A Survey on Willingness to Use and Satisfaction with New Energy Vehicle Charging Piles in Shijiazhuang Rural Areas under the Background of Dual Carbon

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Abstract:*Under the background of "double carbon", China actively promotes the development of new energy vehicles, and charging piles and other infrastructures have become key. This study focuses on the rural areas of Shijiazhuang, aiming to analyze the current situation of charging piles, identify and solve problems, and help new energy vehicles to the countryside. The study adopts a survey questionnaire to investigate the rural population in ten counties and three county-level cities around Shijiazhuang, and finds that the layout of rural charging piles is unreasonable, the number is insufficient, and there are barriers to their use through text mining, descriptive statistics, cross-tabulation analysis, decision tree modeling, K-modes cluster analysis, and structural equation modeling. Users can be categorized into long-distance high-frequency fast-charging, close-distance convenience type, and medium-distance planning type, and the quality of facilities, convenience and other factors significantly affect satisfaction and willingness to use. Based on this, the study proposes optimizing the layout, making charging prices transparent, simplifying the APP, increasing the number, deepening the environmental protection publicity, improving the infrastructure, and exploring multi-dimensional use, in order to promote the development of charging piles and new energy vehicles in rural areas.*

Keywords:*new energy vehicles to the countryside, charging piles, text mining, K-modes cluster analysis, structural equation modeling, decision tree analysis, green economy, rural revitalization*

1. Chapter I. Introduction

1.1. Background of the study

Against the backdrop of addressing the global climate crisis, China has actively integrated into global governance to promote sustainable development, and has put forward a "dual-carbon" goal of achieving "carbon peaking" by 2030 and "carbon neutrality" by 2060. In August 2024, the National Development and Reform Commission (NDRC), the General Administration of Market Supervision (GAMS), and the Ministry of Ecology and Environment (MOE) jointly issued the "Action Program on Further Strengthening the Construction of Carbon Peak Carbon Neutral Standards and Measurement System", which specifies the timetable and roadmap for the formulation and implementation of standards in the field of "dual carbon" from 2024 to 2025. The program specifies the timetable and roadmap for the development and implementation of standards in the field of "dual carbon" from 2024 to 2025. The transportation industry, as one of the industries with high carbon emissions, will mainly promote new energy vehicles and cleaner fuels in order to realize the greening of traffic and transportation of people and goods [1] . The development of new energy vehicles is China's road from a large automobile country to a strong automobile country, and is also a strategic initiative to respond to climate change and promote green development. According to the international consulting organization Garter forecast, in 2025 the global new energy vehicle ownership amounted to 85 million vehicles, China's new energy vehicle ownership amounted to 49 million vehicles, accounting for nearly 57.6% of the global share. China has become the world's largest new energy vehicle market, with production, sales and ownership ranking first in the world for nine consecutive years since 2015 [3] .

Meanwhile, according to the Notice on the 2024 New Energy Vehicle Rural Activities jointly issued by the General Office of the Ministry of Industry and Information Technology, the General Office of the National Development and Reform Commission, the General Office of the Ministry of Agriculture and Rural Affairs, the General Office of the Ministry of Commerce and the Comprehensive Department of the National Energy Administration, the development of new energy vehicles in rural areas is the top priority, and we should focus on the development of new energy vehicles in rural areas to help the new energy vehicles to the countryside to promote the revitalization of the countryside.

As new energy vehicles continue to grow explosively, charging piles have entered a high-speed construction phase. At present, although the construction of charging infrastructure has shown a rapid development trend, but by the geographical environment and economic factors, the distribution of China's charging infrastructure in urban and rural areas in 2024 shows significant differences, with the number of charging piles in urban areas far exceeding that in rural areas. Factors such as decentralized charging demand and grid capacity limitations have led to a lag in the construction of charging piles in rural areas.

The new energy sector is the high point of future competition among major countries, and the public vehicle sector will be fully electrified in the future. Therefore, it is necessary to scientifically layout and accelerate the construction of charging infrastructure, actively promote the integration of electric vehicles and information and communication development, and improve the level of intelligence and the ability of charging service in public places. This paper will combine literature research, case studies and questionnaire surveys to analyze the factors and reasons that affect customer satisfaction with charging piles, so as to formulate a customer satisfaction improvement strategy for some rural areas in Shijiazhuang in line with their own business development characteristics, and to better satisfy the needs of today's social and economic development as well as the high standard of service demanded by users of new energy vehicles.

1.2. Literature review

1.2.1.Current status of related research in China

1.2.1.1. Status of charging facilities

Studies have shown that factors such as the number of electric vehicle charging piles, charging standards, charging products, and planning layout in China have become one of the bottlenecks in the development of electric vehicles. Zeng Zhifei (2019) pointed out that China's electric vehicles are in the stage of industrialization and development, and charging piles, as an important supporting infrastructure necessary for the application and development of electric vehicles, have very important social and economic benefits. Facing the problems of non-uniform charging pile interface standards, poor service information sharing, unsatisfactory use, and uneconomical charging costs, it is proposed to coordinate the interests of all parties in order to accelerate the construction of charging piles in residential areas, to establish a sharing mechanism to enhance the efficiency of charging pile use, to improve the quality of information services and the investment environment, and to rationally distribute and accelerate the construction of charging facilities [4] . QiZhang, HailongLi (2018) et al. argue that limited driving range, charging duration and lack of charging infrastructure become one of the barriers affecting the development of the electric vehicle market. Among them, the underdevelopment of public charging infrastructure, especially fast charging infrastructure, is the most important barrier to accelerate the popularization of electric vehicles. Factors affecting the economics of public charging infrastructure for electric vehicles include facility profitability, charging demand and price, operating costs, location environment, technological factors, policy development, consumer psychology and behavior [5] . Liu Yingqi, Zhang Jing (2019), et al. argue that one of the effective solutions for China to promote industrial structure upgrading and realize energy saving and emission reduction is to develop the electric vehicle industry, in which the charging facilities as the supporting infrastructure affects and restricts the popularization and application of electric vehicles. The planning layout, business model, market development, policies, related industry chain and stakeholders of charging infrastructure are analyzed, and it is believed that the charging infrastructure industry chain is in the stage of continuous expansion, with the gradual increase in the number of industry chain stakeholders, the number of private enterprises, the emergence of new industrial roles in the industry chain, and the gradual integration of the industry chain's upstream and midstream will become the trend of the future development, and will also give rise to the emergence of new Business Models [7] .

1.2.1.2. Charging Product Research

Lin Xiaodan (2023) argues that the current urban charging infrastructure has exposed many problems in the construction of charging piles due to its low utilization rate, including the lack of charging pile operation and maintenance, safety hazards, quantity distribution, cost price and charging speed. She pointed out that charging infrastructure is different from gasoline pumps in gas stations, which are not equipped with professional management personnel, and are in an open environment for a long time, which are greatly affected by natural environmental factors, and are prone to safety hazards such as aging of charging pile lines, leakage of electricity, and oxidation of body materials, etc. It is necessary to improve the quality of charging piles, and to take certain measures to strengthen the protection of the charging pile body. Secondly, it is necessary to analyze the demand of electric vehicle users to ensure the reasonable distribution of charging piles, and parking lots and residential areas are the main areas where charging piles are focused on construction [9] . Wu Hengfei (2019) elaborated on the types of mainstream charging facilities for electric vehicles, pointing out that the current construction of charging piles appears to be cumbersome in the approval process and complicated in the coordination department, the charging equipment is faulty and difficult to maintain, and the business model is imperfect, and it is difficult for the enterprise to make profits and other problems, which impedes the development of electric vehicles. Therefore, it is necessary to put forward relevant solutions from supporting policies, tariff differentiation, enterprises themselves and business models [10] . Zhang Di (2022) believes that the development of supporting charging piles is lagging behind hindering the development of new energy vehicles, and the problems of China's charging piles do not only exist in the product and technology level, but also appear in its construction, operation and maintenance process, and puts forward standardized countermeasures. The technical defects of charging pile products include five aspects: charging speed is too slow, the architectural design of charging pile is unreasonable, charging interface standard is not unified, DC charging communication protocol has differences, and product quality control to be strengthened. She proposes to separate the functions of charging piles modularly, which is convenient for their maintenance and updating, conducive to standardized production, and actively promote the unification of charging interface standards and DC charging communication protocols. For public charging pile installation, construction and maintenance management, should improve the relevant standards and laws and regulations, in the use of public charging pile process, unified operation interface and operation process, reduce the user threshold. Zhang Di pointed out that private charging piles are in the ascendant, but there are many difficulties in the installation and construction, maintenance and management, user use, etc. The implementation of government-enterprise linkage, the adoption of "unified planning, unified construction, unified operation" management mode, more conducive to the development of private charging piles [11] .

1.2.2.Current status of related research abroad

Plenter (2018) conducted an exhaustive charging post willingness to pay survey for a customer base of mid-sized urban utilities in Europe. The results of the study revealed customers' payment preferences for different locations and types of charging piles, and these results were communicated to P2P platforms in the form of price recommendations so that customers could have a comprehensive understanding of charging services [12] . In their study on the deployment of new energy vehicle charging infrastructures by local governments in Australia, DwyerScott et al. (2021) proposed a local government interest-based business canvas methodology aimed at assessing the risks and potential benefits of different business models [14] . Anthopoulos et al. (2021) provide a detailed examination of the ownership structure of new energy vehicle charging infrastructure in Greece and the related operational market model, finding that limited direct vendor investment has a significant impact on driving the Greek electric vehicle charging infrastructure market, even if not with the economic development as the primary goal, but focuses on environmental and sustainability aspects [15] BonsPieterC et al. (2021) conducted a systematic study of the large-scale demonstration project "FleRpower" with 432 public charging stations in Amsterdam between 2019 and 2020, analyzing the project's performance in terms of the number of charging stations. Analyzing the results of this systematic study, it is clear that flexible charging is an approach that will significantly reduce the growing demand for EV chargers and that charging power needs to be continuously increased to meet the growing demand for charging and to ensure a high degree of compatibility with sustainable energy sources, effectively avoiding overloading of the grid.[16]

1.3. Purpose and significance of the study

1.3.1.Research purpose

As a strategic emerging industry, new energy vehicles are included in the "14th Five-Year Plan", accelerating the construction of charging infrastructure, promoting new energy vehicles, stimulating new consumer demand, and boosting industrial upgrading has become a new focus. Charging is the primary problem faced by electric vehicles, but due to the unsatisfactory interconnection and interoperability of charging facility platforms, inconvenient use of charging products, non-uniformity of payment platforms, and insufficient intelligence of charging facilities, users need to complete a variety of steps in order to complete charging. Therefore, the use of charging piles, services, and the construction of supporting public facilities will all become factors that affect the user's charging experience, and the construction of charging systems is imminent. This study will coordinate the relationship between the charging system and the surrounding facility environment according to the real needs of users, improve the user charging experience, and make the electric vehicle charging system have a relatively reasonable service system and ecological environment.

1.3.2.Research significance

With the rapid increase in the penetration rate of electric vehicles, the convenience of charging has gradually become a focus of attention.

As far as the future development trend is concerned, the electric vehicle urban charging system is indispensable, although it has certain difficulties and development bottlenecks. The past research direction of electric vehicle charging system is mostly in the direction of technology and energy, and there are fewer researches from the perspective of service system design. By optimizing the service system to improve the charging infrastructure operation efficiency and user experience, we can provide high-quality services for multiple user roles such as charging infrastructure users, operators and builders, and promote the benign development of charging facilities.

According to the market scale of electric vehicles and user charging demand, systematically formulate the service system and service process of charging infrastructure, comprehensively improve the operational efficiency of charging infrastructure, conform to the national policy guidance, and provide reference for the optimization of electric vehicle charging system service design.

1.4. Research methodology

1.4.1.Documentary research method

To collect and organize the domestic and foreign materials related to the keywords "electric vehicle, charging system, service design" in the last five years, to obtain the key information and to lay the foundation of the dissertation, which is to analyze and research the charging system from the design perspective and to identify the design opportunity points of the subject.

1.4.2.Case study method

Public charging facilities and private charging facilities are selected for case studies to understand their various business functions and operation modes, and to build a more comprehensive understanding of the subject.

1.4.3.Field research method

Conducted field research on charging facilities in some areas of Shijiazhuang City, to get a close understanding of EV users and vehicle charging process, and observe the surrounding supporting public facilities and services. Communicate with the user interviews, mining the user's real demand, for the next step of user analysis to make guidelines.

Figure 1: Rural public charging posts

1.4.4.Text mining

Text mining is the process of extracting hidden information from structured or unstructured text data through computer technology. A large amount of text data was crawled by web crawlers, and word frequency statistics were performed based on the cleaned data to extract key points, analyze them, and generate word cloud diagrams to visualize the issues to be studied. Sentiment analysis was also carried out to study the respondents' sentiment (negative, positive, and neutral) through word frequency statistics and word cloud diagrams.

1.4.5.Tescriptive statistical analysis

Describing and presenting the data as a whole by calculating and summarizing the basic characteristics of the data. For example, analyze the frequency or proportional distribution of age, gender, education, etc.

1.4.6.Decision tree analysis

Decision tree analysis is a rule-based machine learning method that learns from data to obtain data classification and prediction laws for different values of input and output variables and is used to classify and predict new data objects, which is done by constructing a tree-like graph (decision tree) to represent the relationship between the features of the data, the decision rules, and the results.

1.4.7.K-modes cluster analysis

K-modes cluster analysis is a center-based clustering algorithm for categorical data that iteratively groups samples into K classes such that the sum of the distances between each sample and the center or mean of the class it belongs to is minimized.

1.4.8.Structural equation modeling analysis

Through the combination of measurement and structural models, the relationship between latent and observed variables is analyzed.SEM is not only able to test complex theoretical models, but also deal with complex relationships such as mediating and moderating effects, improving the depth and breadth of research.

1.5. Research ideas

In order to carry out the relevant analysis and research more comprehensively and clearly, we constructed a flow chart of the relevant research ideas to show the relevant steps and ideas more intuitively.

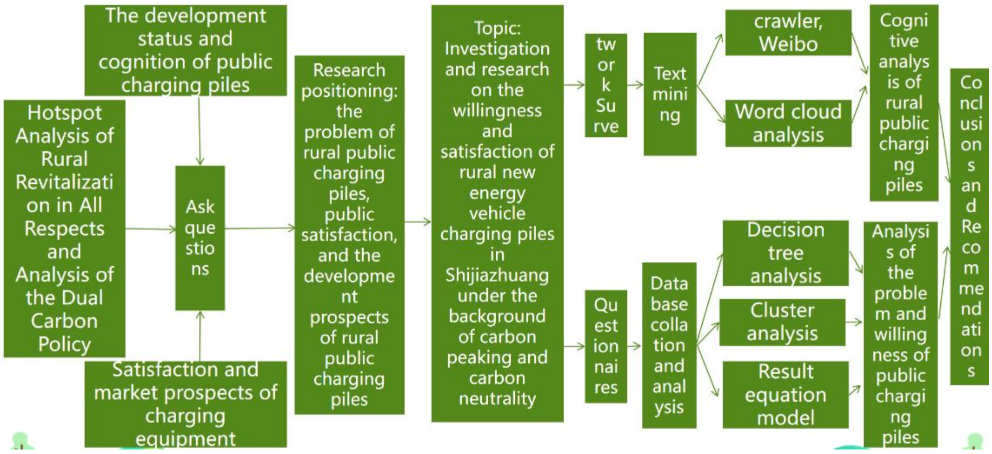

Figure 2: Flow chart of research ideas

1.6. Research Innovation Points

1.6.1.Innovative Text Mining

This study crawls relevant data on social platforms through methods such as web crawler in big data technology, performs word frequency statistics, sentiment analysis and word cloud statistics, analyzes user data in depth, and mines out the needs of different user groups to provide more accurate references for the upgrading and innovation of charging piles.

1.6.2.Innovations in research themes

This study takes the infrastructure of new energy vehicles in rural Shijiazhuang as an entry point, and does not limit itself to the development of new energy vehicles, but starts from deeper influencing factors to explore the impact of the development of charging piles on the development of new energy vehicles in rural areas, and only by constructing a more complete infrastructure system will rural users be more willing to use charging piles and purchase new energy vehicles.

Meanwhile, since the urban-rural distribution of charging infrastructure in China shows significant differences, with the number of charging piles in urban areas far exceeding those in rural areas, and since the state vigorously develops new energy vehicles to the countryside to help rural construction and countryside revitalization, we set our investigation target in the rural area of Shijiazhuang to explore the development and construction of public charging piles in rural areas.

Traditional research focuses on the construction quantity and layout of charging piles for new energy vehicles, but lacks research and analysis on factors driving users to buy new energy vehicles, charging method preference, charging frequency and duration of charging piles, satisfaction with charging piles, and intelligent demand, thus failing to truly meet users' needs. Through data analysis and survey research, this paper analyzes in-depth user demand for charging pile supporting facilities, so as to provide more targeted suggestions for the optimization of charging pile layout and function improvement.

1.6.3.Innovation in research methodology

For the rural charging pile use characteristics, this study adopts the research method of cluster analysis, and because the topic to be studied is a categorical variable, we did not analyze it with

K-means, but based on K-modes clustering of the use characteristics of rural charging pile,, the users are divided into group characteristics, the research method is more accurate.

On the question of exploring the factors of satisfaction and willingness to use, we used structural equation modeling, which can better deal with the complex relationship between multiple variables involving latent variables, meanwhile, since the scale questions in the questionnaire design of this study utilized mature scales, we conducted a validation factor analysis to confirm that the factors had better convergent validity and internal consistency before conducting the analysis.

2. Text Mining Analysis of Rural Chargers

This research utilizes Houyi collector for data collection, crawling microblogs and their comment areas for relevant information about charging piles for new energy vehicles, then counting high-frequency words, performing sentiment analysis, and generating word cloud diagrams based on word frequency statistics to visualize and present more intuitively the problems and related suggestions that the respondents encountered in the process of using charging piles.

2.1. Word frequency statistics

According to the above steps, we collected data twice ("barriers to the use of charging piles" and "suggestions and concerns about the use of charging piles"), and collected about 1,500 pieces of data respectively, and then we cleaned and standardized the collected data to remove duplicated data. After that, we cleaned and standardized the collected data, removed duplicated data, processed the collected data by word division (to prevent "charging pile" from being divided into "charging", etc.), and finally carried out word frequency statistics, and Tables 1 and 2 are the statistics of high-frequency words.

Table 1: Word frequency statistics for barriers to use of charging piles

word (general term including monosyllables through short phrases)	proportions	word (general term including monosyllables through short phrases)	proportions	word (general term including monosyllables through short phrases)	proportions
Difficulty in charging	7.20%	Technical immaturity	4.72%	incompatible	3.35%
small number	6.96%	Insufficiently rationalized structure	4.60%	Still need to speed up construction of charging facilities	2.98%
slow charging	6.34%	Floor locks have a super high failure rate	4.47%	service	2.73%
take time	6.34%	State Grid App Positioning	4.47%	reportedly	2.36%

your (name)	6.09%	Offset Displays available pile arrivals in full fault status	4.22%	new energy vehicle	2.11%
hard find	5.96%	Delayed charging completion prompt	3.85%	step	1.74%
Boosting Charging Piles	5.96%	Poor signal in basement causes code scanning failure	3.60%	long term continuous travel or use	1.37%
a safety hazard	5.22%	Charging cost calculation is confusing	3.35%		

Table 2: Word frequency statistics of usage suggestions and concerns of charging piles

word (general term including monosyllables through short phrases)	proportions	word (general term including monosyllables through short phrases)	proportions	word (general term including monosyllables through short phrases)	proportions
Charging pile coverage	7.52%	government subsidy	5.88%	More charging posts in the countryside please	3.43%
Increase the number of charging posts	7.35%	final kilometer	5.56%	long line of charging vehicles	3.27%
Improved charging speed	7.35%	mileage	5.23%	Accelerating the construction of charging infrastructure	2.78%
Battery Safety	6.86%	Charging pile installers have a lot of tricks up their sleeves.	4.58%	Helping new energy vehicles to the countryside	2.45%
Improvement of support policies	6.37%	hard to find a pile of	4.41%	Insufficiently rationalized structure	2.29%
Do the maintenance work	6.21%	New Energy Vehicles for the Countryside	4.41%	people's livelihood	1.63%
flat fee	5.88%	Building green mobility	3.92%	Difficulty in charging	1.31%

	Boosting Charging Piles	1.31%

2.2. Emotional analysis

We have analyzed the word frequency statistics in the previous section, and we can see from Table 1 that most of the high-frequency words are words with negative emotions because we are analyzing the problems encountered by users in the process of using charging piles. ", "it is understood that", "new energy vehicles", "measures", "range " are neutral words without emotional tendency, accounting for 26%; through the emotional analysis of netizens' barriers to the use of charging piles in the network, we can see that netizens are more dissatisfied with the use of charging piles, and encounter a variety of problems.

As can be seen from the word frequency statistics of suggestions and concerns about charging piles in Table 2, most of the high-frequency words are neutral as we are analyzing respondents' suggestions and concerns about charging piles, while a few words, such as "charging pile installers have a lot of tricks", "the structure is not reasonable enough" and "charging is difficult", express their dissatisfaction. A few words, such as "charging pile installers have too many tricks", "structure is not reasonable" and "charging is difficult", expressed their dissatisfaction. From the type of suggestions and concerns raised by netizens, netizens' concerns about charging piles are mainly gathered in "coverage of charging piles" and "charging speed", etc., and they hope to improve the charging piles more strongly, and the scope of suggestions and concerns is also wider. The scope of their suggestions and concerns is also relatively wide, and they have made suggestions for the improvement and upgrading of charging piles, and have directly hit the pain points and problems of existing charging piles.

2.3. Word cloud statistics

Finally, a word cloud map is generated, through which specific analysis and suggestions for improvement are made.

2.3.1. Word cloud map analysis of barriers to charging pile use

The core contradiction of charging pile experience includes four dimensions: insufficient infrastructure, economic pressure, safety risk and technical performance shortcomings, reflecting that there are still significant shortcomings in the current charging service. The high-frequency words "difficult to charge" and "small number" point out the contradiction between infrastructure layout and user demand; "expensive" reflects the economic controversy brought about by the superposition of electricity price, service fee and various costs, which dissuades some consumers; "security risks" discourages some consumers; and "safety risks" discourages some consumers. The "safety hazard" shows the lack of equipment maintenance, which weakens users' trust and hinders the development of the new energy vehicle industry; and "slow charging" highlights the lack of popularization of fast charging technology and aging equipment, which makes it difficult to meet users' expectations for high-speed charging. It is difficult to meet users' expectations for high-speed charging.

2.3.2.A word cloud analysis of charging pile usage recommendations and concerns

The core demand of users for charging pile service is not only insufficient infrastructure (e.g., "coverage of charging piles", "increase the number of charging piles"), but also the hope that charging piles will be systematically upgraded, including technical efficiency ("improve charging speed"), safety guarantee ("battery safety") and policy support ("government subsidies", "improve support policies") and other dimensions. Charging speed"), safety ("battery safety") and policy support ("government subsidies", "improve support policies") and other dimensions. This shows that the charging pile industry is facing the pressure of transformation from "scale expansion" to "quality optimization": users not only demand to expand the coverage of charging piles to solve the "difficult to find piles" problem, but also hope that technological innovation can solve the problem of "difficult to find piles", and also hope that the charging pile industry can solve the problem of "difficult to find piles" through technical innovation. Users not only demand to expand the coverage of charging piles to solve the problem of "difficult to find piles", but also hope to solve the problem of charging efficiency through technological innovation, and at the same time, they highly hope that the state can introduce relevant policies to reduce the cost of use and reduce the safety risks. The key words "battery safety" and "government subsidies" further reflect users' concerns about the long-term credibility and sustainability of charging piles - if the economy of charging services, If the economy, safety and convenience of the charging service cannot be improved at the same time, it may dampen consumers' confidence in traveling with new energy vehicles.

In order to solve the above problems, it is necessary to build a full-cycle improvement strategy of "short-term relief + long-term optimization": in the short term, it is necessary to give priority to expanding the number of charging piles, reasonably adjusting the charging fees, making the fees transparent, so as to alleviate the controversy over the costs, and at the same time, it is necessary to carry out a special investigation of hidden safety hazards, repairing the faults of the equipment, and strengthening the on-site management; In the medium and long term, it is necessary to improve the charging speed of charging piles, upgrade the old equipment, improve the charging efficiency and compatibility, and build an intelligent charging network. In addition, it is recommended to establish a real-time response mechanism for user feedback, publicize the status of piles, cost details and safety reports through the App, and utilize information transparency to regain the trust of users, solve the problem of charging difficulties, and ultimately enhance the user's experience.

3. Design of the investigation program

3.1. Investigation program

3.1.1.Survey purpose

Through the questionnaire survey, to understand the public on the use of new energy vehicle charging pile status quo and its satisfaction survey, so as to establish a reasonable and scientific charging pile application system, in order to reduce the new energy vehicle charging difficult situation. This survey is mainly to determine based on the dual-carbon background, different groups of the public for the use of new energy vehicle charging piles of the satisfaction of the survey, help to recognize the current new energy vehicle charging piles of the use of the process of the problems, so as to target measures to further improve the use of new energy vehicles in the process of the inconvenience, to do a more convenient initiative to help new energy vehicles to the countryside, and promote the revitalization of the countryside. Revitalization.

3.1.2.Survey design

3.1.2.1.Content of the survey

The survey mainly focuses on Shijiazhuang people's use of new energy vehicle charging piles in Shijiazhuang, satisfaction and willingness to use, aiming to find out the current situation of the public's use of new energy vehicle charging piles and existing problems, and integrate the unreasonable distribution of public charging piles and the problems encountered when charging, and put forward reasonable opinions and countermeasures, so as to improve Shijiazhuang people's sense of well-being in the use of new energy vehicles and contribute to the carbon peak. The aim is to improve the happiness of Shijiazhuang citizens in the use of new energy vehicles, and to contribute to the Carbon Summit.

The structure and theme of the survey content is mainly reflected in the design of the questionnaire structure, which is divided into three parts overall:

(1) Basic information about the investigator; and

(2) Individuals' feelings about the use of charging methods for new energy vehicles (charging method, charging duration, charging frequency, etc.).

(3) Survey on public satisfaction with public charging posts for new energy vehicles (distribution of public charging posts, quality of equipment in public charging posts, convenience of public charging posts, etc.)

3.1.2.2.Target audience

The selected respondents for this survey were rural villages in three county-level cities in ten counties of Shijiazhuang (Yuanzhi, Jingfu, Zhengding, Xingtang, Lingshou, Gaoyi, Shenze, Zanhuang, Wuji, Zhao, Xinji, Jinzhou, Xinle), and also included rural children studying or working outside the countryside, friends and relatives visiting the local villages, as well as tourists traveling to the villages, and so on.

3.1.2.3.Method of investigation

（1）Visit and discuss

Before distributing the questionnaire online, after obtaining the consent of the other party, we found people from the relevant villages online, and conducted preliminary interviews on WeChat and other online communication tools, and used the questionnaire's topics and logic as the outline of the interviews, with a high degree of autonomy and flexibility for in-depth excavation.

At the beginning of the interview, first of all, it should be clear that the purpose of this interview is for academic research, and assure the other party of the privacy of this interview to establish trust; in the questioning process, it should be carried out in accordance with the outline of the questioning, with continuity, avoiding jumps, and the language should be straightforward and commonplace, avoiding guiding words; in the process, it should be paid attention to the interviewee's answers to the record; and finally, the data should be sorted out and entered.

（2）Online questionnaire distribution

Questionnaire survey is a survey method in which the investigator uses a uniformly designed questionnaire to learn about the situation from the selected respondents or to solicit their opinions. It collects information by posing questions in writing, and the researcher prepares a questionnaire with the questions to be studied and fills in the answers either in person or on the Internet, so as to understand the views and opinions of the respondents on a certain phenomenon or issue.

In this study, the pre-survey takes offline distribution of network questionnaires, and the formal survey relies on the investigators to use the online method of filling out network questionnaires for the distribution of questionnaires in the ten counties of Shijiazhuang as well as the three county-level cities, and the respondent's consent to voluntarily fill out the questionnaire after the questionnaire.

And in order to ensure the accuracy of the target audience and that the people who fill out the questionnaire are from the corresponding villages selected in the questionnaire, we negotiated with the interviewee and, after obtaining his or her consent, requested him or her to help us distribute the online questionnaire in the village, post the QR code of the questionnaire in places with high traffic in the village, or distribute the questionnaire on platforms such as the circle of friends, thus guaranteeing that the questionnaire we distributed was sent to the selected sample villages.

3.1.3.Sample design

3.1.3.1.Objective in general

The target population of this survey was mainly people in the rural areas of the ten counties and three county-level cities around Shijiazhuang, including rural children studying or working abroad, friends and relatives visiting the local villages, and tourists traveling to the villages.

3.1.3.2.Sampling methods

This survey was conducted mainly based on the population size of each area to fill out the questionnaire, and then the respondents were surveyed by adopting random sampling and stratified sampling, and finally the results obtained were summarized.

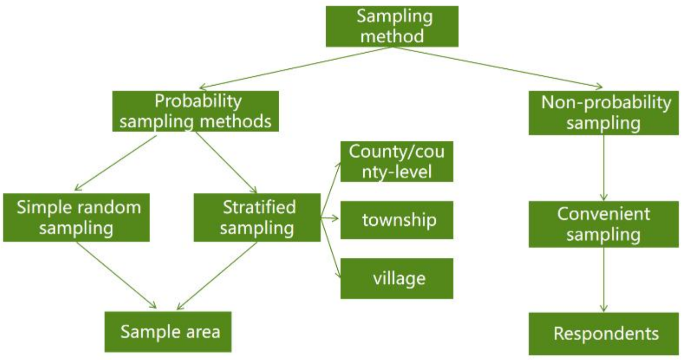

Figure 3: Flow chart of sampling method

In the formal questionnaire survey process, we will survey methods used for the combination of probability sampling and non-probability sampling, mainly including simple random sampling, stratified sampling, convenience sampling, probability sampling to determine the area of the sample, non-probability sampling to determine the respondents. The sampling flow chart is shown in Figure 4. Simple random sampling and stratified sampling are mainly adopted in this probability sampling.

Simple random sampling is based on randomly selecting samples from the whole, ensuring that each sample is selected with exactly the same probability, while the complete randomness of simple random sampling avoids the perceived bias of selection, improves the credibility of the survey, and improves the basis of inference for subsequent data analyses, such as calculating confidence intervals to determine the sample size.

Stratified sampling is mainly to divide the whole population into a certain number of strata according to certain characteristics, and this study is divided into three levels: county/county-level cities, townships, and villages, and is able to independently and randomly draw samples from the strata to improve the precision of sampling and further enhance its credibility.

The main type of non-probability sampling used is convenience sampling. Convenience sampling is to take the most accessible and conveniently available individuals of the whole as a sample, the core of which is the selection of the sample according to the needs of the investigator, rather than randomness and representativeness, this method can immediately carry out the survey and research, and for a specific scenario of the population can soon obtain the preliminary feedback results.

According to the breadth and depth of the data investigated in this paper, simple random sampling and stratified sampling can be utilized for specific data analysis, while for a certain type of population in the data analysis can be taken as a convenience sampling to carry out a specific analysis, to improve the relevance and effectiveness of data analysis. This paper is mainly based on three stages of analysis:

Stage 1: All primary units were sampled 100% by using ten counties and three prefectural-level cities around Shijiazhuang as primary sampling units. At the same time, the total sample size is allocated according to the proportion of the total population in the region to get the sample size of the corresponding counties and prefecture-level cities.

Stage 2: All townships in the ten counties and three prefectural cities around Shijiazhuang are taken as secondary sampling units, and the sampling ratio is used to determine the number of secondary units, and simple random sampling and stratified sampling methods are used to draw the corresponding number of secondary sampling units.

Unit 3: In the corresponding counties and prefectures and townships, the corresponding villages are used as survey sites, and data analysis is carried out on the completion of the questionnaires by the respondents, while non-probability sampling with convenience sampling is used to analyze a specific type of population for the purpose of preparing for the subsequent determination of the sample size.

3.1.3.3.Allocation of sample size

（1）Pre-survey

Target population: people in some rural areas of three county-level cities in ten counties around Shijiazhuang in the conditions of the symbolic questionnaire survey.

Survey method: The form of offline distribution of network questionnaires is used to allow people who meet the survey conditions to fill in the questionnaire as they go.

Content of the survey: through the form of network questionnaire, for the study of the theme and its content for repeated research and discussion, and collect the network respondents on the questionnaire, for some controversial, too far from the actual life and unnecessary questions for screening and deletion, and the questionnaire in the order of a slight adjustment, for the subsequent formal investigation to lay a solid foundation.

Findings: In the questionnaire survey, 120 questionnaires were filled out and 98 were valid.

（2）Determination of sample size

According to the formula for estimating the minimum sample size in a sample survey, the acceptable sampling limit error E was chosen to be 4.2% with a confidence level of 95% (Z=1.96) and the estimation ratio p was taken as 0.5.

N is the overall number, take the value of t when the share is 95%,t=1.96,p is the sample proportion,d is the absolute permissible error,d=0.04, according to the pre-survey results p=0.55. the optimal sample size can be approximated as:

$$n \approx \frac{Z^2 * P(1-P)}{E^2} = \frac{1.96^2 * 0.5 * 0.5}{0.042^2} \approx 5\ 44$$

The final sample size collected was 577 based on the optimal sample size based on the different number of people in each county and county-level city as well as the questionnaire invalid questionnaire due to uncertainty in the data collection or other reasons.

In this survey process, due to the existence of invalid questionnaires and unreasonable questionnaires, after excluding these questionnaires, there were 506 valid questionnaires, and the validity rate of the questionnaires was 87.69%.

3.1.3.4.Determination of final sample size

Table 3: Sample Distribution of Survey Respondents

District/County Level City	Number of persons (10,000)	Sample size (persons)	Effective number of persons (persons)
Yuanzhi county in Honghe Hani and Yi autonomous prefecture, Yunnan	31.56	43	38
Jingfu county in Hubei	30.33	42	39
Zhengding county in Wanzhou suburbs of north Chongqing municipality, formerly in Sichuan	42.35	56	50
Xingtang county in Hebei	30.27	42	39
Lingshou county in Ningxia	31.77	43	36
Gao Yi county in Honghe Hani and Yi autonomous prefecture, Yunnan	32.36	44	40
Shenze county in Honghe Hani and Yi autonomous prefecture, Yunnan	33.85	45	39
Zhanhuang county in Zhanjiang suburbs of Chongqing municipality, formerly in Sichuan	32.39	44	40

Wuji county in Fuling suburbs of Chongqing municipality, formerly in Sichuan	33.56	45	40
Zhao county in Shaanxi	31.76	43	37
Xinji prefecture level city in Henan	33.26	45	40
Jinzhou prefecture level city in Hebei	30.27	42	33
Xinle city in Gansu	31.57	43	35
(grand) total	424.6	577	506

Table 4:Secondary sampling frames

Counties/prefecture level cities	Township name
Yuanshi County	Huaiyang Town,Songcao Town,Nanyin Town,Yincun Town,Nanzuo Town,Jicun Town,Macun Town,Beichu Town
Jingcheng County	Weishui Town,Shang'an Town,Tianchang Town,Xiulin Town,Nanyu Town,Weizhou Town,Xiaozuo Town,Nanjiao Town
Zhengding County	Zhengding Town,XinchengpuTown,Xin'an Town,Nangang Town,Quyangqiao Town,Nanniu Town
Xingtang County	Longzhou Town,Nanqiao Town,Shangbei Town,Oral Town,Duyanggang Township,Anxiang Township
Lingshou County	Lingshou Town,Qingtong Town,Tashang Town,Chenzhuang Town,Ciyu Town,Chatou Town
Gaoyi County	Gaoyi Town,Daying Town,Fucun Town,Wancheng Town,Zhonghan Township
Fukazawa County	Shenze Town,Tiegang Town,Zhaoba Town,Daqiaotou Town,Baizhuang Township,Liucun Township
Zanhuang County	Zanhuang Town, Yuantou Town, Nanxingguo Town, Zhangshiyan Town, Xilongmen Town, Xiyangze Town, Xuting Town
Wuji County	Wuji Town,Qiji Town,Zhangduangu Town,Beisu Town,Guozhuang Town,Dachen Town,Lichengdao Town,Donghoufang Town
Zhao County	Zhaozhou Town,Fanzhuang Town,Beiwangli Town,Xinzhaidian Town, Hancun Town, Nanbaishe Town,Shahedian Town
Xin Bazaar	Xincheng Township,Nanzhiqiu Township,Wangkou Township,Tiangongying Township,Qianying Township,Mazhuang Township,Hemujing Township,Tianjiazhuang Township,Zhonglixiang Township,Xiaoxinzhuang Township

Jinju City	Yingli Town,Zongshizhuang Town,Taoyuan Town,Mayu Town,Dongzhuosu Town,Xiaoqiao Town,Huaishu Town,Donglizhuang Town,Zhoujiazhuang Township
Xinle City	Pengjiazhuang Hui Township,Cheng'an Town, Handai Town,Matoupu Town, Dongwang Town,Dugu Town,Zhengmo Town,Nandayue Town

Table 5: Three-level sampling units

Counties/prefecture-level cities	Township name
Yuanshi County	Akara,Umemura
Jingcheng County	Weishui Village,Wuliu Village
Zhengding County	Xiaoke Village,Zhufutun Village
Xingtang County	Shuiquan Village,Gujun Village
Lingshou County	Liujia Village,Frozen Village
Gaoyi County	Dongyitou Village, Yulin Village
Fukazawa County	Duanzhuang Village
Zanhuang County	Stone Monument Village
Wuji County	Beihu Village,Fotang Village
Zhao County	BeizhuangVillage,Songcheng Village
Xin Bazaar	Miaojiaying Village,Dumping Village
Jinju City	Nie Village,Pang Village
Xinle City	Pengjiazhuang Village,FengmingVillage

3.2. Survey implementation

Before carrying out the survey work, we first systematically understood the relevant processes and learned the relevant knowledge to ensure that the survey work and the subsequent analysis and report writing work went smoothly.

3.2.1.Survey Time Flow

In order to better ensure that the survey work as well as the entry process is carried out properly, we have formulated a work schedule to complete the relevant content at the specified time to ensure the normal progress of the follow-up work. Specific time schedule and content allocation.

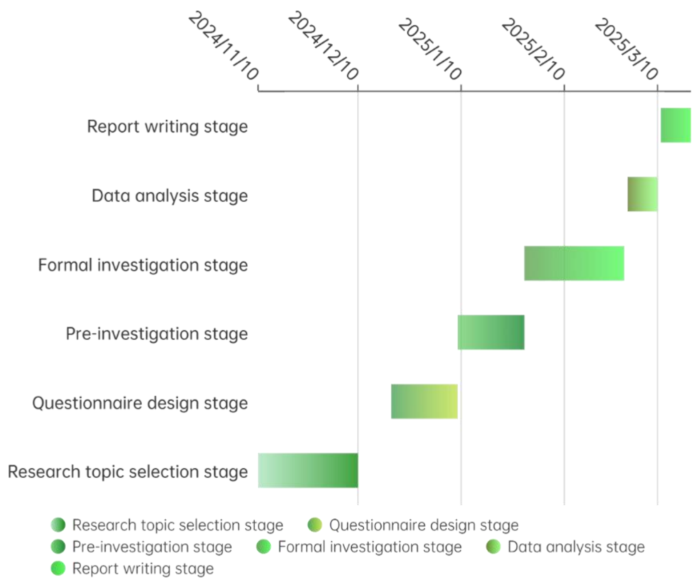

Figure 4: Investigation workflow diagram

3.2.2.Control of survey data volume

3.2.2.1.Pre-survey preparation

Before the formal survey, all members of the survey team to further determine the content and purpose of the survey, to ensure that each member of the survey has a correct and unified understanding of the content of the survey, and to further define the target population and the scope of the survey, to ensure the rigor and accuracy of the selected samples. At the same time, the members of the group were trained on the questionnaire, so that everyone was familiar with the questionnaire, mastered the communication skills and enhanced the sense of responsibility.

Pre-survey with the designed questionnaire, preliminary analysis of the results of the pre-survey, fine-tuning the questionnaire for the pre-survey results of the analysis of the fine-tuning of the questionnaire, in preparation for the subsequent formal survey.

3.2.2.2.Quality control in surveys

Considering that some respondents may encounter difficulties in filling out the online questionnaires, we adopted the offline distribution of online questionnaires during the pre-survey process by going to the corresponding villages and letting the person scan the code to fill out the questionnaires after obtaining the respondents' consent.

During the survey process, controls the process of respondents' filling in the questionnaire, helps those who are illiterate to fill in the questionnaire, or explains the questionnaire to those who are not clear enough and have doubts about the questionnaire, so as to ensure the quality of the data. Through the above methods, it is also possible to record the shortcomings of the pre-survey questionnaire, which can be used to optimize the follow-up questionnaire.

3.2.2.3.Post-investigation processing

For quality control in the survey process, mainly through the questionnaire star background technical restrictions (WeChat authorization login / cell phone authentication code login); IP address restrictions, the IP address outside of Shijiazhuang questionnaire to be excluded; answer time restrictions, the answer time of less than 60 seconds is considered to be an invalid questionnaire to be excluded; and finally, through the questionnaire answer logic to screen, the logic of the questionnaire does not make sense is considered to be an invalid questionnaire to ensure the authenticity of the respondents in the survey process. The authenticity of the respondents in the survey process, for the suspected identical questionnaires or unrealistic questionnaires are recorded in detail to ensure the rigor of filling out the questionnaires, and maximize the efficiency of the data recovered from the questionnaires.

3.2.2.4.Quality control at the data entry stage

During data entry, since the data can be directly exported from the background of Questionnaire Star, we only need to carry out the corresponding quality control on the basis of the exported data. IP address, answer time, questionnaire answer logic screening, identified which are invalid questionnaires, and eliminated, in order to avoid the elimination of valid questionnaires or omission of invalid questionnaires, so we carried out a number of data cleansing, and finally verified, as a way to prevent the loss of key data, to ensure the validity of the subsequent survey data.

3.2.3.Error analysis

In the data processing, to take into account the sampling time simple random sampling and stratified sampling in the existence of the error, as well as the questionnaire part of the questionnaire expression of the ambiguity of the respondents' understanding of the bias, within a certain range, a reasonable increase in the sample size, strict standardization of the survey process, for each filled out questionnaires, a number of audits, and will be out of the outliers, to ensure the rationality of the data for the follow-up of this issue puts forward a strong guarantee. Ensure the rationality of the data, and provide a strong guarantee for the follow-up of this issue.

4. Data Processing and Testing

4.1. Data processing and testing of pre-surveys

After completing the design of the questionnaire, we conducted a trial distribution of the questionnaire based on the sampling frame in some rural areas of the 13 districts and counties included in the sample, and a total of 120 questionnaires were recovered. Based on the recovered questionnaires, the data were item analyzed and tested for reliability and validity to check the identification of the questionnaire topics, the reliability of the measurement results and the validity of the questionnaire.

4.1.1.Reliability testing

Reliability refers to the consistency, stability and reliability of the measurement results of a questionnaire. Simply put, it is whether the results of the same questionnaire are stable and reliable when measuring the same group at different times and in different contexts; the higher the reliability coefficient, the higher the credibility of the questionnaire results. In this paper, Cronbach's α (Alpha) reliability coefficient method is used to test the reliability of the questionnaire, generally $\alpha \geq 0.9$, indicating very good reliability, $0.8 \leq \alpha < 0.9$ indicating better reliability, $0.7 \leq \alpha < 0.8$ indicating acceptable reliability.

We uniformly used the software SPSS 20.0 to test the reliability of the questionnaire and the results of the analysis are shown in the table below.

Table 6: Reliability analysis table for each question item of the pre-survey

subject	Cronbach's Alpha	Cronbachs alpha based on standardized terms	item count (of a consignment etc)	reliability assessment
Q8	0.783	0.781	4	acceptable level
Q25	0.788	0.787	4	acceptable level
Q26	0.813	0.813	5	favorable
Q27	0.835	0.834	5	favorable
Q28	0.821	0.821	4	favorable

As can be seen from the above table, the overall Cronbach's Alpha value of the questionnaire and the Cronbach's Alpha value of each scale question item is greater than 0.7, therefore, the questionnaire has a high reliability.

4.1.2.Validity check

Validity refers to the accuracy and validity of a questionnaire's measurement objectives, i.e., whether the questionnaire truly reflects the concepts that the researcher wants to measure. The higher the validity, the more the measurement results match with the content of the examination, and vice versa, the lower it is. In this paper, the validity of the questionnaire was examined using KMO and Bartlett's test, and the results of the analysis are shown in the table below.

Table 7: Validity analysis table for each question item of the pre-survey

subject	Kaiser-Meyer-Olkin metric of sampling adequacy	validity assessment
Q8	0.776	acceptable level
Q25	0.788	acceptable level
Q26	0.832	favorable
Q27	0.85	favorable
Q28	0.807	favorable

As can be seen from the above table, the overall Bartlett's test is significant (Significance Sig=.000), and the overall KMO value of the questionnaire and the KMO value of each scale question item is greater than 0.7, which indicates that the validity of the questionnaire is good, and the results of the questionnaire are true and valid.

4.2. Data processing and testing of formal surveys

4.2.1.Data processing for formal surveys

（1） *Receiving and exporting data*

After completing the pre-survey, we made some modifications to the questionnaire, such as adjusting the classification categories of charging frequency of new energy vehicles in question 16 and charging duration in question 17, and optimizing the scale of satisfaction in question 23. We used an online electronic questionnaire, and in the survey process, we marked as invalid questionnaires those questionnaires with low cooperation, fast filling speed (less than 60 seconds), random answers and those that were abandoned in the middle of the survey, and excluded those questionnaires that were omitted by the respondents and those with incorrect content. At the end of the questionnaire distribution phase, we exported the data directly from Questionnaire Star, without the need to manually enter data, which effectively avoided the possibility of manual entry errors and accelerated the progress of research implementation and analysis.

(2） Data Cleaning

Database cleansing is the process of checking the database files for coding, logical consistency, and data quality.

(3） Outlier handling

During the questionnaire survey, we strictly control the quality of the questionnaire, in which there are no missing values, but outliers may exist. When the outliers are not significant for the whole model, we keep them. When it may have an effect on the model, it is eliminated or taken to be replaced by using other values such as the mean and the plurality.

4.2.2.Data testing of formal surveys

(1） Reliability testing

A total of 577 questionnaires were distributed in the formal survey, of which 71 questionnaires were invalid and 506 questionnaires were valid, giving a validity rate of 87.69%. The five scales of questions 8, 25, 26, 27 and 28 of the questionnaire were tested for reliability.

Here, Cronbach's coefficient is directly adopted as the test standard, and the test results are shown in Table 7, the Cronbach's alpha value of each level is greater than 0.7, which has a high reliability, thus indicating the scientific and rationality of the questionnaire structure and question item setting.

Table 6: Reliability analysis table for each question item of the formal survey

subject	Cronbach's Alpha	Cronbachs alpha based on standardized terms	item count (of a consignment etc)	reliability assessment
Q8	0.786	0.787	4	acceptable level
Q25	0.798	0.798	4	acceptable level
Q26	0.827	0.827	5	favorable
Q27	0.849	0.85	5	favorable
Q28	0.84	0.84	4	favorable

(2）Validity test

Validity refers to the accuracy and validity of a questionnaire's measurement objectives, i.e., whether the questionnaire truly reflects the concepts that the researcher wants to measure. The higher the validity, the more the measurement matches the content of the examination, and vice versa.

In this paper, the validity of the questionnaire was tested using KMO and Bartlett's test, and the validity of the questionnaire was tested using the software SPSS 20.0, and the results of the analysis are shown in the table below.

Table 8: Validity analysis table for each question item of the formal survey

subject	Kaiser-Meyer-Olkin metric of sampling adequacy	validity assessment
Q8	0.784	acceptable level
Q25	0.795	acceptable level
Q26	0.85	favorable
Q27	0.866	favorable
Q28	0.818	favorable

As can be seen from the above table, the overall Bartlett's test is significant (Sig=.000), and the overall KMO value of the questionnaire and the KMO value of each scale item is greater than 0.7, which indicates that the validity of the questionnaire is good and the results of the questionnaire are true and valid.

5. Descriptive Statistical Analysis

5.1. Analysis of the basic situation of the respondents

The questionnaire was sent to some rural areas in 13 counties and county-level cities in Shijiazhuang City (Jingfujiazhuang County, Zhengding County, Xingtang County, Lingshou County, Gaoyi County, Shenze County, Zhanhuang County, Wuji County, Pingshan County, Yuanshi County, Zhao County, Xinji City, Jinzhou City, Xinle City), and a total of 577 questionnaires were sent out in the survey, and out of 577 questionnaires recovered, there are 506 valid questionnaires, and the validity rate of the questionnaires is 87.69%.

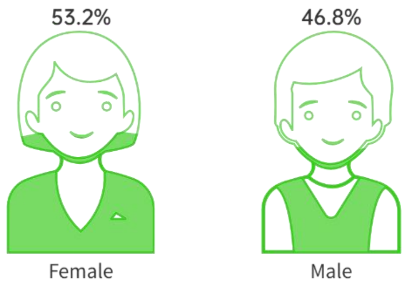

Figure 5: Gender ratio distribution

Among the 506 valid questionnaires recovered, the proportion of females in the total is 53.2%, and the proportion of males in the total is 46.8%, with a more balanced distribution of males and females, and there is no obvious difference between the genders, which indicates that the survey is relatively rigorous and scientific.

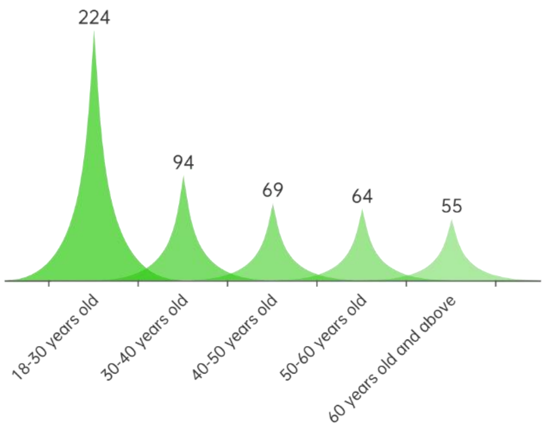

Figure 6: Histogram of age distribution deformation

Regarding the age of the respondents, 44.3% of the total number of respondents were aged 18-30, 18.6% were aged 30-40, 13.6% were aged 40-50, 12.6% were aged 50-60, and 10.9% were aged 60 and above.

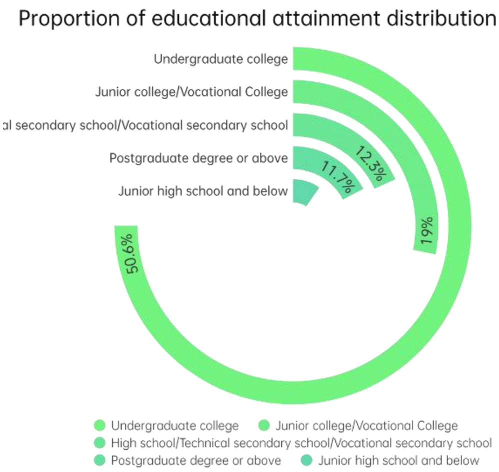

Figure 7: Frequency distribution of educational qualifications

Regarding the education level of the respondents, 6.5% of the total number of respondents had junior high school education or below, 12.3% had high school/middle school/junior college/intermediate education, 19.0% had junior college/higher education, the highest percentage of respondents had a bachelor's degree from a university (50.6%), and 11.7% had postgraduate education or above. Respondents included not only local residents, but also rural children studying or working outside the village, relatives and friends of local villagers, and tourists traveling to the village.

5.2. Analysis of the current situation of the use of rural charging piles

5.2.1.Descriptive Statistical Analysis of Charging Facility Usage and Distance

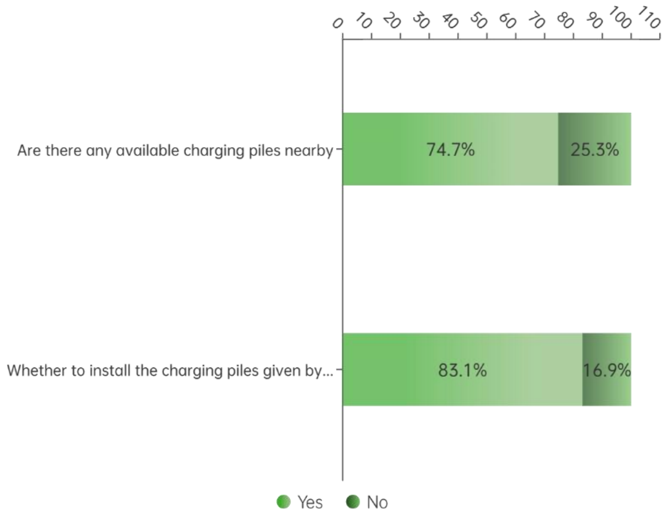

Figure 8: Bar chart of charging pile installation and availability

The stacked bar chart shows that 74.7% of the respondents have available charging piles nearby, indicating that the penetration of charging piles in rural Shijiazhuang is still high, and 83.1% have installed charging piles presented by the manufacturer, while only 16.9% do not, indicating that most of the respondents may find it more convenient to use charging piles presented by the manufacturer.

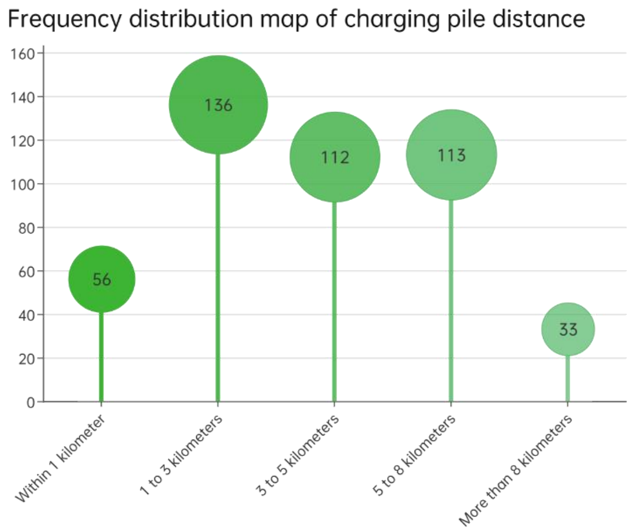

Figure 9: Charging pile distance frequency statistics

However, as can be seen from Figure 10, only 12.4% of the respondents were within 1 kilometer of a charging post, 30.2% of the respondents were 1-3 kilometers, 24.9% of the respondents were 3-5 kilometers, 25.1% of the respondents were 5-8 kilometers, and 7.3% of the respondents were 8 kilometers and above, and most of the respondents' distances from the nearest charging post ranged from 1-3, 3-5, and 5-8 kilometers, which indicates that although there are charging posts near the location of the respondents that are available charging posts, they are not very close and may be less convenient to use.

5.3. Analysis of Barriers and Recommendations for Rural Charging Post Use

5.3.1. Frequency analysis of co-occurrence of barriers to use and recommendations

Heatmap is a visualization tool that shows the distribution, density or correlation of data through changes in color shades or color scale. In the questionnaire, "What problems have you encountered in the process of using charging piles?" and "Do you have any suggestions for public charging piles for new energy vehicles? and "What are your suggestions for public charging piles for new energy vehicles?" in the questionnaire, heat map can be used to visualize and analyze the co-occurrence relationship between the options. When analyzing the co-occurrence of multiple choice questions, the heat map is usually presented in the form of a matrix, with the horizontal and vertical axes representing the options of the questions, and the color reflecting the frequency of co-occurrence or correlation strength between the options.

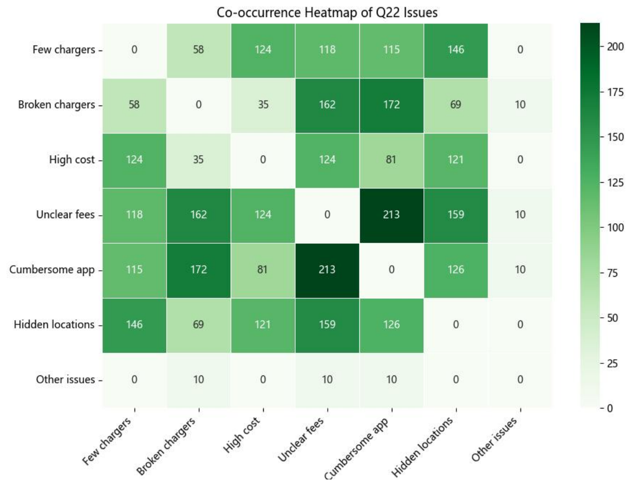

Figure 10: Heat map of co-occurrence of barriers to use

As can be seen from Figure 11, among the charging barriers encountered in using charging piles, "non-transparent charging" and "cumbersome APP" have the highest frequency of co-occurrence, with a selection frequency of 213, which indicates that users have doubts about the charging of charging piles, and find it difficult to understand the charging standard of charging piles clearly, and consider the use of charging APP too cumbersome and not convenient enough. This indicates that users are skeptical about the charging fees of charging stations and have difficulty in clearly understanding the charging standards of charging stations;

"In addition to the problem of "cumbersome APP", the damage of charging piles is also a major obstacle for users to use charging piles. In addition to the problem of "cumbersome APP", the damage of charging pile is also a big obstacle for users to use charging pile. This shows that the quality of charging piles needs to be improved and maintenance services should be emphasized.

"Non-transparent charges" and "damage to charging piles" co-occur with a frequency of 162, and the focus is still on charging and quality issues;

The frequency of "non-transparent charging" and "hidden location" is 159, which indicates that in addition to the problem of charging, the layout of charging posts in rural areas is not reasonable enough, which makes it difficult for users to use them quickly;

The frequency of "small number of charging piles" and "hidden location" is 146, reflecting that the number of charging piles in rural areas is insufficient to meet the needs of users, and the problem of user demand needs to be solved urgently.

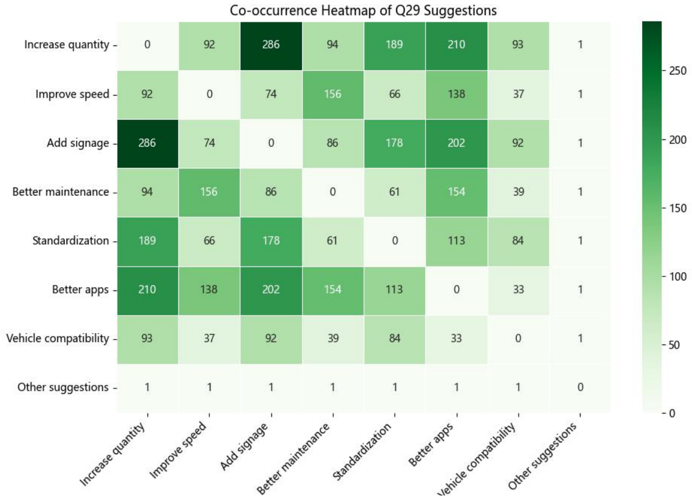

Figure 11: Heat map of the co-occurrence of relevant recommendations

As can be seen from Figure 12, the most frequent suggestions are "set up signs" and "increase the number", reaching 286 times, indicating that the layout of charging piles is not reasonable, which makes it difficult for users to find them, and at the same time, the number of charging piles does not meet the users' needs;

The co-occurrence of "regulating APPs" and "increasing the number" is 210, second only to 286, indicating that the issue of regulating APPs should not be ignored;

The co-occurrence frequency of "setting signs" and "regulating APP" is 202. We have already mentioned the hidden location of charging posts above, and setting signs is for better searching of charging facilities, which indicates that users are eager to solve the problem of poorly finding charging posts. This shows that users are eager to solve the problem of not being able to find charging posts.

5.3.2.Data flow analysis of barriers to use and recommendations

After the heat map co-occurrence of the barriers to the use of charging piles and related suggestions, since the heat map could not show the path flow relationship between the barriers to the use of the barriers and the related suggestions, we then carried out a Sankey Diagram analysis for the two multiple choice questions above. The so-called Sankey Diagram is a visualization tool that shows the flow of data or correlation relationship through nodes and streamlines. The greater the width of the streamlines, the stronger the correlation between the two options.

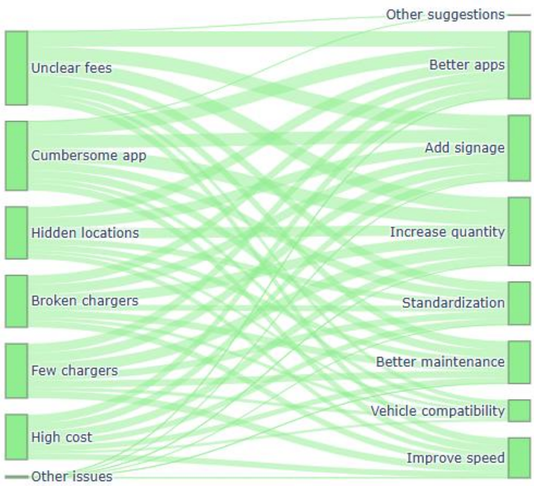

Figure 12: Sankey diagram of barriers to use and recommendations

As can be seen from the above chart, "non-transparent charges", "cumbersome APP", "hidden location", "charging pile damage", "small number of charging piles" all mainly flow to "standardize APP", "set signs", "increase the number". " and "small number of charging piles" are mainly directed to "standardize APP", "set up signs" and "increase the number of charging piles". "The width of the flow lines for "high cost" is more uniform, and there is not much difference in the width of the flow lines to the different suggested options. Therefore, we can get that "standardize APP", "set marking" and "increase quantity" are still the most urgent problems to be solved, only by standardizing the charging APP, can we make the users no longer worry about the charging APP when using the charging pile. Only by standardizing the charging APP, can users no longer worry about the charging APP when using the charging piles; only by setting up obvious signs can the charging piles be easier to find; only by increasing the number of charging piles can we meet the users' charging needs.

5.4. Analysis of the Purchase and Use of New Energy Vehicles

5.4.1.Analysis of the reasons for purchasing new energy vehicles

A total of 506 valid questionnaires were recovered from this survey, of which 450 were from those who own new energy vehicles and 56 were from those who do not have new energy vehicles.

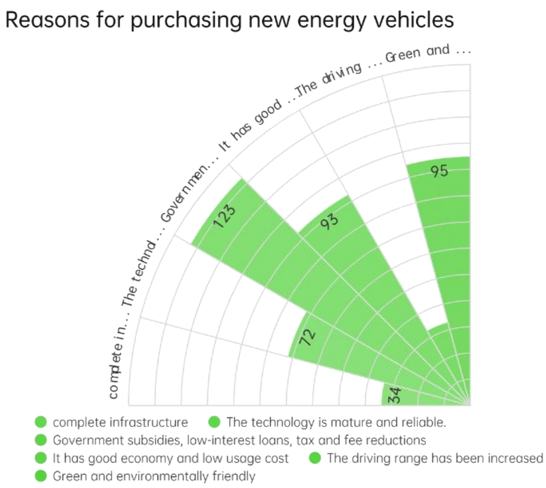

Figure 13: Frequency distribution of reasons for purchase

Figure 14 shows that among the reasons for purchasing new energy vehicles, government subsidies, low-interest loans, and tax exemptions accounted for the largest proportion of respondents, while the proportion of those who chose "improved infrastructure" and "improved mileage" was the smallest. This shows that the government should increase subsidies for new energy vehicles, lower interest rates, and reduce taxes and fees; at the same time, it should pay attention to improving the infrastructure of new energy vehicles, solving the problem of charging cars, and alleviating the pressure of short mileage.

5.4.2.Research on the willingness to expand charging piles on the willingness to recommend new energy vehicles based on column analysis

Contingency Table Analysis (CTA) is a statistical analysis method used to study the association between two or more categorical (or qualitative) variables. Its core is to demonstrate the frequency distributions under different combinations of variables by constructing a concatenated table (crosstab), and to test whether there is a statistically significant association between the variables. In order to understand the relationship between respondents' willingness to expand charging piles and their willingness to recommend new energy vehicles, we conducted a column table analysis.

Table 9: Cross-tabulation chi-square test results table

	(be) worth	df	Progressive Sig. (Bilateral)
Pearson calorimetry	12.507[a]	4	0.014
likelihood ratio	10.347	4	0.035
Linear and linear combinations	3.231	1	0.072
N in valid cases	450		

a. 1 cell (10.0%) has a desired count of less than 5. The minimum desired count is 2.00. b. 1 cell (10.0%) has a desired count of less than 5.

In the column table analysis, the chi-square test is conducted to test the correlation between the variables, as shown in the above table, the p-value of the chi-square test is 0.014, which is less than 0.05, and the original hypothesis is rejected, so there is a significant correlation between the willingness of charging piles to expand and the willingness to recommend new energy vehicles.

Table 10: Cross-tabulation of willingness to expand charging piles and willingness to recommend new energy vehicles

		24. Do you think your village and nearby villages need to increase the number of charging posts installed?					add up the total
		Not at all.	Not really.	general	more demanding	badly needed	
7、Will you recommend new energy vehicles to	be	84	16	82	89	138	409
	clogged	10	6	10	4	11	41

your friends
and family?

The following conclusions were drawn from the cross-tabulations:

1. The majority of respondents who disagreed with the expansion of charging piles would recommend new energy vehicles to their friends and family.

2. Among the respondents who recommend new energy vehicles with different willingness to expand, those who think it is "very necessary" to expand charging posts are more inclined to recommend new energy vehicles than those who have other willingness to expand. Below is a combined bubble chart.

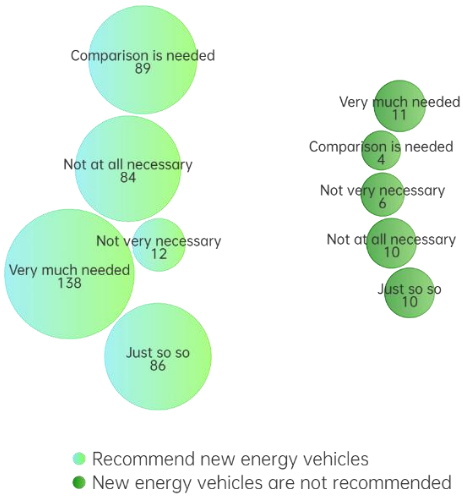

Figure 14: Bubble chart of willingness to expand charging piles and willingness to recommend new energy vehicles

5.4.3.Reasons for not purchasing new energy vehicles and the factors influencing them

We used multiple responses to analyze the reasons and influencing factors for not purchasing new energy vehicles.

Table 11: Frequency table of reasons for not purchasing new energy vehicles

		responsive		
		N	percentage	Percentage of cases
$ Reasons for not purchasing new energy vehiclesa	Poor range, not suitable for long distance driving	31	20.1%	55.4%
	Shorter battery life	23	14.9%	41.1%
	Difficulty in guaranteeing after-sales service	14	9.1%	25.0%
	Low number of charging piles to meet charging demand	24	15.6%	42.9%
	High charging prices	10	6.5%	17.9%
	Immature technology and safety hazards	20	13.0%	35.7%

	Lots of hidden costs (expensive insurance, etc.)	15	9.7%	26.8%
	(sth. or sb) else	17	11.0%	30.4%
(grand) total		154	100.0%	275.0%

a. Subgroups tabulated with a value of 1.

From the multiple response analysis, it can be seen that "the number of charging piles is small and it is difficult to meet the charging demand" is the second most important reason for respondents not to buy new energy vehicles, indicating that the charging problem caused by the small number of charging piles is the main factor hindering the promotion of new energy vehicles.

In the multiple response analysis table of "Factors Promoting the Purchase of New Energy Vehicles", it can be seen that better infrastructure (charging piles, power stations, etc.) will greatly promote the purchase of new energy vehicles by respondents, accounting for 21.7%, so it can be seen that the improvement and development of charging piles can greatly help the promotion of new energy vehicles, and the development of charging piles is a top priority for the development of new energy vehicles. The development of charging piles is a top priority for the development of new energy vehicles.

Among the other influencing factors, 20.2% chose "government subsidies, low-interest loans, tax exemptions", 20.7% chose "improved safety and more mature technology", 18.7% chose "improved range", 11.3% chose "increased awareness of environmental protection", and 5.4% chose "recommendations from friends and relatives". The percentage of those who chose "improved safety, more mature technology" accounted for 20.7%, "improved mileage" accounted for 18.7%, "increased awareness of environmental protection" accounted for 11.3%, "recommendations from friends and relatives" accounted for 5.4%, and other reasons accounted for only 2%.

Table 12: Frequency table of factors promoting the purchase of new energy vehicles

		responsive		
	factor	N	percentage	Percentage of cases
$ Factors promoting the purchase of new energy vehiclesa	Government subsidies, low-interest loans, and tax breaks	41	20.2%	73.2%
	Better infrastructure (charging piles, switching stations, etc.)	44	21.7%	78.6%
	Improved safety and more mature technology	42	20.7%	75.0%
	Increased range	38	18.7%	67.9%
	Increased environmental awareness	23	11.3%	41.1%
	Recommendations from friends and family	11	5.4%	19.6%
	(sth. or sb) else	4	2.0%	7.1%

(grand) total		203	100.0%	362.5%

6. Decision Tree Modeling Based Willingness Analysis of Rural Charging Post Expansion

The purpose of the decision tree algorithm is to obtain the data classification and prediction laws under different values of input and output variables by learning from the data, and to be used for the classification and prediction of new data objects. This model focuses on the subjective perception of the number of charging piles and the willingness to expand charging piles by different groups of respondents, so in this paper, gender, age, and education are used as independent variables, and "Do you think the number of public charging piles in your neighborhood is sufficient" and "Do you think the number of public charging piles in your village and nearby villages needs to be increased? need to increase the number of charging piles installed?" as dependent variables so as to analyze the impact of respondents' basic information on respondents' subjective perceptions of the number of charging piles and whether the number of charging piles should be increased.

6.1. Analysis of the number of public charging piles perceived by different groups of people

6.1.1.Analysis of decision tree results

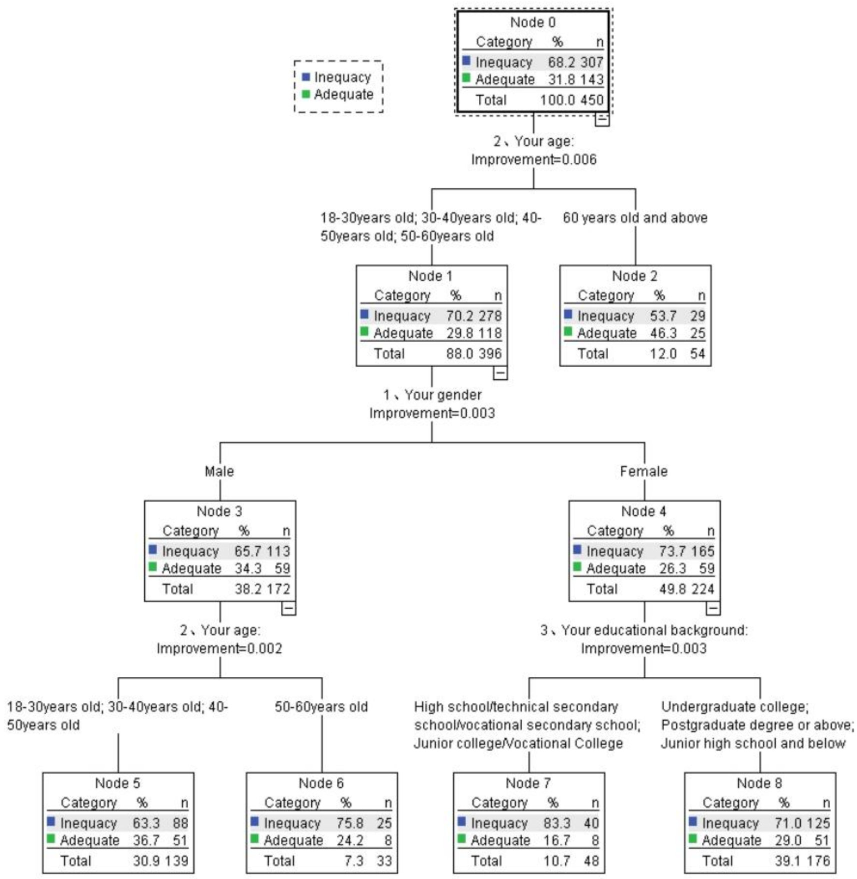

Figure 15: Decision tree analysis of perceptions of the number of charging piles for new energy vehicles

The above figure shows the analysis of the results of the perception of the number of public charging piles, a decision tree with 9 nodes, 5 terminal nodes and a depth of 3 was obtained, and the root node contained a total of 450 samples, with the largest percentage of people who thought that there was an insufficient number of public charging piles at 68.2% and a frequency of 307, while 143 people thought that there was an adequate number of public charging piles, with a percentage of 31.8%. Of the variables chosen, the first best grouping variable for the decision tree was age, with significant differences in perceptions of the number of charging piles among different age groups, and two binary trees were formed from this.

The sample size of 18-30, 30-40, 40-50 and 50-60 years old is 396 people, most of them think that the number of public charging piles is "insufficient", accounting for 70.2%; there are significant differences between different genders. There is a significant difference between genders, with a sample size of 172 males, most of whom think that the number of public charging piles is "insufficient", accounting for 65.7% of the total, and 224 females, most of whom think that the number of public charging piles is "insufficient", accounting for 73.7% of the total;

Among respondents aged 60 and above, there was little difference in their perceptions of the number of charging piles, with 53.7% saying "insufficient" and 46.3% saying "sufficient", which is relatively balanced;

Among men aged 18-30, 30-40, 40-50, and 50-60, the majority of respondents aged 18-30, 30-40, and 40-50 think that the number of charging piles is "insufficient", accounting for 63.3%; the majority of respondents aged 50-60 also think that the number of charging piles is "insufficient", accounting for 75.8%; the majority of respondents aged 50-60 also think that the number of charging piles is "insufficient", accounting for 75.8%; the majority of respondents aged 50-60 also think that the number of charging piles is "insufficient", accounting for 75.8%. The majority of respondents aged 50-60 also thought that the number of charging piles was "insufficient", accounting for 75.8% of the respondents;

As for women aged 18-30, 30-40, 40-50, and 50-60, respondents with different educational backgrounds again showed differences in quantity perception, of which most respondents in high school/middle school/junior college/intermediate school and junior college/higher vocational thought that the number of charging piles was insufficient, accounting for 83.3%; most respondents in undergraduate, graduate school and above, and junior high school and below thought that the charging piles are not sufficient, accounting for 71.0%.

6.1.2.Decision Tree Accuracy Prediction

Table 13: Perceived Forecasting Accuracy of Number of Charging Piles Table

observed	projected		
	inadequate	enough	Percentage correct
inadequate	307	0	100%
enough	143	0	0%
Total percentage	100%	0%	68.2%

Growth method:CRT

List of Dependent Variables: Q23 Adequacy of the number of public charging posts

From the SPSS output table, it can be seen that the accuracy of the respondents' cognitive prediction of the number of charging piles, the accuracy of the prediction of "insufficient" is 100%, the accuracy of the prediction of "not too sufficient" is 0%, and the overall accuracy of the prediction result is 68.2%.

In summary, the decision tree reflects that respondents in general believe that the number of public charging piles is insufficient, and users' needs have not been solved, so the problem of new energy vehicle charging piles and other infrastructure construction needs to be solved.

6.2. Analysis of Different Populations' Willingness to Expand Public Charging Posts

6.2.1.Analysis of decision tree results

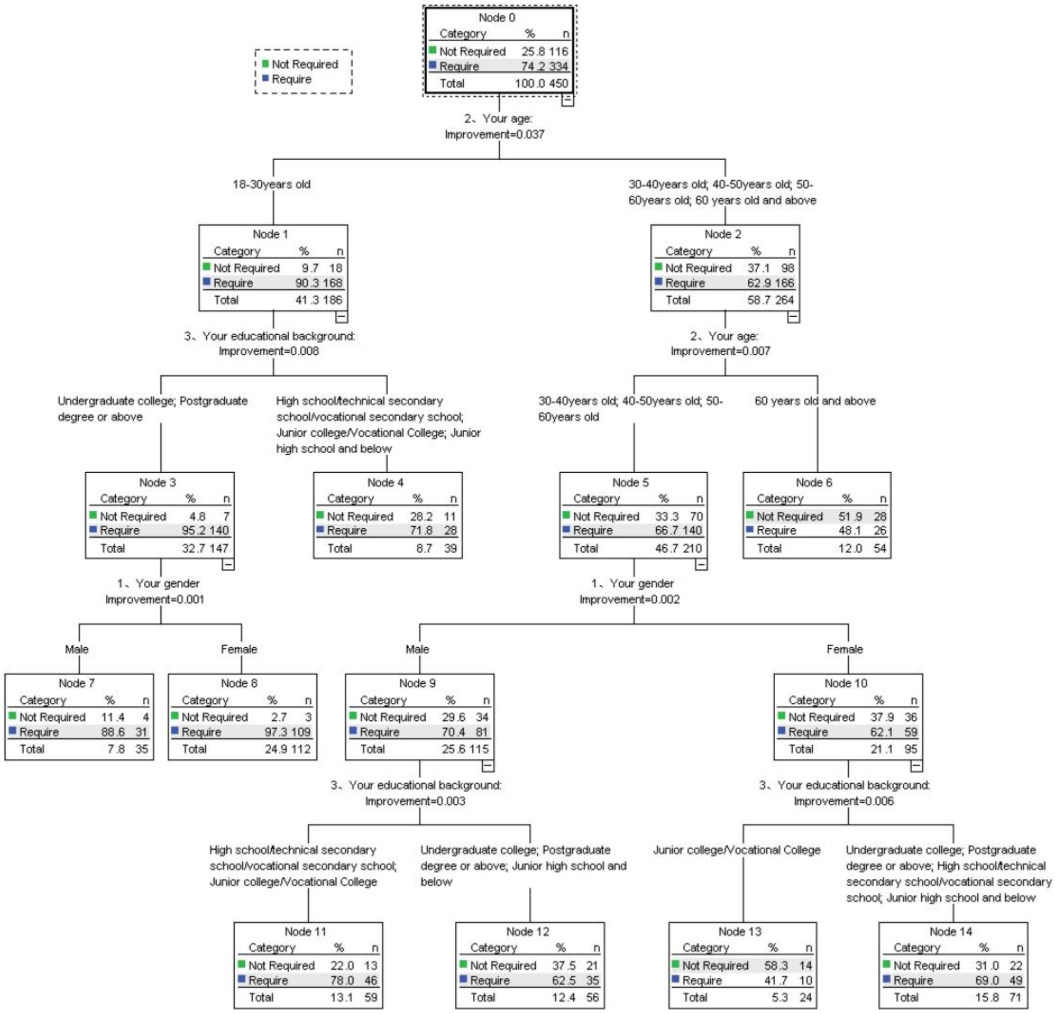

Figure 16: Decision tree analysis of willingness to expand charging piles for new energy vehicles

The above figure is the result analysis of the cognition of the number of public charging piles, a node number of 15, the number of terminal nodes is 8, the depth of the decision tree is 4, the root node contains a total of 450 samples, think "need" to increase the number of public charging piles accounted for the largest proportion of 74.2%, the frequency is 334; think "do not need" 116 people accounted for 25.8%; think "do not need" 116 people accounted for 25.8%; think "do not need" the proportion of 25.8%. There are 116 people who think "no need", accounting for 25.8%. Among the selected variables, the first best grouping variable of the decision tree is age, and there is a significant difference in the willingness of different age groups to expand charging piles, which forms a binary tree.

The sample size of those aged 18-30 was 186, and the majority of them believed that there was a "need" to increase the number of charging piles installed, accounting for 90.3% of the total; the sample size of those aged 30-40, 40-50, 50-60, and 60 and above was 264, and the majority of them believed that there was a "need" to increase the number of charging piles installed, accounting for 62.9% of the total. need" to increase the number of charging piles installed, accounting for 62.9%;

There is a significant difference in the willingness to expand charging piles among people aged 18-30 with different educational backgrounds. Among them, the sample size of undergraduates, graduate students and above is 147, and most of them think that they "need" to increase the number of installed charging piles, accounting for 95.2%; the sample size of senior high school/secondary school/middle school, college/higher vocational, junior high school and below is 39, and most of them think that they "need "increase the number of charging piles installed, accounting for 71.8%;

Among the 147 respondents with education level of undergraduate, graduate and above, there is a significant difference in the willingness of different genders to expand, of the 35 male respondents, 31 think that they "need" to increase the number of charging piles installed, accounting for 88.6%; of the 112 female respondents, 109 think that they "need" to increase the number of charging piles installed, accounting for 97.3%; of the 112 female respondents, 109 think that they "need" to increase the number of charging piles installed, accounting for 97.3%. Of the 112 female respondents, 109 (97.3%) thought that there was a "need" to increase the number of charging posts installed;

Of the 264 sample sizes in the 30-40, 40-50, 50-60, and 60 and older age groups, 210 respondents in the 30-40, 40-50, and 50-60 age groups, and 140 respondents, or 66.7%, believe that there is a "need" to increase the number of charging piles installed, while 54 respondents in the 60 and older age groups, or 66.7%, believe that there is a "need" to increase the number of charging piles installed. The 54 respondents aged 60 and above did not differ much in their willingness to expand the number of charging piles;

Among the respondents aged 30-40, 40-50, 50-60 and 60 and above, there are also significant differences between the genders of the respondents. 81 out of 115 male respondents think that there is a "need" to increase the number of installed charging piles, accounting for 70.4%; 59 out of 95 female respondents think that there is a "need" to increase the number of installed charging piles, accounting for 62.1%; and 59 out of 95 female respondents think that the number of installed charging piles is a "need" to increase the number of installed charging piles, accounting for 62.1%. Of the 95 female respondents, 59 thought that there was a "need" to increase the number of charging piles installed, accounting for 62.1% of the total;

Among the 115 male respondents, there is a significant difference in the willingness to expand charging piles among people with different educational backgrounds. The sample size of high school/middle school/junior college/junior high school and junior college/senior high school is 59, and 46 of them believe that they "need" to increase the number of charging piles installed, accounting for 78.0%; the sample size of undergraduate, graduate school and above, and junior high school and below is 56, of which 35 of them believe that they "need to The sample size of undergraduates, graduate students and above, junior high school and below was 56, of which 35 believed that there was a "need" to increase the number of charging piles, accounting for 62.5%;

Among the 95 female respondents, there is a significant difference in the willingness to expand the number of charging piles among people with different academic qualifications. Among the 24 samples with college/higher education, 58.3% think that they "don't need" to increase the number of charging piles installed; except for college/higher education, the majority of people with other education think that they "need" to increase the number of charging piles installed, accounting for 69.0%. 69.0%.

6.2.2.Decision Tree Accuracy Prediction

The accuracy of predicting the results of the decision tree for the question "Do you think there is a need to increase the number of charging posts in your village and nearby villages?" is 36.2%. it can be seen that the accuracy of the prediction table of the decision tree results is 36.2% for the prediction of "no need" to increase the number of charging piles installed; the accuracy of the prediction of "need" to increase the number of charging piles installed is 89.2%; the overall accuracy of the prediction results is 75.6%. The overall accuracy of the prediction result is 75.6%.

In summary, the decision tree reflects that respondents in general believe that there is a "need" to increase the number of charging piles installed, although a larger proportion of people aged 60 and above believe that there is no need to increase the number of charging piles installed, but only 28 people, which is a relatively small proportion of the overall population. The number of people aged 60 and over who think there is no need to increase the number of charging piles is only 28, which is a relatively small proportion of the total number of people aged 60 and over. Therefore, there is a great need to increase the number of charging piles for new energy vehicles, expand the infrastructure for new energy vehicles, solve the problem of charging new energy vehicles, and promote new energy vehicles to the countryside.

Table 14: Accuracy of Charging Pile Expansion Willingness Prediction Table

observed	projected		
	unnecessary	need	Percentage correct
unnecessary	42	74	36.2%
need	36	298	89.2%
Total percentage	17.3%	82.7%	75.6%

Method of growth: CRT

List of Dependent Variables: q24 Whether there is a need to increase the number of charging piles

7. Characterization of rural charging post usage based on K-modes clustering

Cluster analysis is a center-based clustering algorithm, through iteration, the samples are divided into K classes, so that the sum of the distances between each sample and the center or mean of the class it belongs to is minimum. In order to further explore the satisfaction of the people in Shijiazhuang area for public charging piles and its problems, we choose to do cluster analysis (K-Modes) with python.3.10, based on the analysis of the data for new energy vehicles using public charging piles, to do further segmentation, and to propose targeted strategies.

Cluster analysis was performed for the four questions Q15,Q17,Q18,Q20 based on the similarity between the data, which makes the data objects within the same group more similar to each other, while the data objects between different groups are more different. Through K-Modes clustering, a large amount of data is better organized and understood so as to discover the intrinsic structure and patterns of the data.

7.1. Selection of clustering methods

K-Modes cluster analysis is a method of cluster analysis for categorical data (discrete data classification) data, we choose the independent variable is categorical variables, compared with the K-mean analysis, K-Modes for categorical variables of the data processing is more accurate and rigorous, can minimize the defects. In this market research study, our independent variables are the distance of charging pile, the length of charging, the frequency of charging, the type of public charging pile these four variables as the core research dimensions, need to carry out cluster analysis to identify market segments, but the traditional K-means algorithm has obvious limitations, there may be irrational data processing data analysis, which affects the final analysis, so this time we use the python.3.10 for K-Modes cluster analysis.

7.2. Analysis of clustering results

7.2.1. User Group Characterization

Table 15: Characterization of user groups

norm	Cluster 0 (120)	Cluster 1 (234)	Cluster 2 (96)
Distance to charging post	3 (3-5 kilometers)	2 (1-3 kilometers)	4 (5-8 kilometers)
Types of charging piles	1 (slow charging)	1 (slow charging)	2 (fast charging)
Charging frequency	2 (4-6 times per month)	1 (1-3 times per month)	3 (7-9 times per month)
Charging time	3-6 hours	6-9 hours	N/A (fast charging)

7.2.2. Group Naming and Characterization

Cluster 0 is the medium-distance planning type of users, these users have an average distance of 3-5 kilometers from the charging post, have a monthly charging frequency of 4-6 times, tend to slow charging and accept longer charging time. It can be seen that the coverage of charging facilities in residential areas is insufficient, and periodic planning of charging is required.

Cluster 1 is the proximity convenience type users, as the main group, the distance to the charging pile is within 1-3 kilometers, more inclined to low-frequency slow charging type. Reflects the current charging network coverage is better, but the user activity is limited.

Cluster 2 is long-distance high-frequency fast-charging users, which are 5-8 kilometers away from the charging pile, preferring high-frequency fast-charging (7-9 times per month), and charging duration is not applicable (fast-charging characteristics), which indicates that there is a scarcity of fast-charging facilities around the place of residence/work, and that they need to charge across the region.

7.2.3. Visualization and verification

Observing the principal component analysis graph, principal component 1 (X-axis) in the graph mainly reflects the trade-off relationship between charging frequency and distance. Principal component 2 (Y-axis) reflects the difference between charging type and duration. The three clusters' distribution areas are separated obviously, verifying the validity of clustering.

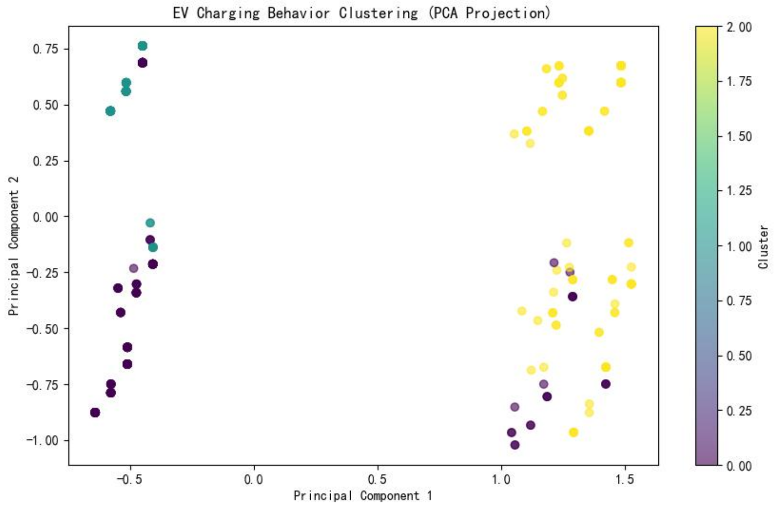

Figure 17: Principal Component Analysis Chart

7.2.4.Variance explained rate

According to the Python output, it can be seen that principal component 1 explains 0.3048805, or 30.49% of the variance, while principal component 2 explains 0.16816601, or 16.82% of the variance. These two principal components explain about 30.49% and 16.82% of the variance in the original data, respectively, with a cumulative explained variance of 0.47304650, or 47.30%. This implies that principal component 1 is more explanatory in comparison to principal component 2 and dominates the data, while principal component 2 also contributes a considerable amount of explanatory power, but not as significant as principal component 1.

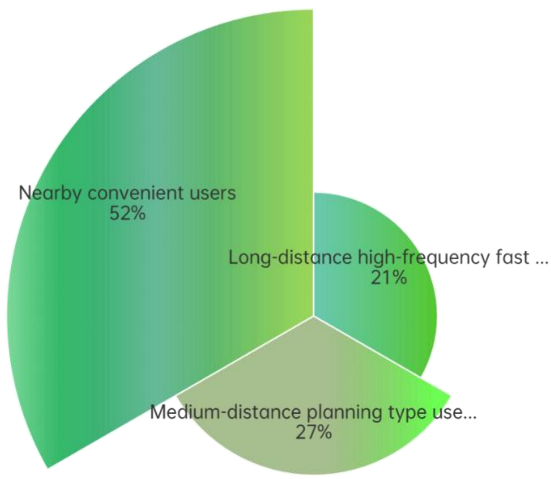

Figure 18: Cluster analysis pie chart

7.2.5.Interpretation of clustering results

According to the above clustering analysis pie chart can be obtained the percentage of people with different needs for the use of public charging piles. Specifically, it can be divided into three main categories:

Long-distance high-frequency fast-charging users: This group accounts for about 21% of the population, who are mainly high-frequency users of new energy vehicles, but there are fewer public charging piles in nearby villages, which can't satisfy daily charging needs, so their frequency distribution is higher, and each charging time is longer, and they have a high demand for public charging piles for new energy vehicles. For this group, the relevant government departments and towns should pay attention to the installation of public charging piles, and reasonably increase the construction of public charging piles in rural areas under the premise of the national dual-carbon policy, so as to further satisfy the needs of this group of people.

Proximity Convenience Users: This group accounts for about 52% of the population, this group of people are mainly traveling more frequently, for the public charging pile demand is greater, because of the relatively large number of public charging pile facilities in the vicinity, so this group of people compared to the lack of public charging pile equipment, their charging frequency is higher, but charging time is relatively small. For this group, we strive to further optimize and upgrade the types of public charging piles under the circumstance of ensuring sufficient public charging piles to enhance the satisfaction of the public.

Medium-distance planning users: this group of people accounted for about 27% of the population, most of this group of people in the new energy vehicle preferential policies, in recent years, purchased new energy vehicles for home use, leisure, etc., the distance from the charging pile is moderate, and therefore the frequency of charging is also relatively low. For this group of people, it is necessary to provide a certain degree of perfect protection for the basic public charging pile equipment, and launch a household charging pile subsidy policy.

8. A Study on Willingness to Use and Satisfaction with Rural Charging Posts Based on Structural Equation Modeling

8.1. Modeling assumptions based on satisfaction and willingness to use

In order to understand the influencing factors of satisfaction and willingness to use charging piles, so as to better improve the construction of charging pile infrastructure for new energy vehicles, we have conducted further research.

Based on practical experience and related literature, we proposed the hypothesis [22] that facility quality is an influencing factor of convenience, that facility quality and facility convenience are influencing factors of satisfaction, and that environmental awareness, facility quality, facility convenience, and satisfaction are influencing factors of willingness to use. We used SPSS 20.0 and AMOS 26.0 for analysis.

Table 16: Table of assumptions related to structural equation modeling

Hypothetical path relationship	
H1	Facility quality positively affects ease of use
H2	Quality of facilities positively affects satisfaction
H3	Ease of use positively affects satisfaction
H4	Facility quality positively influences willingness

	to use
H5	Satisfaction positively influences willingness to use
H6	Environmental awareness positively influences willingness to use
H7	Ease of use positively influences willingness to use

8.2. Structural equation modeling analysis

Structural equation modeling begins with the identification of variables and latent variables based on the research problem and the development of path diagrams based on the relationships between the variables.

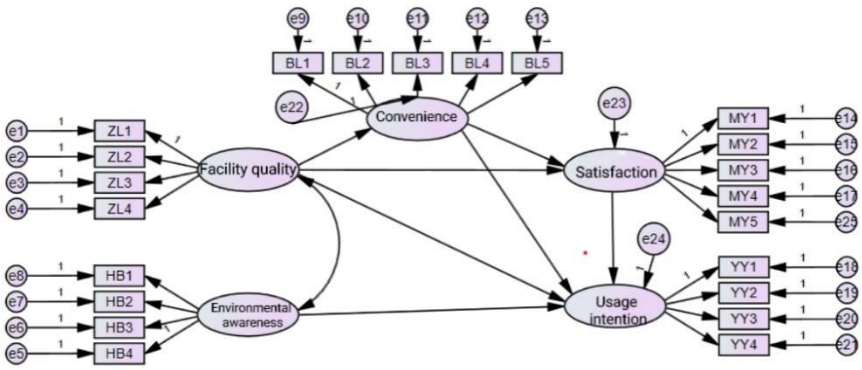

Figure 19: Structural equation modeling diagram

Based on the plotted path diagrams, the relevant data were imported into the Amos26 software to produce the results of the data runs as well as the test results of the model.

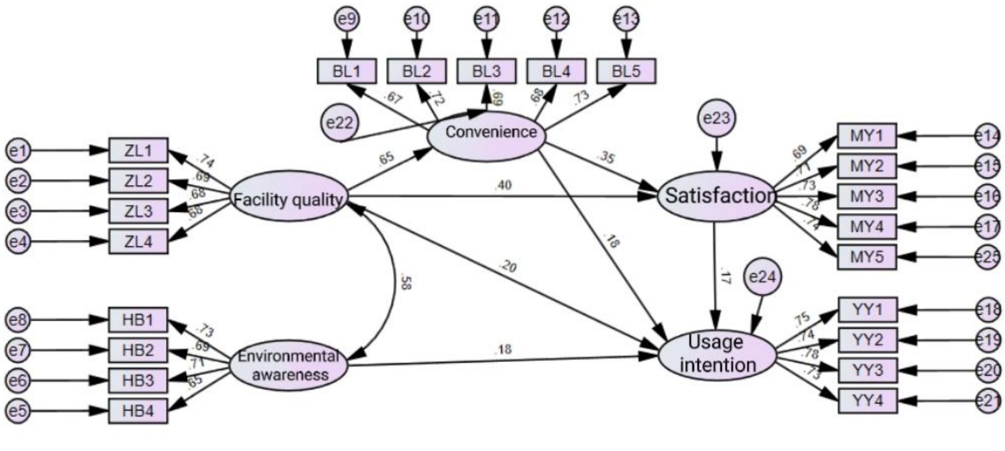

Figure 20: Structural equation modeling run

8.3. Validation factor analysis

After running the structural equation model, the validated factor analysis model was further applied to determine whether the sample data of the questionnaire and the hypothetical structure of the model matched the actual observed data, and most importantly, whether the latent variables of the model were appropriate and could be used to study the willingness to use and satisfaction with the charging piles of new energy vehicles.

AVE indicates the average variance extracted from each factor, which is used to test the convergent validity of the model; AVE ≥ 0.5 indicates that the model factors can explain more than 50% of the variance of the observed variables, and the convergent validity is good; CR refers to the combinatorial reliability, which is used to test the internal consistency reliability of the factors, and if the CR is ≥ 0.7, it indicates that the factors have a good internal consistency. In this study, the CR values of the five variables are all greater than 0.7, so they have good internal consistency; among the AVE values of the five variables, only the AVE values of environmental awareness, facility quality, and facility convenience are 0.48, 0.49, and 0.49, which are slightly lower than 0.5, and the rest of them are all greater than or equal to 0.5, while the AVE values of environmental awareness, facility quality, and facility convenience are very close to 0.5 of the criterion and have high CR values of 0.79, 0.79 and 0.83, respectively, so this study has good convergent validity.The correlation between AVE and CR values is shown in the table below.

Table 17: Validation factor analysis table

norm	(math.) factor	Estimate	Cronbachs alpha based on standardised terms	AVE	CR
environmental awareness	HB4	0.646	0.787	0.48	0.79
	HB3	0.705			
	HB2	0.690			
	HB1	0.732			
Quality of facilities	ZL4	0.683	0798	0.49	0.79
	ZL3	0.684			
	ZL2	0.687			
	ZL1	0.737			
convenience	BL5	0.734	0.827	0.49	0.83
	BL4	0.680			
	BL3	0.685			
	BL2	0.723			
	BL1	0.671			
job satisfaction	MY1	0.688	0.85	0.53	0.85
	MY2	0.705			
	MY3	0.729			
	MY4	0.778			
	MY5	0.743			
Willingness to use	YY1	0.750	0.84	0.57	0.84
	YY2	0.740			
	YY3	0.782			
	YY4	0.734			

8.4. Fitness testing of the model

Table 18: Modified model fitness test

Fitness test indicators	Adaptation Standards	Model results	fitness assessment
CMIN/DF	1 to 3	1.870	favorable
RMSEA	<0.08	0.044	favorable
RMR	<0.08	0.06	favorable
GFI	＞0.90	0.928	favorable
AGFI	＞0.90	0.909	favorable
NFI	＞0.90	0.911	favorable
CFI	＞0.90	0.956	favorable
IFI	＞0.90	0.957	favorable
TLI	＞0.90	0.950	favorable
PNFI	＞0.50	0.793	favorable
PCFI	＞0.50	0.832	favorable

Analysis of model fitness.

The CMIN/DF in the table is the cardinal degrees of freedom ratio, which is used to measure the overall degree of deviation of the model from the data, and its value is between 1 and 3; RMSEA is the root mean square of the approximation error, which measures the approximation error of the model and the data, and it is generally less than 0.08; RMR is the root mean square of the residuals, which is the square root of the residuals of the covariance matrix of the observed data and the covariance matrix of the model prediction, and it is generally less than 0.08; GFI is the goodness-of-fit index, which uses the coefficient of determination and regression standard deviation to test the degree of model fit to the sample observations, and its value is between 0 and 1, and the closer to 1 the better the degree of fit; AGFI is adjusted on the basis of GFI, and its value is between 0 and 1, and the closer to 1 the better the degree of fit; NFI is the canonical fit index, which reflects the relative improvement of the model through the comparison of the target model to the baseline model fit difference, and its value is between 0 and 1, and the closer to 1 the better the degree of fit. NFI is the normative fit index, which reflects the relative improvement of the model by comparing the fit difference between the target model and the baseline model, with a value of 0.9 or above as good; CFI is the comparative fit index, which compares the improvement of the hypothetical model and the independent model (variables are not correlated) with a value of 0-1, and a value of 0.9 or above is good; IFI is the incremental fit index, which is similar to the CFI but corrected for the small-sample bias, with a value of 0-1, and a value of 0-1, and a value of 0-1, and the closer it gets to 1 the better the fit; TLI is the Tucker-Lewis index. Tucker-Lewis index, a fitting index that takes model complexity into account, also known as NNFI (non-normative fitting index), with a value between 0 and 1, and the closer it is to 1, the better the fit is; PNFI is an adjustment to NFI, penalizing complex models by introducing model degrees of freedom, emphasizing the use of fewer parameters to achieve a better fit, generally above 0.5 is good; PCFI is an adjustment to CFI, also through the introduction of model degrees of freedom, and is a good fit. CFI is an adjustment to CFI, which also penalizes complex models by introducing model degrees of freedom, reflecting more robustly the balance between fit and simplicity of the model, and is considered good above 0.5.

From the "model results" in Table 20, it can be seen that the relevant indexes in this paper are within a reasonable range, so the structural equation model has a good fit, indicating that the theoretical study of the path relationship is more consistent with the actual measurement data.

8.5. Path analysis results and conclusions

Table 19: Generating standardized path coefficients

	Estimate	**S.E.**	**C.R.**	**P**
Convenience <- quality of facilities	0.629	0.065	9.709	***
Satisfaction <-- Quality of facilities	0.371	0.067	5.495	***
Satisfaction <-- Convenience	0.337	0.069	4.892	***
Willingness to use< - quality of facilities	0.235	0.112	2.106	0.035
Willingness to use <- satisfaction	0.221	0.094	2.349	0.019
Willingness to use <-- environmental awareness	0.221	0.081	2.73	0.006
Willingness to use <-- Convenience	0.218	0.094	2.326	0.02

Estimate in the table refers to the standardized path coefficient estimates, S.E. refers to the standard error, and C.R. refers to the critical ratio, which is used to determine whether the path coefficients are significantly not equal to zero. The P-values of all paths passed the test with significant results; and the Estimate values in the table are all positive, which means that they are all positively influenced. From the results of the above table, it can be seen that both facility quality and convenience directly and positively affect satisfaction, and indirectly affect the willingness to use by affecting satisfaction. Environmental awareness, facility quality, convenience, and satisfaction directly and positively affect the willingness to use.

The path coefficient of facility quality on convenience is 0.629, which means that facility quality positively affects the convenience of use. It is important to focus on efforts to improve the quality of new energy vehicle infrastructure to ensure that users receive convenient services and charging experiences when using charging posts.

The path coefficient of facility quality on satisfaction is 0.371, i.e. facility quality positively affects satisfaction. It is necessary to improve the quality of rural charging piles, timely maintenance, and minimize the failure rate of charging piles, so as to improve the satisfaction of users of rural new energy vehicle charging piles; the path coefficient of convenience on satisfaction is 0.337, i.e., convenience positively affects satisfaction. It is necessary to simplify the use process of users using charging piles to make it convenient and fast, improve the accuracy of the charging pile navigation information, the diversity of payment methods, and at the same time make the charging pile protocol can be adapted to a variety of car models, so that the charging pile location is easy to find, as a way to improve the user's satisfaction, and to improve the construction of the new energy vehicle charging pile;

The path coefficient of facility quality on willingness to use is 0.235, i.e. facility quality positively affects willingness to use. Improve the quality of charging pile facilities, so that users are more willing to use the charging pile; satisfaction on the willingness to use the path coefficient of 0.221, that is, satisfaction positively affects the willingness to use, to improve the charging speed of the charging pile, to ensure the safety of the equipment, the reasonableness of the layout and the rationality of the cost, to increase the number of charging piles, so as to improve the user's satisfaction, and to promote the further development of China's new energy automobile-related infrastructure. development, drive new energy vehicles to the countryside, promote energy saving and emission reduction, and build a better society. The path coefficient of environmental awareness on willingness to use is 0.221, which means that environmental awareness positively affects willingness to use. We can increase the publicity of the national "double carbon" policy, improve the environmental awareness of new energy vehicle owners, so that new energy vehicle owners realize that our climate problems can not be delayed, so as to enhance the willingness to use the charging pile; convenience on the willingness to use the path coefficient of 0.218, we can improve the convenience of the charging pile to increase the willingness to use the charging pile, or we can improve the convenience of the charging pile to enhance the willingness to use the charging pile. The path coefficient of convenience on willingness to use is 0.218, we can improve the user's willingness to use the charging pile by improving the convenience of the charging pile, or we can indirectly improve the user's satisfaction by improving the convenience of the charging pile, and then improve the willingness to use.

9. Research Conclusions and Recommendations

9.1. Main findings

（1）Rural charging post layout is not reasonable enough

After counting the distance between the respondents and the charging pile, the frequency distribution table of the distance was obtained, the distance of 1-3 kilometers has the highest frequency , and most of them are distributed in 1-3 kilometers, 3-5 kilometers, 5-8 kilometers, thus it can be seen that the distribution of charging piles is not reasonable enough, and users can not use the charging piles to realize the instant stopping and using, and they also need to drive at least 1 kilometer to have the public charging piles available.

（2）Among the barriers to the use of charging piles, "non-transparent charges" and "cumbersome APP" have the highest frequency, and among the related suggestions, "setting up signs" and "increasing the number of charging piles" have the highest frequency. number of charging piles" were the most frequent.

After analyzing the heat map of barriers and suggestions, it is found that the frequency of respondents choosing "non-transparent charging" and "cumbersome APP" is the highest, and they always encounter these two problems at the same time. The highest number of respondents chose both "set up signs" and "increase the number", reflecting the strong demand for accurate location of charging piles and increasing the number of charging piles to meet the demand for charging.

（3）Insufficient number of public charging posts in rural Shijiazhuang

After examining the respondents' perception of the number of public charging posts in rural areas using decision tree analysis, it was found that the majority of respondents (68.2%) of different genders, ages, and educational backgrounds believed that the number of public charging posts in rural areas is insufficient, which creates a great obstacle to the users' charging needs.

（4）Low number of public charging piles will hinder the purchase of new energy vehicles

After counting the reasons why respondents did not buy new energy vehicles, it was found that the small number of charging piles was one of the main reasons, while the reasons that could promote the purchase of new energy vehicles by respondents were also counted, and the improvement of infrastructure accounted for the largest share.

（5）Rural public charging posts need to be expanded

The decision tree analysis reflects that the majority of respondents believe that there is a need to increase the number of public charging posts in rural areas, i.e., to expand public charging posts in rural areas, and that there is an urgent need for public charging posts among users.

（6）Users of rural public charging piles are mainly divided into three categories: long-distance high-frequency fast-charging users, short-distance convenience users, and medium-distance planning users

After analyzing the characteristics of rural charging pile usage through K-modes clustering analysis, the distance to the charging pile, charging duration, charging frequency, and the type of public charging pile are used as the core research dimensions for the user profile, and they are divided into three categories: long-distance high-frequency fast-charging users, short-distance convenience users, and medium-distance planning users, of which the two categories of long-distance high-frequency fast-charging users and medium-distance planning users are groups with a greater demand for charging piles. The two types of users are groups with greater demand for charging piles.

（7）Quality of facilities is a significant influencer of convenience

Among the factors of facility quality, whether the charging pile equipment is in good condition or not, whether the failure rate is high or not, etc. determines that the quality of the facility is a significant influence on the convenience of using the charging pile, and the better the quality of the facility is, the better the convenience of the user in using the charging pile, and the process of using the charging pile will be more fluent, which can save the user's time cost.

（8）Quality of facilities, convenience are significant influencers of satisfaction

Whether the charging pile equipment is in good condition or not, whether the failure rate is high or not, etc. determines the quality of the facility affecting the user's satisfaction in using it, while whether the location of the charging pile is easy to find, whether the car model matches the charging pile or not, and whether the payment method is convenient or not determines the convenience as a significant influencing factor of satisfaction.

（9）Environmental Awareness, Facility Quality, Convenience, and Satisfaction are Significant Influences on Willingness to Use

Respondents' awareness of the dual-carbon goal, whether environmental protection awareness is in place, and their knowledge of environmental issues determine that environmental protection awareness is a significant influence on willingness to use; whether the charging pile equipment is in good condition, whether the failure rate is high or not, etc. determines that the quality of the facility is a significant influence on willingness to use the charging piles; whether it is easy to locate the location of the charging piles, whether the car model and the charging piles are matched, and whether the payment method is convenient determines that Convenience is a significant influencing factor of willingness to use; Charging speed, equipment safety, etc. determine the satisfaction is a significant influencing factor of willingness to use.

9.2. Development proposals

（1）Optimize rural charging post layout planning

For the charging pile layout is not reasonable enough, to carry out scientific planning and layout, so that the user does not have to go to the far charging pile for charging, but also saves the fuel consumption of looking for the charging pile, compressed the hidden cost, save the time cost, so that the user's charging needs can be solved, while getting a good charging experience.

（2）Charging price transparency and simplified charging app

Users of charging piles think that charging charges are not transparent and have doubts about the price, so there is a need to set reasonable tariffs and publicize charging prices, and post the price details of charging near public charging piles; too many types of APPs and cumbersome use cause inconvenience to users, so there is a need to simplify charging APPs, and to promote the One-Code-Pass in the countryside, which only requires scanning a two-dimensional code for displaying the tariffs and scanning the code for charging.

（3）Increase the number of rural charging posts

The insufficient number of public charging piles in rural areas is an important reason that prevents respondents from purchasing new energy vehicles, and at the same time, through the decision tree analysis, it is found that the number of charging piles in rural areas is insufficient, and the respondents have a strong demand for the expansion of public charging piles, so it is necessary to increase the number of charging piles, accelerate the incremental construction of charging piles, and increase the density of charging piles' coverage.

（4）Deepen the publicity of environmental protection concepts and cultivate a green travel culture

Environmental awareness is a significant influence on the willingness to use, so to improve the user's personal awareness of environmental protection, through a number of channels to vigorously publicize the concept of environmental protection, including rural radio propaganda, banner propaganda, village committee activities, etc., to disseminate the advantages of new energy vehicles, emphasize the importance of environmental protection and travel, and call on the villagers to travel for the green, in order to further increase the user's willingness to use the charging pile.

（5）Improve infrastructure, increase willingness to use and satisfaction with charging posts, and increase users' willingness to recommend new energy vehicles

The convenience of using charging piles should be improved by enhancing the quality of facilities; user satisfaction should be enhanced by enhancing the quality of facilities and the convenience of use; and the willingness of users to use the facilities should be further enhanced by improving the quality, convenience and satisfaction of facilities.

At the same time, through the above ways to improve the infrastructure can also improve the user's willingness to recommend new energy vehicles, only the infrastructure of the people's hearts, we will be willing to promote new energy vehicles, new energy vehicles to the countryside to help the process.

（6）Exploring the multi-dimensional use of rural public charging posts

Although rural public charging piles are constructed to meet the charging needs of new energy vehicles, attempts can be made to apply rural public charging piles to other aspects, such as electric tractors, harvesters, drones, and smart irrigation in smart agriculture, which can be first piloted in rural areas where the development of smart agriculture is more advanced, and then further promoted.

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