Location Selection of Electric Vehicles Charging Stations Based on Analytical Hierarchy Process and Clustering Algorithm

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Abstract. In recent years, the charging infrastructure for electric vehicles (EVs) in China has been developing quickly, yet the charging station industry still faces problems such as unreasonable layout, difficulty in profitability and limited coverage. Based on this, this paper systematically compared the key factors of charging facility location and used the AHP method to measure the degree of influence of various factors at different levels on the location of charging stations of enterprises, so as to establish a scientific and reasonable evaluation model for the location of charging stations. Secondly, we selected 12 typical enterprises such as TELD NEW ENERGY Co., Ltd.from the dimensions of company scale and strategic objectives, and then classified them into state-owned enterprises, vehicle enterprises and specialized operating enterprises through k-means clustering. Finally it turns out that various types of enterprises are in the stage of differentiation in the investment and construction speed of charging station enterprises. In addition, this study proposes personalized siting solutions for different types of charging piles, and makes referenceable suggestions for the siting of charging stations.

Keywords: charging stations, site evaluation, analytical hierarchy process, k-means clustering.

1. Introduction

The new energy vehicle charging station industry is in a rapid growth phase, facing complicated problems and difficult construction. Firstly high upfront costs for building charging stations, an unreasonable layout that results in high operation and maintenance costs, and numerous coordination and approval issues all contribute to a lengthy payback period for investment costs, as well as immediate challenges in reaching profitability and significant operational challenges. For example, in 2018, a number of well-known charging station enterprises, including Yung I, closed their operations due to continuous losses and capital chain tension. By locating charging stations reasonably, it can reduce costs and shorten the payback period, thus encouraging enterprises to develop the charging station industry vigorously. Additionally, as the penetration rate of new energy vehicles continues to rise, the demand for charging stations is growing. In 2021, the penetration rates of new energy vehicles in China was estimated to be 13% and the ratio of vehicles to stations was 3:1. Establishing a charging station siting model and providing professional advice to enterprises can improve the charging infrastructure and expand the siting range of charging sation facilities. Therefore, it is crucial for the marketing and development of EVs and can aid in easing consumers' "last mile" concerns about new energy cars. Furthermore, the distribution of charging stations is uneven, mainly concentrated in the eastern coastal region, with Beijing, Shanghai and Guangdong ranking among the top three in terms of public pile ownership. “Mileage anxiety” requires high-density charging networks, especially in low-temperature environments and high-speed driving conditions. It is difficult to quantify the supporting resources and environmental factors. By utilizing the analytic hierarchy process(AHP), the complex problem can be decomposed into various constituent factors from a quantitative and qualitative perspective. And a two-comparison judgment matrix can be established to determine the weight of each indicator, which can assist enterprises in their decision-making and make them consider more comprehensively and scientifically when selecting a site.

With this background, this paper would systematically sort out the existing theoretical and practical researches from three perspectives of users, power grids and charging operators. Then we constructed a set of scientific and reasonable evaluation index systems for charging facility siting, with a view to providing theoretical references for the siting work, reasonable layout and coverage of charging stations under charging operators. While doing so, the basis for improving charging pile construction is also being laid. In addition, this paper chose three charging station types that fall under state-owned enterprises, specialized operating enterprises, and vehicle enterprises for clustering. It then analyzed the benefits and drawbacks of various enterprise types in the siting of charging stations and offers specific recommendations to help the charging station industry develop. Finally it responded to the *New Energy Vehicle Industry Development Plan (2021-2035)* that was officially released by the State Council in October 2020.In response, we will expedite the study of supporting regulations for infrastructure for charging and offer a firm assurance for the execution of the industrial growth plan.

2. Literature Review

2.1 Study of the influencing factors of EV location

Currently, scholars mainly focus on three dimensions: users, power grids and charging operators to discuss the influencing factors of EV location comprehensively. Analysis shows that the charging demand prediction of EV users is a prerequisite for charging facility planning. Futhermore, intrinsic factors such as traffic flow, user travel characteristics and economic cost all have an impact on the location of charging facilities[2]. Chen Jingpeng et al.[3] used the travel chain to simulate and analyze the travel behavior and charging process of EVs in a week, and established a planning model considering the idling cost of users, etc. Ai Xin et al.[4] estimated the number and range of charging stations based on the charging demand of each demand point obtained from the traffic data in the planning area.

With the development of grid technology, new loads and resources are constantly being connected to the power system, with EVs being a typical example[19]. This has been extensively discussed by scholars from the perspective of the power grid, particularly the distribution system. The capacity, structure and operational safety of the distribution network system have an impact on the location selection. If the capacity margin of the access point of the distribution network was close to the capacity of the charging station, the capacity of the charging station need to be adjusted to reduce the service area. And then the service area was divided and the capacity of the charging station was re-sited. If the capacity margin of the access point of the distribution network differed significantly from the capacity of the charging station, the location and access point need to be re-selected[5]. Jia Long et al.[6] analyzed the impact of EV access on distribution system planning. Based on the charging load estimate, the planning of charging facility access to the distribution network should consider both satisfying the charging demand and the availability of access sites, as well as the size of distribution network planning expenditure. To meet the charging demand of EVs on the road, a distribution network must have enough public charging stations, thus their position and capacity determination and distribution network growth planning must be jointly optimized. LIU et al.[7] considered the capacity constraint of transformers, node voltage constraint, and charging power constraint to reduce the negative impact on the distribution system and ensure its safe operation.

Geographical conditions, environmental conditions, service radius, investment costs and the availability of margins for equipment are important elements for charging facility operators to improve the economics of their operations. Some academics have addressed these issues from the aforementioned angles.. Extrinsic facility siting factors such as geography and environment, including carbon emissions and terrain, are fundamental conditions for the siting of charging facilities. EVs consume electricity while generating indirect carbon emissions that cannot be ignored[8], which can negatively affect the environment and contradict the original concept of EVs. In addition, the special topography that Chongqing has is one of the factors necessary to consider when siting charging facilities. The charging facility operator also needs to predict and estimate the profitability by considering the investment cost and the service radius when selecting the site. Wu Yu et al.[9] optimized the placement choice of EVs by using the service range of the charging station site and the overlap of the service range among the sites as constraints and the construction cost and operation cost of the charging station as objective functions.. Shaoyun Ge et al.[19] used a Voronoi diagram to divide the charging station service area, calculated the charging station service radius and determined the location selection plan according to the maximum service radius of each charging station. In addition, reasonable energy prediction is important for the load situation when charging EVs, which can control the charging in real time to meet peak power, reduce power fluctuation and improve the economy of charging stations[10].

2.2 Study on the layout of charging facilities

Against the backdrop of rapid changes in the social environment and the rapid development of science and technology, our government has been actively promoting the development of the EV industry with high quality. Insufficient capacity of the current distribution network and the phenomena of "cars without piles, piles without cars" are both results of the existing layout of charging facilities, which is impeding the growth of the EV business.The supply of EV charging facilities is becoming an urgent need. In response to this, scholars have mainly studied the layout of charging facilities in three dimensions: demand forecasting, distribution system construction and maximizing the benefits of charging facility operators.

The academic community has mainly developed the prediction of EV charging demand from two aspects: point demand model and flow demand model. The idea of point demand model is relatively simple and clear, but it does not consider driving characteristics resulting in low accuracy of the obtained charging demand. Some experts suggested that in order to handle this, we can look at trends in a variety of typical charging power curves, characteristics of disturbance aspects, and gasoline sales at gas stations. By grouping the charging power curves of the EV charging facilities in each section of the city and converting the comparable charging power, it was possible to determine the charging demand in the corresponding locations[11]. Data mining was used by Deyang Kong et al.[13] to create a P-median site selection model. Then, they used the k-means mean clustering algorithm to locate charging facilities using the taxi GPS dataset from Shanghai Johnson, which was analyzed using Python.. He et al.[13] compared three classical charging facility siting models-set coverage model, maximum coverage location model and p- median model. Hodgson et al.[14] proposed a flow-based siting model in 1992, which is more in line with people's travel behavior than the point demand model, but its data acquisition is difficult and it does not account for long-distance travel. And the travel chain could be used to obtain the EV charging demand characteristics of each region at different times[15-16].

The large-scale EV charging load coupled with the base power load makes the existing distribution network capacity insufficient[18]. Therefore some researchers take into account the construction of the distribution system while researching the layout of charging facilities. By removing the uncertainty model through robust peer-to-peer transformation, Bao et al.[10] demonstrated that they used the robust predictive control approach to build a system model and devise a control strategy to successfully deal with the impact of load forecast uncertainty. Li et al.[2] established a collaborative planning model of the distribution system and charging station taking into account EV participation in peak regulation.

The operating economy of charging facility operators ensures the popularity of supporting facilities. Additionally, academics are investigating the design of charging stations from the perspectives of service capacity, service range, and carbon emission. Ai Xin et al.[4] estimated the required range of charging stations in terms of maximum and minimum service capacity based on chaotic simulated annealing particle swarm optimization algorithm. Chen, Guang et al.[8] proposed a charging station planning model that takes into account EV carbon emissions. Wu, Yu et al.'s ideal solution for the station sites of electric cars took into account the service range of charging station sites, the overlap of service ranges across sites and an enhanced immune clone selection algorithm.[9]

2.3 Research Review

The academic community is now debating the various aspects that affect where charging stations should be located. Additionally, they used a particular research approach to examine the planning goals that various stakeholders were taking into consideration. However, because each city has unique characteristics, the existing research did not take into account the spatial characteristics of urban development layout or the functional orientation of that development. It also did not connect to or coordinate with the pertinent urban planning, which made it challenging to put the suggested solutions into practice[17]. Furthermore, the existing researches lacked the discussion on temperature and power consumption of auxiliary equipment, making it impossible to predict the charging demand accurately.

A win-win scenario for users, the grid, and operators can be achieved by further exploring how to reflect the actual charging demand more naturally and realistically, as well as by implementing more reasonable supporting facilities and spatial layout. In order to fully consider the requirements of various interest subjects, this paper used the analytical hierarchy process (AHP) and the cluster analysis method to construct a scientific and reasonable index system for evaluating the location of charging facilities. It then supported the method's objectivity and effectiveness with instances from the real world.

3. Research Model

The AHP method is a qualitative and quantitative approach for solving complex problems. The AHP method is used to solve problems that are difficult to quantify and aid enterprises in location selection decisions by determining the weight of each indicator through a pairwise comparison. It does this by breaking down a complex problem into its component factors and forming a hierarchy according to their dominant relationships. In this study, we reviewed the findings of previous studies and sorted out the meaning and logic of each aspect using an extensive design of indicators that was scientific, methodical, leading, and operational. Then, we matched the aim level, criterion level, and execution level, respectively, to build a thorough evaluation method for selecting the location of charging stations. We then built a two-by-two judgment matrix based on the assessment system and chose a total of 20 experts and users to whom we would deliver questionnaires. Next, we verified and analyzed the collected data, including normalization to obtain subjective weights, maximum eigenvalues, and corresponding eigenvectors. Finally, we calculated the consistency ratio to determine whether it was less than 0.1. If it was not satisfied, we would modify the judgment matrix according to the experts' experience. And if the condition was satisfied, the evaluation results were output. The research process of the indicator system is shown in Fig.1.

This approach aids in comprehending the current state of charging equipment construction, identifying the siting issues with existing charging stations, and providing a benchmark for charging station siting improvement. It can also avoid blindly building charging stations in the future, and guide and set the right direction for rapid development.

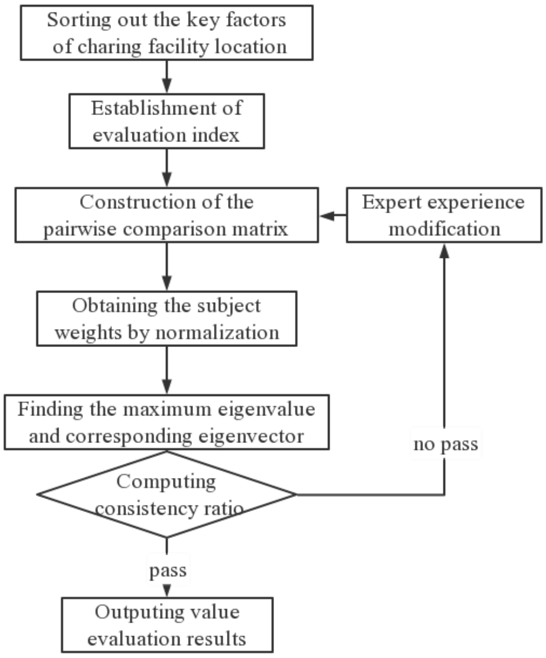

Fig.1 Roadmap for the study of indicator system

3.1 Establishing a hierarchy of charging facility siting evaluation system

Firstly, referring to the existing classical literature, relevant information was collected for three dimensions of users, power grids and operators. Duplicate data was removed and existing research deficiencies were summarized in order to construct a charging facility siting evaluation index system covering four primary indicators and twenty secondary indicators (as shown in Table 1 below).

The operation of the enterprise needed to ensure profitability, a certain amount of traffic and demand. And on this basis, it also needed to consider the surrounding supporting facilities and other resource factors to ensure the normal operation of the charging operator enterprise. Moreover, as a supporting facility for new energy vehicles, the location of charging stations should also include "green" objectives. Therefore, in this study, economics, resources, demands and the environment were considered as the primary indicators of the charging station location evaluation system.

The location of charging facilities have been the subject of numerous theoretical and empirical investigations. This article first identified the primary indicators, then it methodically categorized the essential aspects involved and chose the secondary assessment indicators for each basic indicator.

Table 1 Indicator system table

Primary Indicators	Secondary indicators	Description	Reference Sources
Economy C1	Construction Cost C11	Cost of building electric vehicle charging piles	Cai Zilong et al.[20]
	Maintenance Cost C12	Cost of maintaining facilities in charging stations	Liang Haifeng,Liu Ziyan[21]
	Operating Cost C13	Personnel costs, electricity expenses, etc.	Chen Guangkai et al.[22]
	Distribution Cost C14	Depend on the distance from the utility's property demarcation point to the charging station cable lay and distribution capacity	Cai Zilong et al.[20]
	Payback Period C15	The length of time it takes to recover the cost of investing in charging piles	Liang Haifeng,Liu Ziyan[21]

	Charging equipment C21	Conventional chargers, fast chargers and power exchange equipment (equipment diversity and adequacy)	
	Land Resources C22	Whether the land used is level, nearby traffic, roads, water supply and drainage, and fire protection and other municipal public facilities	Cai Zilong et al.[20]
Resource C2	Service Capability C23	Operating capacity of electric vehicle charging facilities	Li Fei et al.[24]
	Power Distribution Capacity C24	Whether the charging pile is in line with the grid plan and it needs to consider coverage density and ease of access to power	
	Supporting Facilities C25	Living facilities, relying on socialized information service platform, etc.	Zhang Liyan et al.[25]
	Population Distribution C31	User distribution characteristics such as residential travel	Yang Xiaoyu et al.[24]
	Station Site Layout C32	Coverage of station sites	Wu Yu et al.[9] ,Xu Qingshan et al.[15]
Demand C3	Traffic Flow C33	Traffic Convenience	Yan Jun,Yan Feng[25]
	Future EV Possession C34	Potential future EV owners	Choi Hyunhong et al.[26]
	EV power consumption C35	EV power consumption varies from model to model, as does the use of auxiliary equipment in the car.	
	Industry Development C36	Whether the planning of charging piles is compatible with the local electric vehicle development plan	Cai Zilong et al.[20]
	Climate C41	Charging piles have requirements for temperature and weather, and improper protection in bad weather can produce explosions	Li Hongzhong et al.[2]
Environment C4	Environmental C42	Whether the charging pile will pollute the surrounding environment and comply with government environmental protection rules	Liang Haifeng,Liu Ziyan[21]
	Security C43	Whether the charging pile comply with the blasting hazard range, fire spacing	Ma Jun et al.[27]
	Terrain C44	Whether the hydrology and geology are suitable for construction, whether the selected site is flat and low-lying	Liu Z et al.[7]

3.2 Construction of Two-comparison Judgment Matrix and Determination of Weights

Secondly, the expert survey method was used to investigate both users and experts in related fields. The specific composition of the personnel was shown in Table 2.

Table2 Composition of research subjects

Projects	Basic information	Number of people	Composition ratio (%)
Gender Composition	Male	7	46.7
	Female	8	53.3
Personnel Composition	Experts	6	0.4
	Master	6	0.4
	User	3	0.2
Years of driving experience	0-9 years	8	53.3
	10-19 years	5	33.3
	More than 20 years	2	13.4

Users and subject matter experts from relevant fields compared the index system's indicators, scored them two by two, assigned values using the method of a 1–9 scale, and created a judgment matrix to assess the relative importance of the indications at each level. After sorting the values in the original expert scoring matrix, one of the highest and one of the lowest expert scores among the fifteen expert scores were excluded to construct the judgment matrix to ensure the accuracy of the data. We introduced the weight calculating method with the following illustration:

Construct the judgment matrixC_i depicted in Table 3 below.

Table3 Judgment MatrixC_i $i = (1,2,3,4)$

	C_1	C_2	C_3	C_4
C_1	1.00	1.61	0.66	1.16
C_2	0.62	1.00	1.27	1.31
C_3	1.52	0.79	1.00	2.01
C_4	0.86	0.76	0.50	1.00

Calculate the geometric mean of each row of the judgment matrix using the product square root method, W_i :

$$W_i = \left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}} \quad (1)$$

Where a_{ij} represents the elements in the judgment matrix, and n denotes the number of indicators. Obtain

$$W_i = (4.1414,4.1402,4.1221,4.1311)^T \quad (2)$$

The weight coefficients were obtained by normalizing the geometric mean of each row:

$$W_j = (0.2603,0.2513,0.3067,0.1817)^T \quad (3)$$

Calculate the maximum eigenvalue of the judgment matrix λ_{max}:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{\sum_{j=1}^{n} a_{ij}w_j}{w_i} \quad (4)$$

Get $\lambda_{max} = 4.0562$.

Calculate consistency metrics CI and consistency ratio CR:

$$CI = \frac{\lambda_{max}-n}{n-1} \quad (5)$$

Get $CI = 0.0187$. According to Table 4, $RI = 0.90$. Then $CR = {CI}/{RI} = 0.0208 < 0.1$,indicates that the consistency test meets the requirements.

Table 4 Average random consistency index

Number of steps	3	4	5	6	7	8	9	10
RI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Similarly, the weights corresponding to the other indicators can be calculated and summarized as shown in Table 5.

Table 5 λ_{max} , ω and C_R of each judgement matrix

Judgment Matrix	λ_{max}	ω	C_R

Ci	4.1337	[0.2603 0.2513 0.3067 0.1817]	0.0495
C1 -C1j	5.3247	[0.3168 0.2084 0.1860 0.1410 0.1478]	0.0725
C2 -C2j	5.4084	[0.1725 0.3626 0.1618 0.1978 0.1053]	0.0911
C3 -C3j	6.2602	[0.2601 0.1546 0.1520 0.1700 0.0988 0.1645]	0.0420
C4 -C4j	4.0562	[0.2460 0.2671 0.3854 0.1016]	0.0208

The evaluation of charging facility siting can not only uncover the issues of existing charging facilities, but also provide a theoretical basis for future charging facility siting. This study first developed assessment indexes by using the AHP method, and then used the expert evaluation to assess the index weights from the views of users and experts, determining the weight of each index in the system.

4. Empirical analysis

4.1 Sample Selection

Due to the large number of charging stations, it is difficult to conduct site-by-site evaluation. The charging stations under different charging operator enterprises have their own characteristics, which are worth studying and exploring. Therefore, this paper evaluated the charging stations under typical charging operator enterprises with three characteristics: specialized operating enterprises, state-owned enterprises, and vehicle enterprises. Finally 12 charging operator enterprises were selected as the research objects, as shown in Table 6.

Table 6 Sample selection of charging stations

Features	Considerations	Sample
Specialized operating companies	As the earliest and most mainstream mode of operation, they have significant requirements for the operator’s financial size, corporate background, etc. (Operating for profit)	Star Charge, TELD New Energy Co.,Ltd., YKC Clean Energy Technologies, and EV Power
State-owned enterprises	Their main business is energy and grid infrastructure construction. (Operating for promoting charging piles)	State Grid Corporation of China, Potevio Company Limited, and China Southern Power Grid Company Limited
Vehicle enterprises	To advertise their own goods and alleviate consumers' mileage concern, large OEMs take the initiative to design and construct charging infrastructure, which takes more cash from OEMs. (Operating for promoting car sales)	Tesla, Anyo Charging, BYD, Xiaopeng Motors, and NIO

First, each indicator was given a score based on the actual circumstance when the aforementioned charging stations were assessed using the built-in site evaluation system. 0 meant "extremely unsatisfactory" or "completely unnecessary," 1 meant "less satisfactory" or "unnecessary," 2 meant "general," 3 meant "more satisfactory" or "necessary," and 4 meant "very satisfactory" or "very necessary." The final evaluation results were shown in Table 7.

Table 7 Evaluation results of charging operator companies

Enterprise	Total Score	Economy	Resources	Demand	Environment
Star Charge	3.5767	3.5682	3.5988	3.6893	3.3683

TELD New Energy Co.,Ltd.	3.7830	3.6930	3.6322	3.9242	3.8822
YKC Clean Energy Technologies	2.9716	2.6987	2.9001	2.9552	3.4892
EV Power	3.0330	3.2022	3.1025	2.8658	2.9769
Tesla	2.3586	2.9632	2.0998	2.3988	1.7825
Anyo Charging	2.9170	3.0632	2.6542	2.9652	2.9898
BYD	2.6996	2.6986	2.0987	3.2133	2.6651
Xiaopeng Motors	2.5471	2.5216	1.9288	2.8321	2.9578
NIO	2.3798	2.3035	1.9981	2.3551	3.0588
Potevio Company Limited	3.0752	3.0002	3.0012	2.9665	3.4685
State Grid Corporation of China	3.6563	3.4098	3.5906	3.9002	3.6888
China Southern Power Grid Company Limited	3.0311	3.0382	2.6776	3.0582	3.4642
Average value	3.0024	3.0134	2.7736	3.0937	3.1493
Standard deviation	0.4549	0.3992	0.6130	0.4925	0.5319

Second, the mean and standard deviation of the evaluation results of the sample charging facility operator companies were plotted as a line graph, as shown in Fig.2.

This led to the following points:

The indicator with the lowest mean value is resources, which indicates that each charging facility operator company pays less attention to resources. Resources include charing equipment, land resources, service capacity, power distribution capacity, and supporting facilities. This shows that modern charging station operators largely disregard charging equipment layout optimization and prudent charging site planning in favor of environmental factors like investment and construction speed, which boost profitability and safety.

(2) The highest standard deviation is resources, which indicates a large degree of dispersion. Resources include charging equipment, land resources, service capacity, power distribution capacity and supporting facilities, which is one of the factors that cannot be ignored when enterprises operate. Calculating and measuring each resource, optimizing the layout of charging equipment and reasonably planning the site can ensure the sustainable development of enterprises, which is the inevitable trend of the industry development. In accordance with the fact that different types of businesses construct charging stations for various purposes, Table 7 shows that some charging operator enterprises concentrate on the resource factor when choosing the location of charging stations while other charging operator enterprises ignore this factor.

In conclusion, the influencing factors of each charging facility operator's location selection are uneven. Leading enterprises such as Star Charge have nearly thorough in their consideration of charging station location selection and only need to make minor adjustments. Whereas, poorly operated enterprises still have much room for improvement and should learn from more mature charging facility operator enterprises and continuously improve the level of consideration of their own enterprises in location selection.

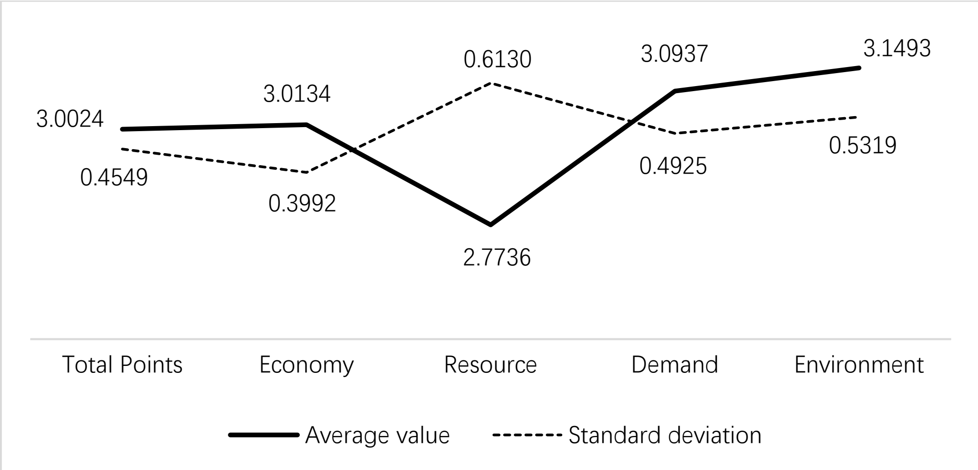

Fig. 2 Average value and standard deviations of sample charging facility operator companies

4.2 Cluster analysis

Further investigate the data and present the various focuses of each category of charging operators in terms of location choice in real-world scenarios. Additionally, enhance the operating efficiency of charging stations, sustain strong upstream and downstream cooperation links, and stay current with industry development while offering tailored ideas for where to locate charging stations for each type of charging operators. Based on the outcomes of the major indices' evaluation, this study performed a k-means clustering analysis on the businesses of charging facility owners. We conducted the k-means cluster analysis to group charging operators with similar properties into one category, and the results are shown in Fig.3.

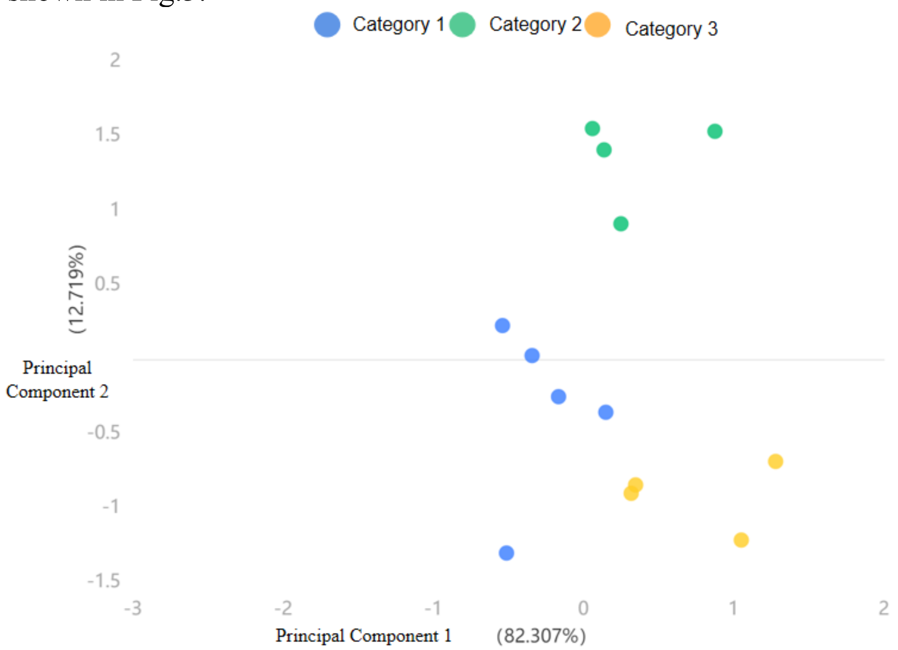

Fig. 3 Cluster analysis according to the first-level indicators

This study divided the 12 sample charging operator enterprises into three groups, as shown in Fig. 3. These groups corresponded to vehicle enterprises whose primary goal is to promote new energy vehicle products. The second one was state-owned enterprises whose main business is the construction of energy and grid infrastructure. And the last one was specialized operating enterprises whose primary goal is to operate for profit, as shown in Table 8.

Table 8 Classification and ranking of charging facility operator companies

Category 1	Category 2	Category 3

Serial number	Name	Serial number	Name	Serial number	Name
1	Tesla	1	Potevio Company Limited	1	Star Charge
2	Anyo Charging	2	State Grid Corporation of China	2	TELD New Energy Co.,Ltd.
3	BYD	3	China Southern Power Grid Company Limited	3	YKC Clean Energy Technologies
4	Xiaopeng Motors			4	EV Power
5	NIO				

For each type of charging facility operator companies, we calculated the mean value of the evaluation results, and the results are shown in Fig.4.

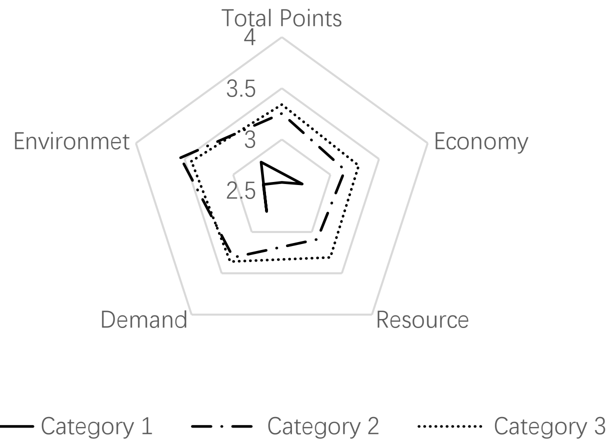

Fig.4 Average level 1 indicators of various charging facility operators

As a result, it is feasible to summarize the evaluation of the three different charging facility operator enterprises' location as follows:

The first type of enterprises is the vehicle enterprises whose main purpose is to promote new energy vehicle products, which mainly focus on demand and are more negligent about resources. Since the vehicle enterprises are not aiming to develop the charging post market but to promote cars, their market share is relatively low, and they pay attention to the traffic flow, population distribution and future EV ownership involved in demand factors. According to the results of AHP, the weight of resources in location selection is 0.2513, therefore, this category of enterprises needs to follow the industry development in the future and gradually enter the stage of layout optimization.

The second group of enterprises is the state-owned enterprises mainly engaged in the construction of energy and power grid infrastructures, and they consider all factors in a more comprehensive manner. The state-owned firms are trying to promote charging stations, which is in line with the three-stage general goal put forth in the 14th Five-Year Plan, according to the overview of *China's new energy vehicle charging station sector in 2020*. From Fig. 5, it is clear that they give resources less thought than they should. As a result, they should give resources more thought when choosing sites in the future and move on to the stage of differentiation of investment and construction speed of public stations.

In terms of the total score, the third category of enterprises scores the highest, which is in line with *the* 2020 *overview of China's new energy vehicle charging station industry*. Wherein specialized operational enterprises, who are the dominant businesses in the charging station sector, hold more than 75% of the market share for public charging station operations. The third category of enterprises is specialized operating enterprises that operate for profit, and operator enterprises almost always consider economic and environmental aspects most when selecting a site. Since calculating an enterprise's economic elements can help it establish its break-even point and profitability model, businesses in this category concentrate on how economic factors may affect the choice of a future location.

In conclusion, the scoring of each charging operator company can highlight the limitations of various operator firms in terms of charging station placement, according to the findings of the analytical hierarchy method. For instance, Tesla doesn't take the environment into account when placing charging stations. It would result in safety risks for the neighborhood, environmental pollution, or damage to the charging stations due to geological factors, lowering the company's profitability and affecting the growth of the industry. The industry as a whole ignores the resource factor when deciding where to place charging stations, according to the mean and standard deviation..And the rate of charging station building is beginning to vary, with Specialized operating companies continuing to expand quickly while vehicle enterprises gradually slowing down investment and construction speed and entering the layout optimization stage. The target businesses were then divided into state-owned, vehicle, and specialized operating enterprises by using k-means clustering. And their priorities and shortcomings in terms of choosing charging station locations were compiled so that specific recommendations could be made. For instance, the whole-vehicle firms built charging stations to encourage car sales, giving weight to demand variables like traffic flow, population distribution, and potential EV ownership while ignoring resources and the environment. Based on the results derived from the analytical hierarchy process(AHP), operators of such charging facilities will now need to move on to the phase of layout optimization.

5. Summary

This paper built an evaluation system for siting charging stations based on AHP, taking into account users, power stations, and charging operators, all against the backdrop of the rapidly developing new energy vehicle market. The system contained 20 indicators and their weights in four dimensions: economy, demand, resources and environment. The assessment index system showed that the location of a charging station is mostly determined by economic and demand factors. The economy ensured the profitability of the enterprise, which is the fundamental purpose of operation for all kinds of enterprises. The demand ensured the sustainability of the enterprise. The frequency of utilizing the charging station was determined by the passenger flow, EV future forecast, EV power consumption, etc. These factors also affected whether the business and industry can grow. Operators continue to prioritize the survival of the business when choosing the placement of the charging station because it is still in the development stage. And the optimal layout and environmental factors of the resources are still lacking. Among them, the optimized layout represents both a trend for the industry's future growth and a turning point in the differentiation of the pace at which charging stations are built. The environmental element is the fundamental goal of new energy vehicles. Therefore, the charging infrastructure also needs to focus on the environment in the future. This paper selected 12 charging facility operator enterprises and clustered them by k-means, dividing them into three different types of charging facility operators, including vehicle enterprises, state-owned enterprises, and specialized operating enterprises. This was done in order to provide more precise, accurate, and useful location selection recommendations for various types of charging facility operator enterprises. This will the chance to update and enhance their strategic goals, achieve optimization, and fix any understanding-related location selection flaws. Additionally, this study can assist government organizations in resolving issues with inadequate funding, arbitrary spending choices and other issues brought on by ignorance. It can also serve as a resource for further encouraging the installation of charging stations.

This study also has certain limitations, including the subjective influence of experts in the determination of indicators at all levels and the limited accessibility of some indicator data. Second, the charging heaps in this study are simply included in the charging infrastructure and are not separated into private, public, and special stations. The "intelligent slow charging station + high power fast charging station" charging facility system may also be the subject of future research. There is a dearth of actual data on location selection and operator enterprises, and the site selection plan itself has not been taken into account in terms of economics, convenience, convergence, or coordination with relevant urban planning. The aforementioned plan can be further validated and enhanced in the future using actual data.

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