and selection play an important role, and their decisions have significant implications for resource utilization efficiency and the development of environmental protection. When choosing a power battery recycling channel, users will consider various factors, such as the convenience of the recycling point, the high or low recycling price, the reputation of the recycling enterprise, and so on. These factors collectively affect users' recycling behavior. In terms of user recycling channel selection, existing research mainly focuses on analyzing the advantages and disadvantages of different recycling channels, exploring the factors that users consider when choosing recycling channels, such as price, service quality, environmental awareness, and convenience. They put forward suggestions for optimizing recycling strategies through empirical research, while emphasizing the importance of technological innovation and policy support in promoting the development of the power battery recycling industry. For example, Tang designed questionnaire to investigate the recycling behavior of residential users**,** and used structural equation modeling to analyze the differential effects of residents' recycling cognition and recycling attitude preferences [3]. Wang *et al.* considered consumers' channel preferences and found that an increase in consumers' preference for third-party recycling channels would reduce the recycling volume and profits of retailers or manufacturers [4]. Zhong *et al.* established a dual channel selection influencing factor model based on Theory of Planned Behavior (TPB), Technology Acceptance Model (TAM), and Benefit Risk Analysis (BRA) [5], and found that consumers' attitudes towards recycling and perceived usefulness are important factors affecting channel selection, followed by perceived time cost and perceived benefits. Perceived ease of use and perceived risk have

similar effects on recycling willingness, while subjective norms and perceived behavioral control have relatively weak effects. Wang *et al.* found that perceived usefulness, perceived benefits and subjective norms had a positive impact on the "Internet+recycling" attitude, while perceived ease of use and perceived risk had no significant impact on it; Gender, age, education level and income have a significant impact on residents' attitude and willingness to participate in "Internet+recycling" [6]. The recycling of power batteries is a complex and massive project that involves multiple links and technical challenges. In studying users' choices of power battery recycling channels, existing research lacks comparative analysis of different individual characteristic groups, and sample sources and scales are limited.

This article uses the TPB and a multi class logistic regression model to analyze users' recycling channel selection behavior, studying the influence and correlation of gender, age, occupational category, and education level on recycling channel selection behavior. It helps the government or enterprises understand users' inner thoughts, facilitate the establishment of a more complete recycling mechanism, and improve the revenue of power battery recycling.

2. Analysis of the Current Status of EV Power Battery Recycling Channels

The power battery recycling channel is a diversified and complex system. The existing power battery recycling channels mainly include manufacturer recycling, professional recycling companies recycling, dealers and repair shops recycling, government recycling, third-party platform recycling, community and private recycling [7].

2.1 Manufacturer Recycling

Many new energy vehicle manufacturers have battery recycling programs, which encourage car owners to return used batteries when their vehicles are retired. Manufacturers collect and reuse batteries, or entrust them to professional battery recycling institutions for disposal. The manufacturer's recycling program ensures that the battery recycling process meets its technical standards and environmental requirements, as shown in Figure 1.

2.2 Professional Recycling Companies Recycling

Professional battery recycling companies establish recycling networks through cooperation with manufacturers, distributors, and car owners, specializing in the collection, transportation, dismantling, and recycling of power batteries. They are equipped with advanced equipment and technology to efficiently and safely dispose of waste batteries, and their recycling process is shown in Figure 2.

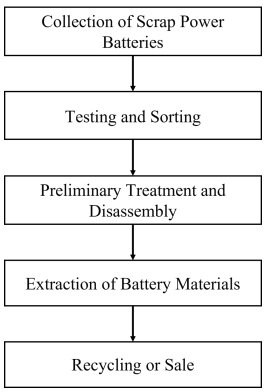

Figure 1. Manufacturer's Recycling Process

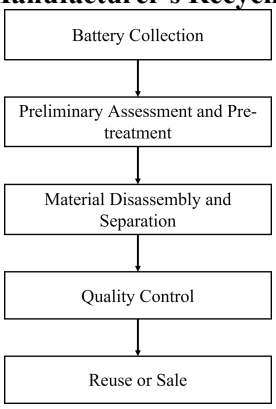

Figure 2. Recycling Process of Professional Battery Recycling Companies

2.3 Dealers and Repair Shops Recycling

Dealers and repair shops are usually also involved in battery recycling work. When a vehicle needs maintenance or battery replacement, dealers and repair shops are responsible for collecting and properly disposing of used batteries.

2.4 Government Recycling

The government usually establishes specific recycling projects to provide economic incentives (such as subsidies or tax exemptions) to encourage citizens and businesses to participate in the recycling of power batteries. The recycling process is shown in Figure 3.

2.5 Third-party Platform Recycling

Third party recycling platforms collaborate with manufacturers, recycling companies, or governments to promote the recycling of power batteries, typically providing online and offline services to facilitate car owners in disposing of used batteries.

2.6 Community and Private Recycling

In some areas, some community organizations or individuals may also participate in the recycling of power batteries. Some environmental organizations will set up dedicated recycling points to collect and properly dispose of waste batteries.

The comparison of the advantages and disadvantages of various recycling channels is shown in Table 1.

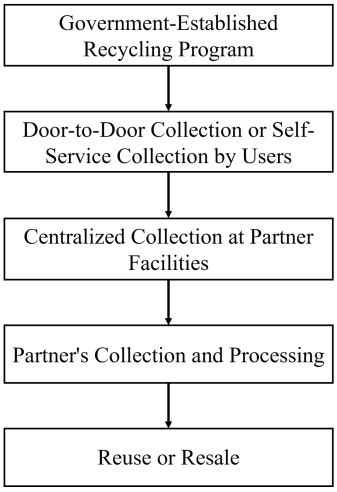

Figure 3. Government Recycling Project Recycling Process

Table 1. Comparison of Advantages and Disadvantages of Various Recycling Channels

Recycling Channels	Advantages	Disadvantages
Manufacturers	The recycling process is standardized and technologically advanced, which contributes to the enhancement of brand image. The reuse or cascading utilization of recycled batteries is more convenient	May face the pressure of a large volume of recycling, and the recycling channels may be limited by geographical restrictions, targeting only their own products
Professional Recycling Companies	Equipped with professional technology and equipment, the recycling efficiency is high, capable of recycling various brands and types of batteries, providing one-stop services for user convenience	May encounter market competition and cost control issues, requiring cooperation with multiple parties, which can be challenging to coordinate and may face the risk of policy changes
Dealers and Repair Shops	The recycling channels are extensive and user-friendly, increasing revenue by combining sales and repair services, and promoting recycling more conveniently through frequent contact with users	May lack professional recycling technology and equipment, limiting the types and quantities of batteries that can be recycled, and may be affected by market competition
Government	Supported by the government, the recycling channels are stable, beneficial for environmental protection and resource recycling, and can provide policy incentives and subsidies to encourage user participation	May be influenced by policy changes, the recycling process may be cumbersome, and may face issues with funding and management
Third-Party Recycling Platforms	The recycling channels are extensive, covering multiple brands and types, offering online appointment and offline recycling services, which are convenient and fast, and can provide points or rewards to encourage user participation	May have information asymmetry and fraud risks, requiring cooperation with multiple parties, which can be challenging to coordinate, and facing market competition and cost control issues
Community or Private	The recycling channels are flexible and user-friendly, increasing recycling volumes by combining community activities or personal relationships, increasing residents' environmental awareness, and promoting community harmony	Lack professional technology and equipment, the recycling efficiency may be low, the types and quantities of batteries that can be recycled are limited, and there are safety risks and management issues

3. Basic Theory

3.1 Theory of Planned Behavior

Theory of Planned Behavior (TPB) is a rational behavior theory that holds that behavioral intention is influenced by behavioral attitudes and subjective norms, and is a direct factor in determining actual behavior. Behavior is caused by attitudes, social norms, and individuals' perceived control over themselves. People consider various behaviors, weigh the consequences of each choice, and then decide how to act [8-10]. TPB determines users' ultimate actions by analyzing four factors: behavioral beliefs, normative beliefs, control beliefs, and behavioral intentions. The theoretical diagram of TPB is shown in Figure 4.

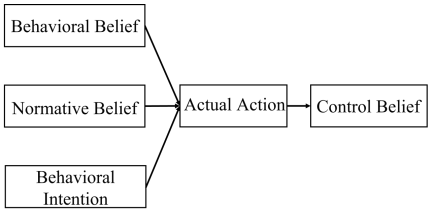

Figure 4. The Theoretical Diagram of TPB

3.2 Multi Class Logistic Regression Model

This article establishes a multi class logistic regression model to explore the influence of various factors on users' choice of recycling channels, and verifies the degree of difference in independent variables through chi square test. As shown below:

$$\ln Y / K_a = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ...\beta_n X_n \quad (1)$$

Where Y is the reference comparison term, K is the premise term of Y reference, a=1, 2, 3... n, X is the independent variable, β_0 is the regression coefficient, β_1, $\beta_{2....}$ β_n are the regression coefficients of the independent variable.

The chi square test is as follows:

$$X^2 = \sum (A-T)^2 / T \quad (2)$$

Where A represents the actual frequency, and T represents the theoretical frequency.

4. Analysis of Power Battery Recycling Selection Behavior Based on TPB and Multi class Logistic Regression

This article collected a total of 356 valid questionnaires through a questionnaire survey using Wenjuanxing. The gender ratio, age ratio, occupational category, and education level ratio were appropriate. The questionnaire covered the basic information of the respondents, their understanding and attitude towards power battery recycling, as well as their behavioral intentions.

Using the level of understanding of policies and channels related to the recycling of power batteries as the dependent variable Y, the gender, age, education level, and occupation of users as independent variables X_1, X_2, X_3, and X_4, and very understanding as the reference item, analyze the impact of individual characteristics of users on their level of understanding, as shown in Table 2.

Table 2. Analysis of User's level of Understanding of Power Battery Recycling

Fairly Familiar	Regression Coefficient	Standard Error	z-Score	Wald χ2	p-Value	Odds Ratio	95% CI for Odds Ratio
Gender	0.608	0.426	1.428	2.038	0.153	1.838	0.797~4.237
Age	0.102	0.232	0.441	0.195	0.659	1.108	0.703~1.746
Level of Education	0.199	0.235	0.844	0.712	0.399	1.220	0.769~1.934
Occupational Category	-0.194	0.194	-0.998	0.995	0.318	0.824	0.563~1.205
Intercept	0.480	1.088	0.441	0.194	0.659	1.615	0.192~13.620
Limited Understanding	Regression Coefficient	Standard Error	z-Score	Wald χ2	p-Value	Odds Ratio	95% CI for Odds Ratio
Gender	0.557	0.423	1.318	1.738	0.187	1.746	0.763~3.996
Age	0.248	0.229	1.084	1.176	0.278	1.282	0.818~2.007
Level of Education	-0.041	0.230	-0.180	0.032	0.857	0.959	0.611~1.507
Occupational Category	-0.100	0.191	-0.527	0.278	0.598	0.904	0.623~1.314
Intercept	0.778	1.070	0.727	0.528	0.467	2.176	0.267~17.720
Completely Unfamiliar	Regression Coefficient	Standard Error	z-Score	Wald χ2	p-Value	Odds Ratio	95% CI for Odds Ratio
Gender	0.736	0.554	1.329	1.765	0.184	2.088	0.705~6.184
Age	0.182	0.297	0.614	0.377	0.539	1.200	0.671~2.146
Level of Education	-0.627	0.299	-2.098	4.400	0.036	0.534	0.298~0.960
Occupational Category	0.031	0.241	0.128	0.016	0.898	1.031	0.643~1.654
Intercept	-0.075	1.385	-0.054	0.003	0.957	0.928	0.061~14.017

Compared to having a very good understanding, the model formulas obtained are as follows (Y_1 for very good understanding, Y_2 for relatively good understanding, Y_3 for very little understanding, Y_4 for completely bad understanding):

$$\ln(Y_2 / Y_1) = 0.480 + 0.608X_1 + 0.102X_2 + 0.199X_3 - 0.194X_4 \quad (3)$$

$$\ln(Y_3 / Y_1) = 0.778 + 0.557X_1 + 0.248X_2 - 0.041X_3 - 0.1X_4 \quad (4)$$

$$\ln(Y_4 / Y_1) = -0.075 + 0.736X_1 + 0.182X_2 - 0.627X_3 + 0.031X_4 \quad (5)$$

It can be seen that when there is no understanding at all, there is a significant difference in education level (z=-2.098, p=0.036<0.05), with an odds ratio (OR) of 0.534, indicating that when the education level increases by one unit, the change amplitude is 0.534 times (from very understanding to completely unknown). The higher the education level, the higher the understanding of recycling, and there is a significant deviation in the perception of recycling among groups with different educational levels.

Similarly, the factors influencing the selection of recycling channels were analyzed using the convenience of recycling as a reference, and the results are shown in Table 3. It can be seen that compared to convenience, there is no significant difference under the premise of

recycling profitability. When environmental protection is taken as the premise, there is a significant negative correlation in education level, indicating that groups with higher education levels pay more attention to environmental protection compared to convenience. This reflects that there is still a bias in environmental education, and groups with lower education levels may not be clear about or willing to understand the importance of environmental protection.

Based on the above analysis results and TPB, this article summarizes the impact of seven factors on users' choice of recycling channels and corresponding measures, as shown in Table 4.

Table 3. Analysis of Factors Influencing the Selection of Recycling Channels

Profitability	Regression Coefficient	Standard Error	z-Score	Wald $\chi 2$	p-Value	Odds Ratio	95% CI for Odds Ratio
Gender	-0.114	0.267	-0.427	0.182	0.670	0.892	0.529~1.505
Age	-0.042	0.146	-0.288	0.083	0.774	0.959	0.721~1.276
Level of Education	-0.287	0.150	-1.916	3.671	0.055	0.751	0.560~1.007
Occupational Category	0.030	0.123	0.242	0.059	0.809	1.030	0.809~1.311
Intercept	0.773	0.708	1.092	1.193	0.275	2.166	0.541~8.673
Environmental Friendliness	Regression Coefficient	Standard Error	z-Score	Wald $\chi 2$	p-Value	Odds Ratio	95% CI for Odds Ratio
Gender	-0.031	0.259	-0.121	0.015	0.904	0.969	0.584~1.609
Age	0.194	0.138	1.402	1.965	0.161	1.214	0.926~1.593
Level of Education	-0.284	0.143	-1.987	3.946	0.047	0.753	0.569~0.996
Occupational Category	0.107	0.116	0.923	0.853	0.356	1.113	0.887~1.398
Intercept	0.089	0.683	0.130	0.017	0.897	1.093	0.286~4.169

Table 4. The Impact of Various Factors on Users' Choice of Recycling Channels and Corresponding Measures

Influencing Factors	Impact Modes	Degree of Impact	Countermeasures
Price	Consumers contemplate the pricing elements of various recycling channels, including the cost of recycling and transportation expenses. The level of pricing significantly influences their selection decisions	Middle	Implement reasonable pricing strategies, such as increasing recycling prices and reducing transportation costs, to attract consumers.
Environmental Protection	There is a heightened demand for the ecological friendliness of recycling channels, with a preference for processes that minimize environmental impact	High	Enhance environmental awareness and improve the ecological performance of recycling channels, such as using eco-friendly materials and reducing pollution
Convenience	Consumers are more inclined to opt for recycling channels that offer ease and speed, such as doorstep collection and self-service recycling	High	Offer a variety of recycling methods, such as doorstep collection, self-service recycling, and fixed-point recycling, to meet diverse consumer needs
Official Channels	Channels that are officially recognized typically enjoy greater credibility and trustworthiness, making them the preferred choice for consumers	High	Strengthen the construction and promotion of official channels to increase consumer trust
Subjective Norms	Consumer behavior is influenced by the suggestions and evaluations of their social environment, including family, friends, and colleagues	High	Utilize social media and word-of-mouth marketing to improve consumer recognition and trust in recycling channels.
Attitude Toward Behavior	The attitude and perception of consumers towards recycling behavior directly affect their choice of action, such as the perceived value and sense of responsibility associated with recycling	High	Intensify recycling promotion and education to raise environmental consciousness and sense of responsibility, guiding consumers towards a positive recycling attitude
Perceived Behavioral Control	The perceived ease or difficulty of the recycling process and the barriers perceived by consumers influence their choice of action, such as the complexity of the process and the availability of time and energy	High	Optimize the recycling process to reduce the operational difficulty and time cost for consumers, enhancing their perceived behavioral control capabilities

5. Conclusion

The user's choice behavior is not random or isolated, but is influenced by a combination of multiple factors. Price, convenience, safety, and environmental friendliness are the most important considerations for users when making recycling decisions. There is a positive correlation between education level and understanding of power battery channels and policies. The group with higher education level pays more attention to environmental protection compared to convenience. The recycling price directly affects the economic

interests of users, who often compare the recycling prices of different channels in order to seek the maximum economic return. Meanwhile, convenience is also an important factor that cannot be ignored. In modern fast-paced life, users tend to choose recycling channels that can provide door-to-door recycling, quick response, and convenient operation. With the increasing awareness of environmental protection, more and more users are paying attention to the environmental performance of recycling channels, and are more inclined to choose recycling methods that can achieve resource recycling and reduce environmental pollution.

The promotion and advertising of recycling channels have a significant impact on user decision-making. Understanding users' choice behavior and its influencing factors can help recycling companies better grasp market demand and user preferences. Revealing the differences in choices among different user groups can help businesses segment the market and accurately target their customer base. By delving into the needs and characteristics of different user groups, enterprises can develop recycling products and services that better meet the needs of target customers, thereby achieving differentiated competition and personalized services. Recycling enterprises need to continuously optimize and improve the construction of recycling channels and service systems to enhance users' experience and satisfaction in the recycling process. At the same time, government departments, industry associations, and all sectors of society should work together to create a better environment for the healthy, orderly, and sustainable development of the power battery recycling industry. But, this study lacks comparative analysis of different regions and social groups, and the sample source and scale are limited. The paper lacks an interdisciplinary research perspective and is limited to a single country or region. The theoretical framework and methodology need to be further enriched and improved.

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