

Article

Research on the Formation Mechanism of the Purchasing Behavior of Electric Vehicles with a Battery-Swap Mode

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Abstract: The driving range and replenishment problem of electric vehicles have become the main contradictions that interfere with consumers' purchasing decisions. To alleviate these problems, battery-swap technology has been introduced into the public view. Existing research rarely explores the factors that affect consumers' decision of purchasing electric vehicles. This article introduces the Technology Acceptance Model (TAM), as well as the Theory of Planned Behavior (TPB) with its extensions and the perceived risk, to construct the structural equation model (SEM) based on TAM and TPB, and studies the influence mechanism of the purchase intention of electric vehicles with a battery-swap mode. A total of 530 valid questionnaires were collected from participants in Beijing, providing a representative sample for the study. The results show that attitude, technological development, perceived behavior control, environmental awareness, and subjective norm have significant positive influences on the purchase intention, and the influences increase in turn; perceived risk has a significant negative effect; subjective norms and environmental awareness have an indirect positive effect.

Keywords: battery-swap mode of electric vehicles; structural equation model; purchase intention; influencing factors; mediation effect



Academic Editor: Grzegorz Sierpiński

Received: 26 December 2024

Revised: 31 January 2025

Accepted: 3 February 2025

Published: 7 February 2025

Citation: Xu, S.; Hu, G.; Han, H. Research on the Formation Mechanism of the Purchasing Behavior of Electric Vehicles with a Battery-Swap Mode. *World Electr. Veh. J.* **2025**, *16*, 85. <https://doi.org/10.3390/wevj16020085>

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1. Introduction

The vigorous development of electric vehicles (EVs) is crucial for China's automotive industry in its transition from a major player to becoming a dominant force. It represents a strategic initiative in response to climate change, promoting green development and achieving carbon peak and carbon neutrality goals. Since 2020, EVs have gained significant momentum, with EV sales accounting for 29% of total automotive sales from January to July 2023. However, EVs still face challenges such as high prices, inconvenient charging, limited range, and low charging infrastructure coverage [1], factors that significantly influence consumer purchase intentions. Studies have shown that these challenges, particularly the limited availability of charging stations, are key barriers to the consumer adoption of EVs [2], as highlighted by Zhang et al. The rapid deployment of high-power, super-fast charging stations to alleviate range anxiety may strain the power grid and pose safety concerns.

In contrast, battery swapping offers advantages in reducing vehicle acquisition costs, eliminating range anxiety, alleviating charging infrastructure shortages, and enhancing safety. Unlike previous studies that focus primarily on the technical and infrastructural aspects, this research extends the application of battery swapping by incorporating consumer

decision-making factors, which is essential for the broader adoption of EVs. As demonstrated in recent research [3], battery-swapping technology not only addresses challenges related to charging time and range anxiety but also plays a crucial role in enhancing the overall user experience with EVs, thereby improving the convenience [4] and practicality [5] of pure electric EVs. In October 2021, the Ministry of Industry and Information Technology issued a notice to initiate a pilot program for the application of the EV battery-swapping model, selecting 11 cities, including Beijing, to accelerate its adoption [6]. Simultaneously, companies like CATL, NIO, and XPeng have actively expanded into the battery-swapping model, establishing extensive networks domestically [7] and promoting its application in sectors such as taxis and public buses. Consumer decisions regarding the adoption of battery-swapping EVs will significantly impact the development of this model. However, there is a scarcity of existing literature exploring the factors influencing consumer decisions in purchasing battery-swapping EVs.

This study focuses on Beijing, one of the first cities selected for the national battery-swapping model pilot program, constructing a structural equation model based on the TAM and TPB. While previous studies have applied these models to investigate consumer adoption intentions for battery-swap technology [8], this study expands on this by incorporating additional consumer perception factors such as environmental consciousness and perceived risk, which provides a solid theoretical foundation for this research. It aims to investigate the key factors influencing consumer decisions in purchasing battery-swapping EVs, providing valuable insights for government policy formulation and the product development and marketing strategies of EV manufacturers.

2. Constructing and Investigating Hypotheses with a Structural Equation Model Based on TAM and TPB

The purchasing behavior of EVs is influenced by a multitude of factors, both directly and indirectly, encompassing variables such as gender, education level, occupation, income, and more. This article, anchored within the frameworks of the TAM and TPB and their extensions, including perceived risk, constructs a structural equation model to investigate the pivotal factors shaping the decision-making process for the adoption of battery-swapping EVs.

2.1. Technology Acceptance Model and Its Extensions

TAM is a theoretical framework used to explain the extent to which individuals adopt new technologies. It posits that perceived usefulness and perceived ease of use are critical factors influencing an individual's decision to adopt a particular technology and whether they continue to use it. The existing literature often simplifies the TAM by overlooking certain variables. For instance, Adu-Gyamfi [8] argued that consumers may lack actual experience with electric vehicles, leading to the omission of perceived ease of use. Given that many consumers may have limited knowledge and experience with battery-swapping technology, this study similarly omits perceived ease of use and quantifies perceived usefulness through factors such as vehicle condition perception, battery-swapping station location perception, battery-swapping station charging-status perception, predictive maintenance perception, and user feedback perception. Drawing from common assumptions in the existing literature [9,10], we propose the following hypotheses:

H1: *Perceived usefulness is positively correlated with the purchase decision of battery-swapping EVs.*

H2: *Perceived usefulness has a positive impact on the attitude toward adopting battery-swapping EVs.*

Building upon Adu-Gyamfi's observation [8] that the emergence of battery-swapping technology alleviates consumer range anxiety and the time-consuming nature of charging, we introduce an additional construct related to the development of battery-swapping technology:

H3: *The development of battery-swapping technology positively influences consumer decisions to purchase battery-swapping EVs.*

2.2. Theory of Planned Behavior and Its Extensions

TPB aims to explain why individuals engage in specific behaviors [11,12]. It posits that decisions to engage in a particular behavior are primarily determined by three factors: attitude [13], subjective norm [14], and perceived behavioral control (PBC) [15]. Duong [16] and Pourjahanshahi [17] consider attitude as a critical factor in shaping behavioral decisions, while Van [18] and Shareef [19] have found attitude to be a significant influencing factor in behavioral decisions. This article proposes the following hypothesis:

H4: *Attitude has a positive impact on the purchase decision of battery-swapping EVs.*

Adu-Gyamfi [3] argues that subjective norm is a key factor in decision formation, and Adu-Gyamfi [8] and Singh [20] suggest that subjective norm (SN) significantly influences decision formation. This article proposes the following hypotheses:

H5: *Subjective norm positively influences consumers' attitudes toward purchasing battery-swapping EVs.*

H6: *Subjective norm positively influences consumers' decisions to purchase battery-swapping EVs.*

Wallace [14] and Khasni [15] posit that perceived behavioral control (PBC) is a significant influencing factor in behavioral decisions. This article proposes the following hypothesis:

H7: *Perceived behavioral control positively influences consumers' decisions to purchase battery-swapping EVs.*

Lavuri [21] suggests that a green attitude has a direct positive mediating effect on purchase decisions, and environmental emotions regulate attitudes and purchase decisions positively. Parashar [22] found a strong association between the consumption of organic food and heightened health and environmental awareness. Presently, environmental consciousness is deeply ingrained. This article proposes the following hypotheses:

H8: *Environmental protection consciousness positively influences consumers' decisions to purchase battery-swapping EVs.*

H9: *Environmental protection consciousness positively influences consumers' subjective norm regarding the purchase of battery-swapping EVs.*

2.3. Perceived Risk

Perceived risk refers to an individual's subjective assessment of the potential occurrence of hazardous events. Empirical studies often regard perceived risk as a crucial reference factor. Adu-Gyamfi [17] suggests that perceived risk inhibits the willingness to adopt battery-swapping models. Gibson [8] found that perceived risk significantly negatively influences attitudes, perceived usefulness, and the willingness to adopt battery-swapping technology. Consumers consciously or subconsciously consider potential risks

associated with their actions, whether they are physical, psychological, or financial in nature, and any form of risk is detrimental to the widespread adoption of battery-swapping models. This article proposes the following hypotheses:

H10: *Perceived risk negatively influences the willingness to purchase battery-swapping EVs.*

H11: *Perceived risk negatively influences the decision to purchase battery-swapping EVs.*

H12: *Perceived risk negatively influences the practical value consumers perceive from adopting battery-swapping technology.*

In conclusion, the theoretical framework proposed in this article is illustrated in Figure 1. The “+” symbol in the figure indicates that “a” has a positive, constructive effect on “b”, meaning “a” positively influences “b”. The “−” symbol represents that “a” has a negative, detrimental effect on “b”, meaning “a” negatively impacts “b”.

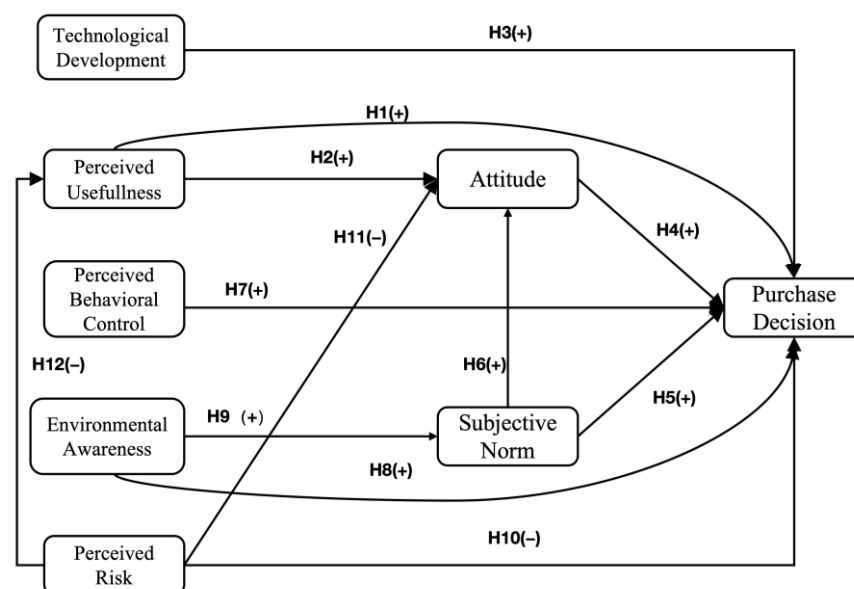


Figure 1. Structural equation model framework based on TAM and TPB.

3. Data Collection

The data for this study were collected through a questionnaire survey, and the detailed content of the questionnaire can be found in the Supplementary Materials. Beijing, as one of the first pilot cities for the application of battery-swapping models in EVs in China, had a total of 292 operational battery-swapping stations as of March 2023. By the end of 2022, the number of registered EVs in Beijing exceeded 660,000, indicating well-established infrastructure and a high level of consumer awareness regarding EVs. Therefore, individuals in Beijing with potential intentions to purchase EVs were chosen as the survey participants, as they could provide valuable insights into the key factors influencing consumer decisions to purchase battery-swapping EVs. The sample was stratified based on the potential purchase intent of consumers. Specifically, participants were selected from those who showed an interest in purchasing EVs and were well aware of EVs and their benefits. The questionnaire survey was conducted both offline and online. Offline surveys were carried out among consumers visiting larger EV markets and 4S dealerships in Beijing, where surveyors directly engaged with consumers to distribute questionnaires and invite them to participate in the survey, while online surveys were conducted through platforms

such as online questionnaire websites, automotive enthusiast groups, and social media platforms like Weibo, where participants could conveniently fill out the survey remotely.

To enhance the scientific rigor of the questionnaire and probe participants' potential purchase intentions, the questionnaire design included several key measurement items, such as perceived usefulness (PU), attitude (ATT), subjective norm (SN), and perceived behavioral control (PBC) [3,8,17,23]; perceived risk (PR) [24], battery-swapping technology development (TD), and environmental consciousness (ENV) [25,26] were optimized based on a comprehensive review of the literature. The aim was to understand the decision-making factors of consumers when considering the purchase of battery-swapping EVs. Participants were selected from those with a willingness or potential intent to buy, and stratified sampling was then performed, ensuring the inclusion of key factors influencing their purchasing decisions. They were sourced from 4S dealerships, EV markets in Beijing, and online social platforms, ensuring a diverse and representative sample. This method of selection ensured a representative sample, capable of providing valuable insights. Prior to the formal distribution of the questionnaire, a preliminary survey was conducted with 68 owners of battery-swapping EVs to refine the survey content and ensure that it accurately captured the key factors influencing purchasing decisions.

During the survey period (February to April 2023), a total of 629 questionnaires were distributed, of which 562 were successfully collected, resulting in a response rate of 89.3%. After excluding 32 incomplete or excessively brief/long questionnaires, a final set of 530 valid questionnaires was obtained. The ratio of offline to online sources of the survey data is 11:1, and the questionnaires were distributed by the research team. The sample size was calculated using the formula $n = \frac{z^2 \cdot p \cdot (1-p)}{d^2} = \frac{1.96^2 \cdot 0.5 \cdot 0.5}{0.05^2} \approx 384$. This sample size met the minimum requirement and was deemed sufficiently representative for the study. Here, $z = 1.96$ represents the z-value for a 95% confidence level, $p = 0.5$ indicates the estimated population proportion, and $d = 0.05$ is the margin of error tolerance.

Table 1 presents demographic descriptions of the participants in this study. The gender distribution of the respondents consisted of 282 males (53.2%) and 248 females (46.8%). Regarding age, 87 individuals (16.4%) were below 30 years, with the majority falling between the ages of 30 and 50, accounting for 405 individuals (76.4%). Among the 530 respondents, 182 (34.3%) were employed in corporate positions or the service industry. A total of 53.6% of respondents held a bachelor's degree or higher, and 54% reported a per capita annual household income of over USD 7700 but not exceeding USD 17,500. The respondents were evenly distributed across various districts and counties within Beijing.

Table 1. Characteristics of respondents.

Demographics	Options	Frequency	Percentage (%)
Gender	Male	282	53.2%
	Female	248	46.8%
Age (Years)	19–30	87	16.4%
	31–40	250	47.2%
	41–50	155	29.2%
	51–60	30	5.7%
	61–70	8	1.5%
Educational Level	High School and below	95	17.9%
	Junior College	153	28.9%
	Bachelor	192	36.2%
	Master's/PhD	90	17.0%

Table 1. Cont.

Demographics	Options	Frequency	Percentage (%)
Occupation	Enterprise/company staff member	75	14.2%
	Party, government and government organs and public institutions	41	7.7%
	Freelancer	66	12.5%
	Worker	47	8.9%
	Agriculture, forestry, animal husbandry, fishery and water conservancy workers	47	8.9%
	Professionals	55	10.4%
	Service personnel	107	20.2%
	Other	92	17.2%
Income Level	Under 7700 USD	100	18.9%
	7700–11,900 USD	143	27.0%
	11,900–17,500 USD	143	27.0%
	17,500–23,100 USD	90	17.0%
	More than 23,100 USD	54	10.1%
Family Structure	Multi-generational household (Two generations)	147	27.7%
	Two-person married couple	140	26.4%
	Three generations and above living together	133	25.1%
	living alone	110	20.8%
Vehicle Usage Conditions	No car	206	38.9%
	A car	219	41.3%
	Two or more cars	105	19.8%

The occupational classification in the questionnaire is based on the content from the following link: <https://baike.baidu.com/item/%E8%81%8C%E4%B8%9A/2133531#> (accessed on 1 January 2025).

4. Data Analysis

4.1. Battery-Swap Function Focus and External Influencing Factors Explore

In order to thoroughly explore consumers' understanding of the battery-swapping model and the emphasis on functionality, external factors such as policies, costs, infrastructure development, and other factors affecting consumers' purchasing intentions will be discussed sequentially in relation to the ranking questions involved in the aforementioned aspects. Statistics suggest that when calculating the average composite score, different weights should be assigned to each variable, known as weights; the average calculated rationally according to these weights is termed the weighted average. In ranking questions, due to variations in the importance of options, weighting is necessary. It is calculated based on the order in which respondents make their choices, thereby reflecting the comprehensive ranking of options, with higher scores indicating greater favorability and preference among consumers. The calculation method is as follows: the comprehensive score of options = $(\sum \text{frequency} \times \text{weight}) / \text{number of respondents for the question}$, where the weight depends on the order in which the options are ranked by the respondents. In this study, there are four options involved in the ranking, with a weight of 4 for the first position, 3 for the second position, 2 for the third position, and 1 for the last position.

The advantages of the battery-swapping mode were comprehensively evaluated in Figure 2, with integrated scores in aspects such as alleviating range anxiety (A), addressing home charging issues without charging infrastructure (B), reducing vehicle acquisition costs (C), fast battery-swapping speed (D), achieving orderly charging (E), lowering safety hazards during driving (F), and minimizing battery-swapping wait times (G). The results indicate that consumers prioritize the following four aspects in descending order: $F > C > A > E$, with scores of 6.24, 5.36, 4.51, and 2.89, respectively.

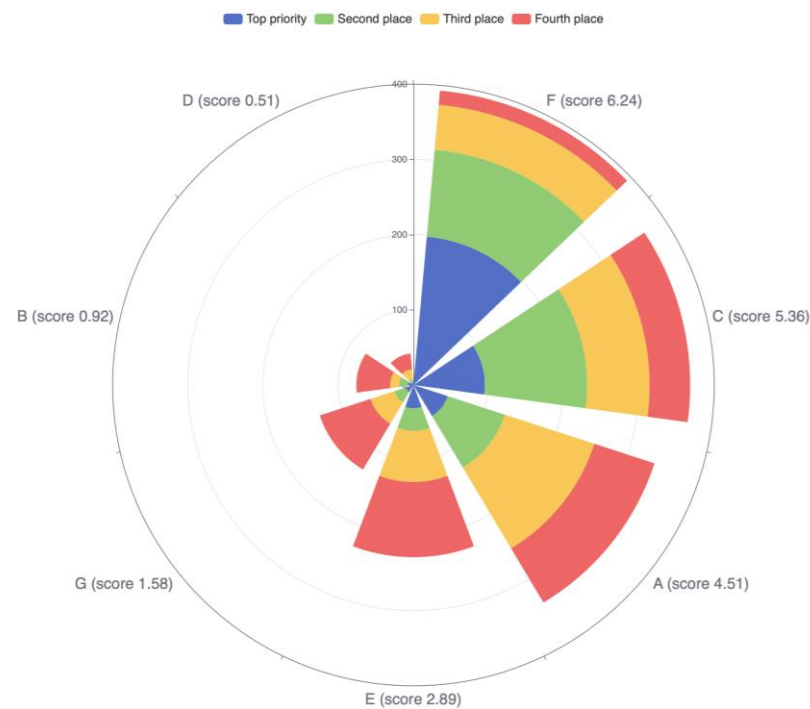


Figure 2. An exploration of the advantages of battery-swapping mode.

As depicted in Figure 3, it is evident that in terms of the emphasis on battery-swapping content (A for battery leasing and service fees, B for battery safety concerns, C for the service radius of battery-swapping stations, D for the duration of a single battery-swapping service, and E for the down payment on battery-swapped vehicles), consumers prioritize the following four aspects in the order of $C > B > D > E$, with scores of $4.25 > 3.59 > 2.93 > 1.93$.

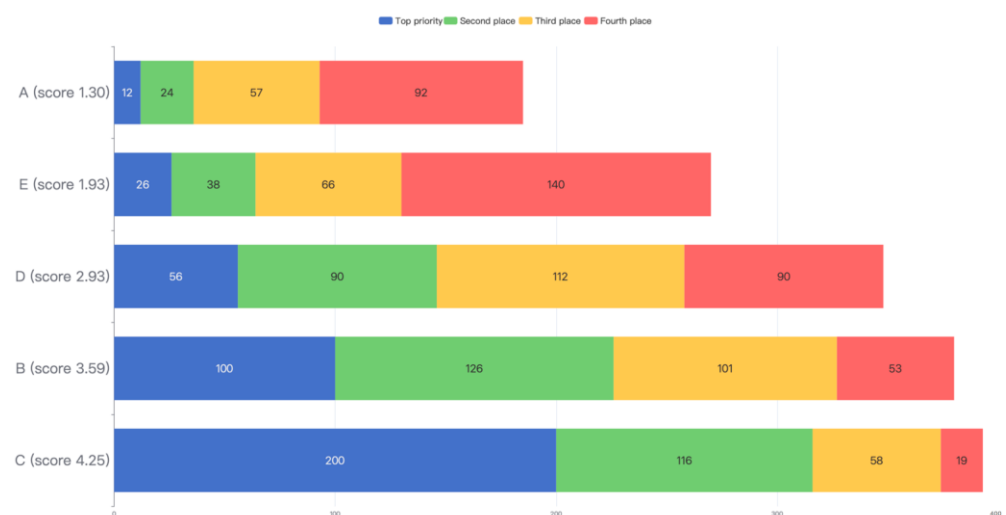


Figure 3. Emphasis on battery-swapping content concerns.

Figure 4 indicates that in terms of policies, consumers prefer the priority of lottery, no restrictions on driving, and parking fee discounts, reflecting the challenges faced by motor vehicles on the road in Beijing. In terms of infrastructure, consumers are more concerned about the supporting functions and services of battery-swapping stations, reasonable layout, and the time required for battery swapping.

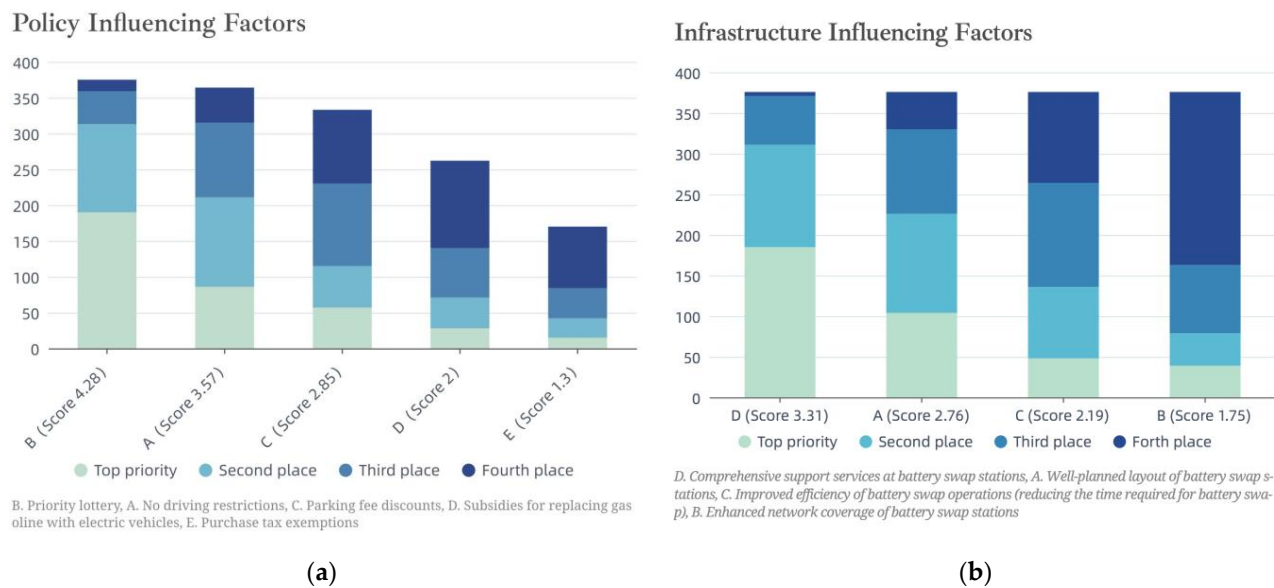


Figure 4. External influencing factors: (a) policy influencing factors; (b) infrastructure influencing factors.

4.2. Confirmatory Factor Analysis (CFA) for Scale Validation

To ensure the robustness of the structural equation model (SEM) analysis, this study conducted a CFA on the scale data. The results indicated that the scale data exhibited strong internal consistency, with the measurement model demonstrating sufficient composite reliability, convergent validity, and discriminant validity. This confirmed the reliability and validity of the research constructs.

The model fit assessment results revealed a chi-squared-to-degrees-of-freedom ratio (CMIN/DF) of 1.105, a Root Mean Square Error of Approximation (RMSEA) of 0.016, and goodness-of-fit indices including the Incremental Fit Index (IFI), Normed Fit Index (NFI), Comparative Fit Index (CFI), Goodness-of-Fit Index (GFI), and Adjusted Goodness-of-Fit Index (AGFI) all exceeding 0.9, indicating excellent model fit (see Table 2).

Table 2. Model fit test.

Metric	Reference Standard	Measured Results
CMIN/DF	1–3 for excellent, 3–5 for good	1.105
RMSEA	<0.05 were excellent and <0.08 was good	0.016
IFI	>0.9 for excellent, >0.8 for good	0.992
CFI	>0.9 for excellent, >0.8 for good	0.992
NFI	>0.9 for excellent, >0.8 for good	0.918
GFI	>0.9 for excellent, >0.8 for good	0.928
AGFI	>0.9 for excellent, >0.8 for good	0.914

The results of the reliability analysis and discriminant validity assessment indicate that the overall reliability coefficient of the scale is 0.94. Most of the standard factor loadings for measurement items exceed the threshold of 0.7, and both composite reliability (CR) and average variance extracted (AVE) values exceed the 0.7 and 0.5 thresholds, respectively. Furthermore, the standardized-factor-loading coefficients for all measurement items are above 0.5, indicating good reliability (see Table 3).

Table 3. Reliability analysis and convergent validity discrimination.

Latent Variable (Cronbach's α)	Number	Question Variable	Std.	CR	AVE
Attitude (0.663)	ATT1	I think it's very wise to introduce the switching mode right now	0.76	0.807	0.516
	ATT2	I think the switching mode is more convenient than the traditional charging mode	0.738		
	ATT3	I think the mode of changing electricity can bring greater changes and influence to the urban traffic	0.648		
	ATT4	I think the electricity changing mode has a bright prospect, which is also the trend of future development	0.86		
Perceived Usefulness (0.641)	PU1	The power changing mode can meet the long-distance energy supplement demand	0.761	0.809	0.519
	PU2	The electric changing mode can effectively solve the problem of no charging pile near my home	0.54		
	PU3	The power changing mode can significantly shorten the energy supplement time and improve the travel efficiency	0.742		
	PU4	The use of power changing mode can significantly reduce the car purchase expenditure (25–40%)	0.809		
Perceived Risk (0.83)	PR1	I am worried that the replaced battery will not meet the driving needs	0.918	0.838	0.514
	PR2	The distribution of electrical changing stations is not wide enough, resulting in too long queuing time	0.643		
	PR3	New energy vehicle battery standards are not unified, the battery may not be compatible	0.626		
	PR4	The switching mode is always expensive, and I worry that it will increase the economic burden	0.693		
	PR5	After-sales service (battery ownership, quality assurance) is not perfect, there are protection risks	0.666		
Perceived Behavioral Control (0.814)	PBC1	I understand the cost of using the switching mode	0.710	0.817	0.528
	PBC2	I have a good understanding of the advantages and disadvantages of the switching mode	0.681		
	PBC3	I can get the information about the power changing mode from multiple channels	0.738		
	PBC4	When I wanted to buy an electric car, I was convinced that I had the ability to buy it	0.773		
Technological Development (0.834)	TD1	The range increase strengthens my purchase intention	0.690	0.840	0.571
	TD2	The improvement of the changing technology will increase my confidence in the changing mode	0.698		
	TD3	Effectively controlled battery safety issues can ease my concerns	0.717		
	TD4	The replacement of the intelligent system will enhance my confidence to use the power changing mode	0.897		
Environmental Awareness (0.723)	ENV1	The electric changing mode is more significant to the global environmental protection than the charging	0.683	0.820	0.532
	ENV2	The use of electric changing mode can actively reflect the personal image and social responsibility	0.673		
	ENV3	The successful launch of the electricity changing model ecosystem is conducive to the country's low-carbon prospects	0.655		
	ENV4	The battery in the changing mode can be charged off peak to improve energy efficiency	0.677		
Subjective Norm (0.851)	SN1	My family supported me to adopt the power changing mode	0.92	0.874	0.635
	SN2	Relatives and friends support me to adopt the switching mode	0.734		
	SN3	The user's personal experience will influence my purchase decisions	0.784		
	SN4	The guidance of the public opinion on the electricity changing mode will affect my purchase decision	0.730		

Table 3. Cont.

Latent Variable (Cronbach's α)	Number	Question Variable	Std.	CR	AVE
Purchase Intention (0.842)	PI1	I would like to recommend the switching mode to my friends and family	0.743	0.836	0.560
	PI2	I want to use the products and services of the electric changing mode	0.716		
	PI3	I plan to use the products and services of the electric changing mode	0.787		
	PI4	I prefer to buy electric cars compared to the charging mode	0.747		

Discriminant validity tests reveal that the standardized correlation coefficients between all dimensions are less than the square root of the AVE values corresponding to those dimensions, demonstrating satisfactory discriminant validity (see Table 4).

Table 4. Discriminant validity test results for scale dimensions.

	Attitude	Perceived Usefulness	Perceived Risk	Perceived Behavioral Control	Technological Development	Environmental Awareness	Subjective Norm	Purchase Intention
Attitude	0.516	0.519	0.528	0.532	0.571	0.635	0.56	0.514
Perceived Usefulness	0.61							
Perceived Risk	0.588	0.521						
Perceived Behavioral Control	0.657	0.496	0.346					
Technological Development	0.59	0.432	0.311	0.979				
Environmental Awareness	0.548	0.515	0.379	0.287	0.29			
Subjective Norm	0.579	0.577	0.41	0.327	0.316	1.009		
Purchase Intention	0.573	0.494	0.603	0.364	0.353	0.38	0.411	
AVE value square root	0.718	0.72	0.727	0.729	0.756	0.797	0.748	0.717

4.3. Structural Equation Model Analysis

4.3.1. Comparison Among Theoretical Models

In this study, structural equation models were employed to compare the effectiveness of different combinations in explaining the purchase decision of battery-swapping EVs. Compared to other combinations, the fit indices of the structural model in this study were favorable (see Table 5). It was observed that the TAM explained 27.64% of the total variance, while the original TPB model explained 37.71% of the total variance. The combined model of TAM and TPB explained 60.11% of the total variance. When the modified TAM and TPB were further extended to include technological development and environmental consciousness, the structural model explained 72.35% of the total variance. Overall, the structural model used in this study outperformed TAM, TPB, and the combined TAM and TPB models in explaining the purchase decision of battery-swapping EVs.

Table 5. Structural model fit indices.

Fit Indices	χ^2/df	GFI	AGFI	PGFI	RMSEA	IFI	CFI	NFI	PNFI	PCFI
Acceptance Standard	<3.00	>0.9	>0.9	>0.5	<0.08	>0.9	>0.9	>0.9	>0.5	>0.5
TAM	1.105	0.928	0.914	0.639	0.014	0.992	0.992	0.918	0.745	0.771
TPB	1.119	0.959	0.941	0.717	0.017	0.996	0.996	0.961	0.798	0.827

Table 5. Cont.

Fit Indices	χ^2/df	GFI	AGFI	PGFI	RMSEA	IFI	CFI	NFI	PNFI	PCFI
The combined TAM and TPB model	1.089	0.953	0.939	0.731	0.015	0.996	0.996	0.950	0.798	0.836
Modified TAM and TPB Extensions	1.074	0.977	0.964	0.773	0.016	0.997	0.997	0.964	0.812	0.877

4.3.2. Path Relationships Between Purchase Intention and Attitude and Hypothesis Testing Results

Path analysis was employed to quantitatively assess the impact effects of causal relationships among latent variables, including direct effects (standardized path coefficients), indirect effects (the product of standardized path coefficients through intermediary variables), and total effects (the sum of direct and indirect effects). These effects, respectively, reflect the direct influence, indirect influence via intermediary variables, and overall influence of exogenous variables on endogenous variables. As shown in Table 6 and Figure 5, with the exception of hypotheses H1, H11, and H12, the absolute values of the path hypothesis coefficients (C.R.) in all models exceeded 1.96 (reaching a significance level of 95%). Therefore, hypotheses H2, H3, H4, H5, H6, H7, H8, H9, and H10 were supported, and these hypotheses were found to be valid.

Table 6. Path relationships and hypothesis testing results.

Hypothesis	Path Relationship			Standardized Path Coefficient	C.R.	p-Value	Test Results
H1	PU	→	PI	—	—	—	Rejected
H2	PU	→	ATT	0.314	4.733	***	Accepted
H3	TD	→	PI	0.250	3.487	0.048	Accepted
H4	ATT	→	PI	0.165	2.477	0.027	Accepted
H5	SN	→	PI	0.479	12.353	***	Accepted
H6	SN	→	ATT	0.192	2.114	0.036	Accepted
H7	PBC	→	PI	0.358	3.592	***	Accepted
H8	ENV	→	PI	0.448	4.461	***	Accepted
H9	ENV	→	SN	0.323	5.543	***	Accepted
H10	PR	→	PI	−0.612	−14.569	***	Accepted
H11	PR	→	ATT	—	—	—	Rejected
H12	PR	→	PU	—	—	—	Rejected

The “***” in the table represents statistical significance, indicating a p -value smaller than 0.001. It means the result is highly significant, providing strong evidence of a relationship between variables in the study. And the “→” symbol represents a path.

Firstly, in the expanded TAM, the standardized path coefficients of perceived usefulness on battery-swapping attitude and technology development on the purchase decision of battery-swapping EVs are 0.314 and 0.250, respectively, and both have passed the significance test at the 5% level. This suggests that the practical value brought to consumers by adopting battery-swapping technology has a significant positive impact on their attitudes towards the battery-swapping mode. Battery-swapping technology effectively reduces charging time by quickly replacing batteries, significantly enhancing the overall user experience. Users only need to visit a battery-swapping station before their battery is depleted, and they can complete the battery replacement in a matter of minutes, avoiding issues such as queuing at charging stations and long charging times. This approach also reduces the cost of large-scale charging infrastructure construction, thereby accelerating the development of electric vehicles and the establishment of a clean-energy transportation system.

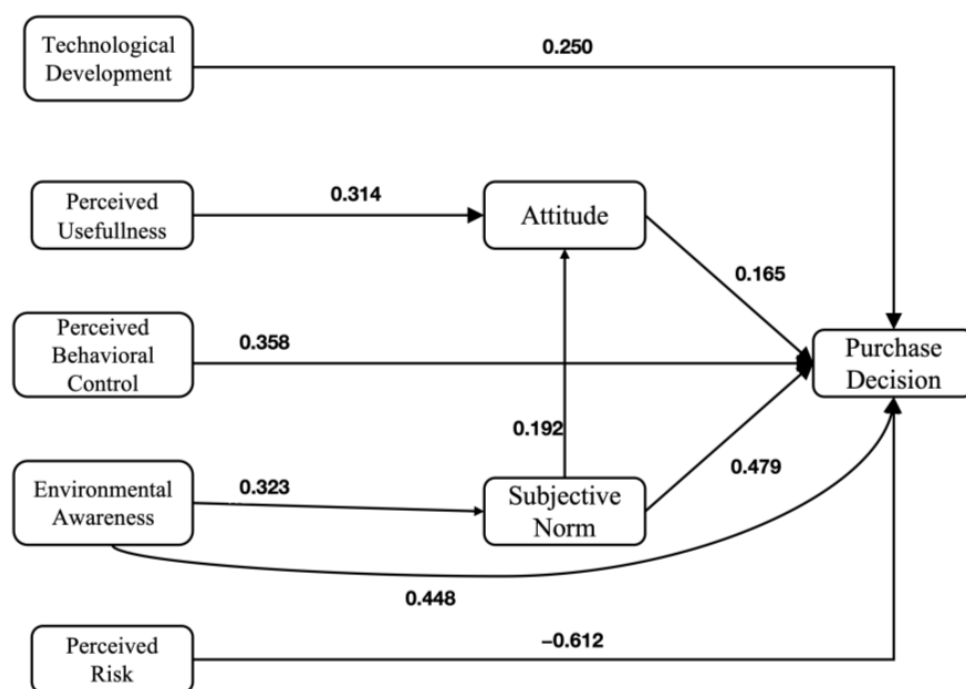


Figure 5. An illustration of the hypothesis testing results.

Simultaneously, the development of battery-swapping technology generates positive utility for consumers considering the purchase of battery-swapping EVs. Higher battery capacity and extended driving ranges imply longer single-trip distances, offering greater flexibility and convenience for users. This attracts consumers who require long-distance travel or prefer not to frequently charge or swap batteries. The charging speed and durability of the batteries reduce charging time and maintenance costs, increasing the attractiveness of battery-swapping EVs. Therefore, hypotheses H2 and H3 are supported.

Furthermore, within the extended TPB framework, the path coefficients between attitudes, perceived behavioral control, subjective norm, and the purchase decision of battery-swapping EVs were found to be 0.165, 0.358, and 0.479, respectively. All three paths passed the significance test at a 5% level, indicating that consumers' intuitive evaluations of battery-swapping models, their perception of control over acquiring battery-swapping EVs, and the social environmental factors they consider when making a purchase decision all have a significant positive impact on their purchase decisions. This confirms the validity of hypotheses H4, H5, and H7.

Notably, the standardized path coefficient of subjective norm on purchase intention significantly surpasses those of behavioral attitude and perceived behavioral control. This suggests that consumers' attitudes towards others' opinions, personal values, and moral standards are the primary factors influencing their purchase decisions. The standardized path coefficient of subjective norm on behavioral attitude is 0.192, passing the significance test at a 5% level, indicating that the social environmental factors consumers perceive when contemplating a purchase significantly positively influence their purchase decisions regarding battery-swapping EVs, confirming hypothesis H6.

Environmental consciousness exhibits standardized path coefficients of 0.448 and 0.323 on purchase intention and subjective norm, respectively, both passing the significance test at a 5% level. This illustrates that consumers' environmental consciousness has a significant positive impact on their purchase decisions regarding battery-swapping EVs and the social environmental factors they consider when making such decisions. Thus, hypotheses H8 and H9 are supported.

Lastly, the standardized path coefficient of perceived risk concerning purchase intention was -0.612 , indicating that safety concerns related to the power battery directly influence consumer purchase decisions. Consumers commonly prioritize battery stability, durability, and fire safety when contemplating a purchase. They are more inclined to choose brands and models that undergo rigorous testing, possess strong safety performance, and adhere to relevant certification standards, thereby maximizing their driving and property safety. Consequently, manufacturers must continuously enhance battery technology research and development, improve product safety and reliability, in order to gain consumer trust and support. This underscores that consumers' consideration of potential risks has a negative impact on their purchase decisions regarding battery-swapping EVs, supporting the validity of hypothesis H10.

4.3.3. Exploration of Mediation Effects Among Latent Variables

As evident from the path diagram in Figure 2, there are certain mediation effects among latent variables. The SEM-PLS bootstrapping method was employed to analyze these mediation effects, specifically examining the mediating roles of attitudes and subjective norms between several latent variables and purchase decisions. Based on the theoretical framework discussed earlier, a theoretical model (Figure 3) was selected to investigate the existence of mediation effects between latent constructs. The following hypotheses were proposed based on Figure 6.

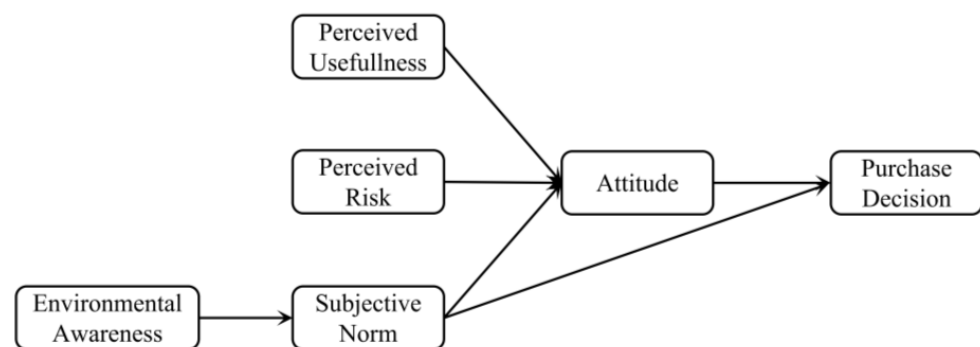


Figure 6. Theoretical model of mediation effects.

H13: *Attitude mediates between perceived usefulness and purchase decisions.*

H14: *Attitude mediates between perceived risk and purchase decisions.*

H15: *Attitude mediates between subjective norm and purchase decisions.*

H16: *Subjective norm mediates between environmental consciousness and purchase decisions.*

Table 7 presents the mediating effects of attitude and subjective norm on consumer purchase decisions. It was found that attitude positively mediates subjective norm and purchase decisions ($p < 0.05$), with an indirect effect value of 0.21. Subjective norm positively mediates environmental consciousness and purchase decisions ($p < 0.05$), with an indirect effect value of 0.24. The verification of hypotheses H15 and H16 indicates that attitude exhibits a significant mediating effect between subjective norm and purchase decisions, while subjective norm plays a significant mediating role between environmental consciousness and purchase decisions.

Table 7. Mediation analysis.

Path	Path Coefficient	p-Value	Mediation Path	Standardized Indirect Effect Value	Path	95% Confidence Interval	
						Lower Bound	Upper Bound
Perceived Usefulness → Attitude	0.363	0.005	Perceived Usefulness → Attitude → Purchase Decision	0.01	−0.03	0.029	
Perceived Usefulness → Purchase Decision	—	—					
Attitude → Purchase Decision	0.032	0.413					
Perceived Risk → Attitude	0.201	0.03	Perceived Risk → Attitude → Purchase Decision	0.006	−0.007	0.017	
Perceived Risk → Purchase Decision	—	—					
Attitude → Purchase Decision	0.028	0.351					
Subjective Norm → Attitude	0.417	0.005	Subjective Norm → Attitude → Purchase Decision	0.21	0.114	0.268	
Subjective Norm → Purchase Decision	0.58	0.002					
Attitude → Purchase Decision	0.241	0.002					
Environmental Awareness → Subjective Norm	0.292	0.003	Environmental Awareness → Subjective Norm → Purchase Decision	0.24	0.118	0.323	
Environmental Awareness → Purchase Decision	—	—					
Subjective Norm → Purchase Decision	0.86	0.003					

The “→” symbol represents a path.

4.4. Analysis of the Influence of Individual Attributes on Purchase Decisions of Battery-Swapping Electric Vehicles

The connection between respondents' individual characteristics and their purchase decisions is closely intertwined. Given the complex and diverse nature of individual attributes, a single characteristic may not be the most suitable for the group of consumers interested in purchasing battery-swapping electric vehicles. This study initially conducted a multifactor analysis of variance regarding the impact of gender, age, education level, occupation, and household per capita income on purchase decisions (see Table 8). The scores of the item variables on the purchase decision scale were weighted and averaged (see Table 9). The data revealed that the combination of gender, age, education, and occupation had the most significant effect. However, except for gender and occupation, age, education, and income did not reach statistical significance ($\text{sig} > 0.05$). Therefore, these five factors cannot independently influence consumer purchase decisions.

Table 8. Multifactor analysis of variance.

Source	Type III Sum of Squares	Degrees of Freedom	Mean Square	F-Value
Gender	10.635	1	10.635	5.111
Age	6.637	4	1.659	0.797
Education	11.059	3	3.686	1.772
Occupation	30.419	7	4.346	2.089
Income	2.15	4	0.538	0.258
Gender * Age * Education * Occupation	93.476	32	2.921	1.404
Error	403.656	194	2.081	
Total	9064.875	376		
Total after adjustments	817.213	375		

The “*” here represents the combination of the four variables, which is different from Table 6.

Table 9. Mean purchase intention.

Source	Variable	Average Purchase Intent
Gender	Male	4.56
	Female	4.83
Age	19–30 years old	4.54
	31–40 years old	4.84
	41–50 years old	4.44
	51–60 years old	4.63
	61–70 years old	5.44
Education	High school or below	4.60
	Associate degree	4.55
	Bachelor’s degree	4.82
	Master’s degree	4.69
Occupation	Corporate/Company employee	4.56
	Government or public institution employee	4.41
	Freelancer	4.69
	Worker	4.86
	Laborer in agriculture, forestry, animal husbandry, fishery, or water conservancy	4.62
	Professional and technical personnel	5.20
	Service industry employee	4.74
	Other	4.50
Income	Less than 50,000 yuan	4.77
	60,000–80,000 yuan	4.66
	90,000–120,000 yuan	4.70
	130,000–160,000 yuan	4.58
	Above 170,000 yuan	4.75

Gender-wise, the female car-buying market is on the rise, with women showing a greater inclination towards purchasing battery-swapping electric vehicles compared to men. Women exhibit a higher level of acceptance for battery-swapping electric vehicles, leading to a higher percentage of female owners of such vehicles in the new energy car market. Even when purchasing cars as a household unit, it is often female consumers who make the final decision. Compared to male consumers who may focus more on car performance, women tend to have simpler and more straightforward car requirements. Battery-swapping electric vehicles, with their simple construction, ease of maintenance, and durability, are more appealing to female consumers. These vehicles also feature novel exterior designs, a strong sense of modernity, and alignment with current trends, further catering to the psychological preferences of women.

Regarding age, the consumer group aged 31 to 40 is economically robust, and compared to the younger age group of 19 to 30, they have better financial conditions and a more forward-looking consumption philosophy, resulting in a strong willingness to purchase battery-swapping electric vehicles. On the other hand, consumers aged 40 and above tend to have a higher acceptance of traditional gasoline-powered cars and a relatively lower acceptance of battery-swapping electric vehicles.

In terms of education, consumers with bachelor’s degrees, compared to those with associate degrees or lower, possess more significant financial reserves and have a stronger inclination towards energy conservation and environmental protection concepts, making them more likely to purchase battery-swapping electric vehicles.

Regarding occupation, professionals and technical personnel are more receptive to new technologies and models, showing a preference for battery-swapping electric vehicles.

Income-wise, there is no significant differentiation in purchase decisions among different income groups.

5. Conclusions and Recommendations

5.1. Conclusions

Attitude, subjective norm, perceived behavioral control, environmental consciousness, and technological development have a positive impact on purchase decisions. Consumers who have a more favorable attitude toward purchasing battery-swapping electric vehicles, are influenced positively by societal environmental factors, possess stronger behavioral control, exhibit a higher degree of environmental consciousness, and encounter more advanced battery-swapping technology development, which offers convenience in operation, tend to have a stronger intention to purchase battery-swapping electric vehicles.

The perceived potential risks associated with battery-swapping electric vehicles have a negative influence on consumer purchase decisions. The stronger the perceived risks, the more significant the negative impact on purchase decisions.

Attitude plays an intermediary role between subjective norm and purchase decisions, while subjective norm mediates between environmental consciousness and purchase decisions. Consumers' direct evaluations of battery-swapping electric vehicles positively mediate their perception of societal environmental factors and purchase decisions. The perception of societal environmental factors positively mediates environmental consciousness and purchase decisions.

Consumer individual characteristics (gender, age, education, income) exhibit differentiation in their willingness to purchase battery-swapping electric vehicles. Female consumers are more inclined to purchase battery-swapping electric vehicles, and individuals in the age group of 31 to 40, as well as professionals and technical personnel, are more willing to purchase battery-swapping electric vehicles.

5.2. Recommendations for Relevant Measures

5.2.1. Government Level

It is recommended to accelerate the development and iteration of battery-swapping technology and standards at the government level. This includes standardizing battery-swapping interfaces, communication protocols, and battery sizes, which will establish a standardized foundation for battery swapping between different brands of electric vehicles. Strengthening the construction of battery-swapping infrastructure is essential while continuously optimizing the operating environment for battery-swapping electric vehicles to enhance convenience.

Furthermore, efforts should be made to promote energy conservation, environmental protection, and the "dual carbon" strategy through positive public opinion guidance. Specifically, promoting centralized battery storage and charging, unified management, and unified testing can effectively reduce safety risks such as fires caused by battery aging and improper charging. It can also mitigate the impact on the power grid, alleviate the safety hazards of overloading the grid due to high-current fast charging, and facilitate off-peak charging to improve energy utilization. This strategy can efficiently accommodate intermittent renewable energy sources like wind and solar power and accelerate the realization of the "dual carbon" strategy.

5.2.2. Enterprise Level

Enterprises are advised to strengthen investment in battery-swapping technology research and development to quickly establish a leading technological advantage. For instance, expediting the development of intelligent battery-swapping technology to reduce swapping time and enhance user experience is crucial.

Precision marketing should be implemented to identify target audiences promptly and increase consumer brand awareness. Particularly, targeting female consumers, those aged

30 to 40, individuals with bachelor's degrees, and professionals and technical personnel, companies should tap into the recognition of the advantages of electric vehicles among post-80s and post-90s generations. Expanding brand exposure through channels such as social media and offering customized services can be especially effective.

Furthermore, disseminating knowledge about battery-swapping technology can help reduce consumer anxiety and concerns resulting from information asymmetry regarding the technology and reliability of battery swapping.

6. Summary and Discussion

In this article, we expanded the structure of the TAM and TPB to construct a model for the purchase intention of electric vehicles. We found that multiple factors have direct or indirect effects on purchase decisions. Additionally, we analyzed the impact of consumer individual characteristics on the willingness to purchase battery-swapping electric vehicles.

At the government level, we recommend expediting the development and iteration of battery-swapping technology and standards, enhancing the construction of battery-swapping infrastructure, and continuously optimizing the operating environment for battery-swapping electric vehicles to improve convenience. Promoting energy efficiency and the efficient utilization of intermittent renewable energy sources, such as wind and solar power, to accelerate the realization of the “dual carbon” strategy is also advised. On the enterprise level, it is suggested that companies not only strengthen battery-swapping promotion but also delve into the development of related technologies. They should closely monitor the social and environmental sentiment that consumers perceive when considering purchases, effectively reduce the risk factors associated with battery-swapping vehicles, and fundamentally enhance consumers' willingness to purchase battery-swapping vehicles in response to the national calls for carbon peak and carbon neutrality.

Incorporating findings from previous studies, such as those by Adu-Gyamfi [8], it is evident that perceived risk significantly affects consumers' purchasing behavior, a result that aligns with the negative influence found in this study. Additionally, research by Zhang [2] further supports the positive impact of technological development on purchase intentions, which is also mirrored in the current research. The role of subjective norms and environmental consciousness, as highlighted by Lavuri [21], reinforces the mediation effects observed in this study, offering a more robust understanding of the purchase decision process for battery-swapping EVs.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/wevj16020085/s1>, This link include: Informed Consent Statement and Survey Questionnaire.

Author Contributions: Conceptualization, S.X. and G.H.; methodology, G.H.; software, G.H.; validation, G.H.; formal analysis, G.H.; investigation, G.H.; resources, G.H.; data curation, G.H. and H.H.; writing—original draft preparation, G.H. and H.H.; writing—review and editing, S.X. and G.H.; visualization, G.H. and H.H.; supervision, S.X.; project administration, S.X. and G.H.; funding acquisition, S.X. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Associate Professor Siyan Xu with the Beijing Municipal Natural Science Foundation (1222004), and North China University of Technology Yuyou talent project (107051360022XN708).

Institutional Review Board Statement: In China, non-interventional studies such as surveys, questionnaires, and social media research typically do not require ethical approval. This is in accordance with the following legal regulations: Measures of People's Republic of China (PRC) Municipality on Ethical Review; Measures for Ethical Review of Biomedical Research Involving People (revised

in 2016); Measures of National Health and Wellness Committee on Ethical Review of Biomedical Research Involving People (Wei Scientific Research Development [2016] No.11).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Conflicts of Interest: Hui Han is an employee of Beijing Engineering Corporation Limited. The paper reflects the views of the scientists, and not the company.

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