

Exploring User Acceptance of EV Charging Stations: The Mediating Role of Perceived Value In Chengdu, China

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Abstract

This study examines the factors influencing individuals' intentions to use electric vehicle (EV) chargers, focusing on perceived value, utility, ease of use, and familiarity with electric vehicles. Grounded in the Technology Acceptance Model (TAM), the research incorporates perceived value as a mediating variable to explore the relationships between these factors and their impact on user behavior. Data were collected from 454 respondents in Chengdu, China, through online and offline surveys. The findings reveal that perceived value mediates the relationship between EV knowledge and the intention to use public charging stations, as well as between perceived utility, perceived ease of use, and perceived usefulness. The results underscore the importance of service quality, reliability, and accessibility in shaping users' attitudes and intentions. These insights provide valuable guidance for stakeholders in the EV industry to enhance charging infrastructure and promote sustainable mobility solutions.

Keywords: electric vehicle (EV) charging stations, perceived usefulness, perceived ease of use, EV knowledge, perceived value, and the Technology Acceptance Model (TAM).

Introduction

Electric vehicles (EVs) have been identified as a means of reducing carbon emissions and promoting sustainable development, leading to a complete transformation in the global transportation industry due to their rapid adoption. However, this expansion has been accompanied by challenges, particularly in the optimization of EV charging infrastructure to meet consumer demands. Addressing these issues and ensuring the success of this transition necessitates a comprehensive understanding of the behavioral factors influencing users' intentions to adopt and utilize EV charging stations.

Even with the growing number of EV charging stations, consumers still face a variety of challenges, such as uneven charging rates, limited accessibility, and less-than-ideal user interfaces. This emphasizes the need for a deeper and more complex comprehension of the elements influencing user behavior. Building on earlier research, including the Technology Acceptance Model (TAM), this study examines how users' desire to use EV charging stations is influenced by perceived utility, perceived ease of use, EV awareness, and perceived value. By using perceived value as a mediating factor, the study provides insights into user behavior and strategies for pricing infrastructure optimization.

This study extends the Technology Acceptance Model (TAM) by incorporating an emphasis on EV charging stations, thus representing a significant contribution to the extant literature. By methodically examining the manner in which value, knowledge, utility, and

simplicity of use interact to influence user intention, it addresses lacunae in the extant literature. The findings provide practical advice for legislators, EV manufacturers, and charging station operators, with the aim of improving infrastructure, encouraging sustainable transportation practices, and increasing customer satisfaction. The study's conclusion advocates for the widespread adoption of EVs and the development of effective and convenient charging infrastructure.

RQ1. What impact does perceive usefulness, perceive ease of use and knowledge of EV have a factor as perceive value and intension of using charging piles.

RQ2. How does perceive usefulness, perceive ease of use and knowledge of EV affect intension of using charging piles?

Literature Review

2.1 Theory of Technology Acceptance Model (TAM)

One of the fundamental theories for comprehending technology adoption is the Technology Acceptance Model (TAM), which was created by Davis in 1989 and subsequently improved in 1993. By concentrating on two main factors—perceived utility (PU) and perceived ease of use (PEOU), it seeks to forecast how people will embrace and utilize new technologies. These elements affect users' behavioral intention to use a system, which in turn affects how often it is used. TAM is a crucial tool for analyzing user acceptance of technology since it expands upon the Theory of Reasoned Action and integrates psychological viewpoints into information systems research.

According to TAM, users' attitudes about technology are influenced by their judgments of its usefulness and ease of use, which are influenced by external factors such as system characteristics. Individual assessments of the advantages (usefulness) and the work needed (ease of use) form the basis of these perceptions, which are consistent with Bandura's theories of self-efficacy and outcome judgment as well as Rogers' diffusion of innovation theory, which highlights the perceived complexity of an innovation.

Key to TAM's predictive ability is its validation of multi-item scales that assess perceived ease of use and perceived usefulness. These constructs have been shown to reliably predict user acceptance, providing valuable insights for practitioners and researchers in technology design and adoption strategies (Davis, 1989; Davis, 1993).

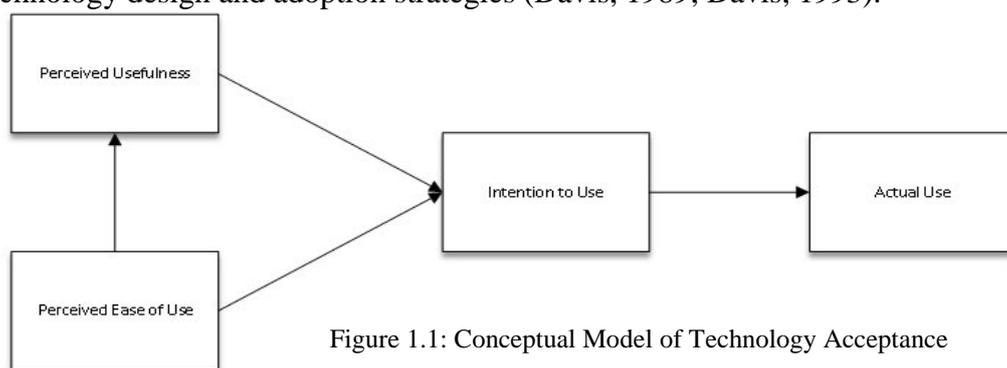


Figure 1.1: Conceptual Model of Technology Acceptance

2.2 Relevant Research Variables

-Intention of Use (IU)

The willingness of a user to use technology, service, or product is known as intention of use, and it is a direct predictor of actual user behavior. TAM emphasizes how usage intention is influenced by perceived utility and usability (Davis, 1989). Other elements that influence usage intention have also been found by research, including perceived value, social influence, and knowledge (Ling Keong et al., 2012; Venkatesh et al., 2003). These elements

highlight how crucial it is to match customer expectations with product design and provide favorable social and informational environments in order to promote adoption.

-Perceived Usefulness (PU)

The idea that utilizing technology will improve performance or satisfy user needs is known as perceived usefulness. PU, a fundamental component of TAM, has been validated as a predictor of both adoption and sustained use of technology (Davis, 1989; Venkatesh & Davis, 2000). Task relevance, prior experience, and social influence are among the factors that affect PU (Agarwal & Karahanna, 2000; Venkatesh et al., 2003). Useful products are more likely to be accepted by users and promote adoption.

-Perceived Ease of Use (PEOU)

The term "perceived ease of use" describes how simple users think a piece of technology is. It has a big impact on how people feel about utilizing technology (Davis, 1989). Research indicates that perceived utility and desire to use are directly impacted by simplicity of use (Venkatesh & Davis, 2000). Users' perceptions of ease of use are influenced by several factors, including training, system design, and prior experience (Hong & Tam, 2006; Thong et al., 2012).

-Knowledge of Electric Vehicles (KEV)

According to research, user intention to embrace electric vehicles is strongly influenced by knowledge about them. Increased understanding reduces skepticism and anxiety about technology and results in more positive attitudes regarding EVs (Cheng et al., 2019). Peer pressure and educational initiatives are essential for raising awareness and encouraging the adoption of EVs (Klein et al., 2018). An important factor in influencing how users view the utility and usability of EVs is their level of knowledge about them.

-Perceived Value (PV)

Users' overall evaluation of a technology's benefits in relation to its price is known as perceived value, and it has a direct influence on adoption decisions. Adoption is more likely when perceived value is higher (Zeithaml, 1988; Sweeney & Soutar, 2001). Research indicates that perceived value is shaped by functional, emotional, and social value dimensions, which in turn affect customer satisfaction and loyalty (Kim & Sullivan, 2019; Siegel et al., 2021). Designing and promoting products that satisfy consumers' expectations and increase adoption rates requires careful consideration of perceived value.

Fig.1.1 depicts the interrelationships between perceived usefulness, perceived ease of use, intention of use, and actual usage behavior. It highlights how external factors influence users' perceptions, which in turn shape their behavioral intentions toward adopting new technologies. The model underscores the importance of understanding cognitive and emotional responses to design systems that foster higher adoption rates.

The ongoing relevance of TAM in contemporary technology adoption research is demonstrated by this succinct overview of pertinent elements, especially when considering new technologies like electric cars and the infrastructure supporting their charging. When it comes to encouraging user adoption and enhancing user experiences with new technologies, the characteristics that have been discussed—intention of use, perceived usefulness, perceived ease of use, understanding of electric vehicles, and perceived value—continue to offer insightful information to both researchers and practitioners.

Research methodology

3.1. Data collection procedure

The researchers collected raw data through questionnaire surveys targeting Chinese individuals who own electric vehicles (EVs) and have used public charging stations in Chengdu, Sichuan, China. Offline surveys were conducted at high-traffic locations of EV charging stations, including Chunxi Road, Global Center, and Tianfu Square. Additionally, online surveys were distributed to reach a broader audience. A total of 230 valid offline questionnaires and 224 valid online questionnaires were obtained, resulting in 454 usable responses for analysis.

3.2. Measurement scales

The questions for all variables are sourced from various published journals, which use different content or phrasing to describe these variables. The perceived ease of use and perceived usefulness are adopted from Will & Schuller (2016), the knowledge of electric vehicles is adopted from Dash (2021), the perceived values are adopted from Zeithaml (1988), Kalsi and Singh (2019), and Appolloni et al. (2014), and the intention of use is adopted from He Sun and Luo (2022).

Sampling

4.1. Sampling

The majority of respondents (95.15%) were locals, with a small percentage (4.85%) being non-locals. Gender: The gender distribution was fairly balanced, with 51.98% males and 48.02% females, minimizing potential gender bias. Most respondents were between 21-30 years old (51.98%) and 31-40 years old (30.84%), indicating a younger sample. Respondents aged over 41 were less represented. The education level was relatively high, with 57.05% holding a bachelor's degree and a combined 42.95% holding other higher qualifications. Most respondents earned between 6,000 to 9,000 yuan per month (51.32%), followed by 3,000 to 6,000 yuan (32.82%). Lower-income (under 3,000 yuan) and higher-income (above 9,000 yuan) groups were less represented. The majority were ordinary employees (52.2%), with a smaller percentage in specialized roles (16.52%). Other professions, such as students and drivers, were less represented.

Table 4.1 Descriptive statistics.

Items	Variab les	Percenta ge (%)	Items	Variables	Percenta ge (%)
Local User	Yes	95.15	Income (monthly)	Less than 3000 RMB	4.40
	No	4.85		3000-6000 RMB	32.18
Gender	Male	52.31		6000-9000 RMB	51.85
	Female	47.68		More than 9000 RMB	11.57
Age	18-20	3.93	Occupatio n:	Student	8.80
	21-30	51.39		Driver	11.11
	31-40	31.71		Employees	52.78
	41-50	9.03		Commissio	16.67

	More than 51	3.93		ner / enterprises	
				Others	10.65
Educational level	Lower than bachelor's degree	25.69			
	Bachelor's Degree	56.71			
	Higher than Bachelor's Degree	17.59			

4.2. Descriptive Analysis of Charging Station Usage

Table 4.2 shows: Intention to Use Charging Stations: The respondents' intention to use charging stations showed moderate to positive levels, with average values ranging from 3.26 to 3.56, close to the neutral point (3).

A standard deviation between 1.133 and 1.154 indicated some variation in the respondents' views, reflecting different experiences and trust in charging stations.

Charging Station Attributes: Reliability & Maintenance: Respondents had a generally positive view on the reliability and maintenance of the charging stations, with items like "charging equipment in good condition" (3.82) and "maintenance issues resolved promptly" (3.80) scoring the highest.

Convenience & Location: The convenience and location of charging stations were also rated positively, with "convenient location" (3.76) and "accessibility for people with disabilities" (3.63) scoring high, showing recognition for the distribution and accessibility of stations.

Standard deviations ranged from 1.012 to 1.207, indicating some variation, particularly regarding convenience and efficiency across different locations.

Knowledge of Electric Vehicles: Respondents generally had a solid understanding of electric vehicles, with "understanding the technical differences between electric and fuel vehicles" (3.85) receiving the highest score. However, knowledge on specific topics like charging connectors showed greater variation, with the highest standard deviation (1.334) indicating differing levels of awareness among respondents.

Value of Charging Stations: Respondents believed that charging stations added value to their electric vehicle ownership experience, with the highest score for "charging service adds significant value" (3.74).

However, the perceived quality of the charging experience was somewhat lower, with "providing a high-quality charging experience" scoring 3.58.

Standard deviations ranged from 1.040 to 1.206, indicating varying opinions on the value and quality of the charging stations. The highest standard deviation (1.206) indicated greater differences in views regarding how charging services enhance the vehicle ownership experience.

Overall, the sample showed a positive but varied perception of electric vehicle charging stations, with differences in attitudes based on location, convenience, reliability, and the value provided by the service.

Table 4.2 Mean & Standard Deviations

Variable	Mean	S.D.
1. Intention of use		
1.1 I plan to use the charging station frequently in the future.	3.50	1.154
1.2 I would recommend the charging station to a friend or family member.	3.26	1.147
1.3 I would consider looking for charging stations in different locations to meet my charging needs.	3.56	1.133
2. Perceived Usefulness		
2.1. The charging station is reliable (e.g., high uptime, minimal outages).	3.63	1.036
2.2. Maintenance issues are resolved promptly.	3.80	1.060
2.3. I think the charging equipment is in good overall condition.	3.82	1.052
2.4. I think issues with the charging station are easy to report and resolve.	3.62	1.031
2.5. I think the charging price is reasonable and transparent (e.g., per kWh, per hour).	3.44	1.065
2.6. The price of the charging service is good value for money.	3.69	1.036
3. Perceived Ease of Use		
3.1. Charging stations are conveniently located.	3.76	1.158
3.2. Charging stations are easily accessible.	3.49	1.207
3.3. The charging process is efficient.	3.32	1.184
3.4. Different charging connectors and compatibility options are available.	3.37	1.178
3.5. Charging stations are integrated into navigation apps for easy finding.	3.52	1.062
3.6. Charging stations are accessible to people with disabilities	3.63	1.012
4. Knowledge of Electric Vehicles		
4.1. I understand how electric vehicles (EVs) differ in technology from traditional gasoline-powered vehicles.	3.85	1.218
4.2. I am familiar with the various types of electric vehicle charging connectors and their compatibility.	3.74	1.334
4.3. I know the average range of most electric vehicles on a single charge.	3.82	1.047
4.4. I am aware of the different battery technologies used in electric vehicles.	3.76	1.028
4.5. I understand the maintenance requirements unique to electric vehicles compared to traditional vehicles.	3.74	0.952
5. Perceived Value		
5.1. Does the charging station provide high-quality charging experience?	3.58	1.114
5.2. Is the cost of charging reasonable relative to the value you receive?	3.64	1.112
5.3. Does using the charging station make your experience with your electric vehicle more convenient?	3.55	1.040
5.4. Does the charging service add significant value to your electric vehicle ownership experience?	3.74	1.206

4.3 Validity of Model

To ensure the validity of the measurement model, Confirmatory Factor Analysis (CFA) was conducted. The model's goodness-of-fit was assessed using key indices, including Chi-square/df, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Root Mean Square Error of Approximation (RMSEA). The results indicated an acceptable model fit, confirming that the measurement model adequately represents the underlying constructs.

Table 4.3 Model fit indices

Model	χ^2 /df	G FI	A GFI	N FI	I FI	C FI	R MR	R MSE A	T LI
Measurement model	1.141	.964	.952	.873	.982	.982	.031	.028	.978
Structure model	1.344	.943	.930	.806	.940	.938	.036	.028	.933

Note: Recommend index $\chi^2/df \leq 3$, RMR ≤ 0.08 , RMSEA ≤ 0.08 , NFI ≥ 0.90 , IFI ≥ 0.90 , TLI ≥ 0.90 , CFI ≥ 0.90

Discussions

This study aimed to explore the factors influencing Chengdu locals' willingness to use public electric vehicle (EV) charging stations. By analyzing data from 454 respondents, the research identified key variables related to users' intentions to charge at these stations, including their knowledge of EVs, perceived value, ease of use, and station convenience.

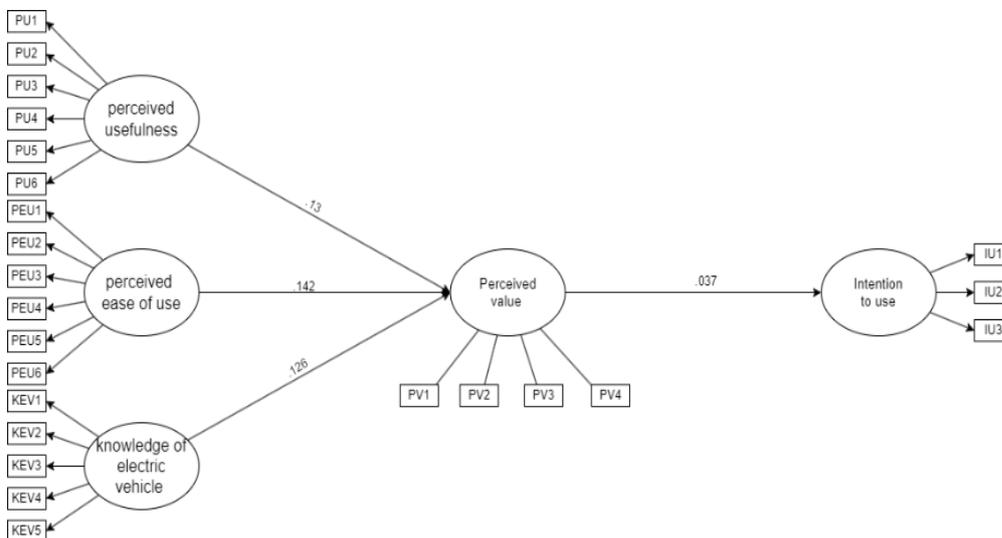


Figure 4.1 Structural model

Table 5.1 Findings from mediation analysis

The analysis of perceived usefulness (PU) on intention to use (IU) through perceived value (PV) reveals that the indirect effect is statistically significant, with a value of 1.531 and a 95% confidence interval of [0.197, 2.302]. PV plays a full mediating role, indicating that PU does not directly influence IU but impacts it indirectly through PV. This suggests that users' perception of a feature's usefulness enhances their intention to use only when it is accompanied by a strong sense of value.

Similarly, the impact of perceived ease of use (PEU) on IU through PV demonstrates a significant indirect effect of 1.651, with a 95% confidence interval of [0.136, 2.304]. PV acts as a full mediator in this relationship, meaning that the effect of PEU on IU is primarily achieved indirectly through PV. While the direct effect of PEU on IU is not statistically significant, the mediating role of PV significantly influences users' behavioral intentions.

Finally, another analysis of PEU's impact on IU through PV confirms a significant indirect effect of 1.664, with a 95% confidence interval of [0.101, 2.235]. Once again, PV

Path	Effect	Effect Size	Bias-corrected 95%CI		Results
			<i>Lower</i>	<i>Upper</i>	
H1	Indirect effects	1.531	0.197	2.302	Full mediation effect
H2	Indirect effects	1.651	0.136	2.304	Full mediation effect
H3	Indirect effects	1.664	0.101	2.235	Full mediation effect

serves as a full mediator, demonstrating that PEU's contribution to IU is realized entirely through its impact on PV. The findings emphasize the critical role of perceived value in shaping user decision-making.

Implications

Theoretical Contributions

An extension of the Technology Acceptance Model (TAM) is proposed. This study builds upon TAM by incorporating perceived value as a mediating factor between perceived usefulness, perceived ease of use, and EV knowledge on user intention. In doing so, the research offers a detailed examination of the complex interplay between these factors and their influence on user behavior in the context of EV charging stations.

Insights into EV Charging Station Adoption: The present study contributes to the limited existing literature on the factors affecting the usage of EV charging stations by focusing on psychological determinants (e.g., perceived value) and user knowledge. This framework provides a foundation for future studies investigating technology adoption in sustainable transportation.

Understanding Consumer Knowledge and Perceptions: By analyzing users' knowledge of EV technology and their perceptions of value, this study highlights the importance of

informational and experiential factors in technology adoption, providing a basis for further theoretical exploration.

The following section presents the practical contributions to the field.

The following guidance is intended for those responsible for the operation of charging stations. The study identifies the principal user expectations regarding ease of use, reliability, and service quality. Operators may therefore seek to enhance customer satisfaction and encourage regular usage by leveraging these key user expectations. Proposals to enhance the accessibility and maintenance of charging stations can assist providers in meeting user demands effectively.

Implications for Marketing Strategies: The findings on perceived value and environmental benefits indicate that a marketing strategy should emphasize both the economic and eco-friendly aspects of EV charging. Operators and policymakers may utilize this insight to develop campaigns that align with users' values and perceptions, thereby promoting increased EV adoption.

The development of policy for sustainable mobility: The insights derived from this study can inform the development of targeted incentives and educational programs designed to address gaps in EV knowledge and promote sustainable energy use. Policies that emphasize the environmental benefits and cost-effectiveness of electric vehicles (EVs) and charging stations may encourage their adoption on a larger scale.

The enhancement of the user experience is a key objective. The study identifies specific areas for improvement in the user experience, including transparent pricing, convenient location, and reliable service. These insights can inform the allocation of resources for infrastructure development, with the objective of enhancing the EV charging ecosystem and user satisfaction.

These contributions emphasize both the academic value and the real-world applications of the findings, offering actionable insights for the advancement of the EV charging station industry and the support of sustainable mobility initiatives.

Practitioner contributions

This study underscores the pivotal role of perceived usefulness, perceived ease of use, and perceived value in influencing user intention to adopt charging stations. Practitioners, including charging station operators and designers, can leverage these findings to optimize the design of charging stations. Enhancing features such as faster charging speeds, intuitive interfaces, and prompt maintenance services can considerably improve perceived usefulness and ease of use, thereby increasing user adoption rates. The strategic placement of charging stations in high-traffic and easily accessible areas, emphasizing convenience and accessibility as key factors in perceived ease of use, is identified as a crucial aspect of this research. This approach ensures that users experience minimal effort in locating and using charging facilities, thereby increasing overall satisfaction and usage.

The findings of the study indicate that users perceive the pricing of charging services as moderately fair but see potential for greater transparency and uniformity. In order to enhance trust and promote utilization, charging station providers are advised to implement standardized and transparent pricing models, as well as advocate the long-term cost benefits of electric vehicles. The study also demonstrates that users' awareness of electric vehicles has a direct impact on their perceived value and the intention to use charging stations. Policymakers and EV manufacturers can implement educational campaigns to increase public awareness of EV benefits, technical aspects, and charging compatibility. These educational initiatives have the potential to mitigate user uncertainties and cultivate greater confidence in EV adoption.

It is imperative that policymakers use this research as a basis to formulate regulations and incentives that align with user preferences and behaviors. For example, the provision of subsidies for the development of charging infrastructure or the introduction of tax benefits for EV users has the potential to further enhance the perceived value of electric vehicles and accelerate their adoption.

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