The Comprehensive Evaluation Model of Charging Station Location based on FAHP

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Abstract

Aiming at the problem of the charging station layout optimization, a charging station location index model based on FAHP is established. Through AHP, the population, economic development, transportation, policy and other factors to construct the weight vector, so as to get the weight of index. Then using fuzzy comprehensive evaluation, constructs the evaluation matrix, derived demand index, a sort of demand set up according to the results. Through the analysis of the United States, China, South Korea and other areas, electric vehicle should be taken the lead in popularizing in populous, economically developed and heavy-traffic areas.

Keywords

The Comprehensive Evaluation Model, FAHP, the Influence Factor, the Weight of the Evaluation Index.

1. Introduction

With the development of science and technology, as well as the needs of environmental protection and economic development, more and more consumers are now inclined to buy electric vehicles. In fact, many countries have now greatly supported the popularity of electric vehicles. Judging from the current global sales of electric vehicles, many countries have actively promoted the switch from fuel-powered cars to electric vehicles, and some countries have even announced that they will ban the use of gasoline and diesel vehicles in the future.

But with the popularity of electric vehicles, there is also a new problem, that is, the establishment of charging stations. How to set up enough charging stations in the most suitable places, ideally in a region or a country, When the fuel truck is completely transformed into an electric vehicle, all the gas stations are converted to charging stations. However, there are many constraints in this process. How to plan the distribution of charging stations, the popularity of electric vehicles in a country is very important.

Understand the demand for electric vehicles in different regions in order to identify the best investment locations and investment volumes better, but the factors affecting demand in a region are not single, some of which have fixed and numerical relationships, some of them only have qualitative description and can't give their specific relations accurately, such as government guidance, geographical location, etc. Fuzzy comprehensive evaluation is introduced here to normalize each index, and at the same time confirm the influence degree of different indicators.

2. Model

2.1 Influence factor analysis

In order to select various factors in the evaluation index system, we following the index system and choose the maneuverability principle, the completeness principle, the objective authenticity principle and independence principle. In this paper, we combine the advantages of fuzzy mathematics to deal with t uncertainty of objective things and the advantages of Analytic hierarchy process in dealing with Index weights, introduce this method into the primary election of charging station. It is convenient and concise, and can play a better role.

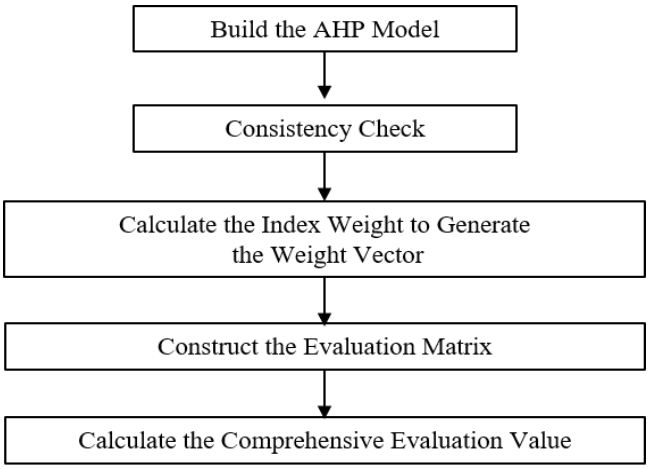

Fig.1 FAHP Flow Chart

According to the analysis of the principle of location of charging station and its influencing factors, we analyze this question in 5 respects including population, economic development, traffic, policy and other.

2.1.1Population

Fixed charging stations can only satisfy a certain number of users, in densely populated areas, more often need to be put on.

2.1.2Economic development

The area of charge station is generally larger. In a city with high economic development, the price of land is bound to account for a large proportion of the initial station cost. Therefore, when selecting the site, the location of the candidate point is a factor to be considered. The construction cost of construction stations in different places and the corresponding management fees are different.

2.1.3Traffic

The density of the network around the charging station affects the convenience of traffic near the charging station to some extent, thus affecting the weight of the candidate point. Traffic congestion and patency affect the ability to attract more users, the more convenient the traffic, the more time the user can save.

2.1.4Policy

The planning of charging stations should satisfy the current policy factors and the future policy trends. According to the policy support degree, the government's expansion plan and the potential development of candidate points, the strength of candidate points is analyzed.

2.1.5Others

The different specific conditions in different regions, the impact factors will be different, such as power grid factors, environmental protection, safety, and so on will affect the location of charging stations in varying degrees.

2.1.6Index system establishment

According to the construction principle of evaluation index system and the analysis and description of the above factors, we finally establish the index system.

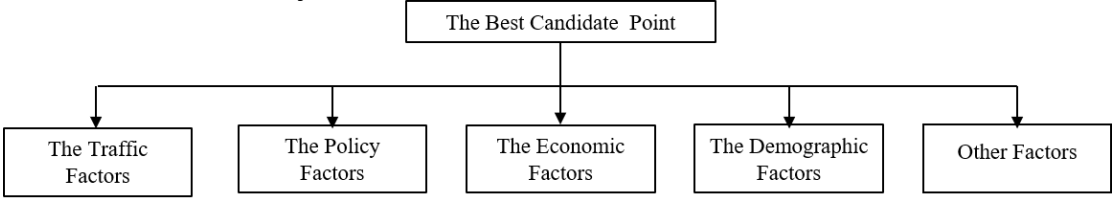

Fig. 2 The Influence Factor Classification

2.2 Fuzzy Comprehensive Evaluation based on membership function

2.2.1 Establishment of the set of judgment factors U and V

Through the analysis of the index system established by 2.1set up factors set accordingly, Express as follows:

$$U=\{U_1,U_2,U_3,U_4,U_5\}$$

This paper divides the candidate sites into four level V={V_1,V_2,V_3,V_4},respectively representing the degree of excellence in the site selection, that is {excellent，good，medium，poor}，the values given are {100,80,60,20}.

2.2.2 Determine the weight of the evaluation index

Step 1: according to the index system established in this paper, a hierarchical model can be built.

Step 2: the construction of the judgment matrix and the consistency check, the concrete method is as follows:

Defining consistency indicators CR.

If the consistency indicators CR 0.10，it is considered that the judgment matrix satisfies the requirement of consistency and can be accepted without revaluation.

Step 3: calculate the maximum characteristic root to judge the matrix and the corresponding feature vector.

Step 4: calculate the weights of each index.

Step 5: make the weight coefficient matrix.

W= {W_1, W_2, W_3, W_4, W_5}.

2.2.3 Solution of Fuzzy Matrix S

The evaluation criteria are determined and the evaluation matrix is constructed according to the distribution of samples.

$$R=\begin{bmatrix}R_1\\R_2\\\vdots\\R_M\end{bmatrix}=\begin{bmatrix}r_{11}&r_{12}&\cdots&r_{1n}\\r_{21}&r_{21}&\cdots&r_{2n}\\\cdots&\cdots&r_{ij}&\cdots\\r_{m1}&r_{m2}&\cdots&r_{mn}\end{bmatrix}$$

If the influence is prominent, only a general evaluation should be given, and the fuzzy judgment level can be determined by using M (∧,∨), and the maximum membership principle can be used to judge.

$$S_i=W\circ R_i=(s_k)_{1\times n} \tag{1}$$

If there is a need to compare the potential of selection, Then the fuzzy judgement set S determined by M(•,⊕) operator， judge according to weighted average principle, then assign an evaluation level {excellent, good, medium, poor}={100,80,60,20},put it into formula, we can get the demand index of each state.

$$u_{k=1}^{*}=\frac{\sum_{i=1}^{4}\mu(v_i)\cdot s_i}{\sum_{i=1}^{4}s_i} \tag{2}$$

$\mu(v_i)$ represents the value assigned to the evaluation index.

3. The Assessment of the Needs of Each States of the US

Synthesis of the views of some experts, establish a judging matrix, get the corresponding weight, then conduct the consistency check. The subjective experience is given here. The weight vector is:

$$W = (W_1, W_2, W_3, W_4) = (0.5, 0.2, 0.2, 0.1)$$

Establish evaluation indicators and set evaluation criteria as follows:

Table 1 The Evaluation Stadared

Index	Excellent	Good	Medium	Poor
Population density (per square mile)	>750	250-750	100-250	<250
Per capita GNP (Thousands of dollars)	>60	60-55	55-50	<50
Traffic flow	congestion	good	congestion	idle
Policy orientation	popularize	support	neutrality	oppose

And then sampling each county in each state, get the number of samples under each indicator, then the evaluation matrix R is obtained. Two states are now being graded to calculate the fuzzy matrix S, for example, in Florida and Maine:

$$S_1 = (0.5, 0.3, 0.1, 0.1) \circ \begin{pmatrix} 0.10 & 0.25 & 0.18 & 0.47 \\ 0.09 & 0.19 & 0.37 & 0.35 \\ 0.09 & 0.21 & 0.34 & 0.36 \\ 0.33 & 0.31 & 0.36 & 0 \end{pmatrix} = (0.33, 0.3, 0.1, 0.1)$$

$$S_2 = (0.5, 0.3, 0.1, 0.1) \circ \begin{pmatrix} 0.03 & 0.20 & 0.27 & 0.50 \\ 0.11 & 0.13 & 0.27 & 0.49 \\ 0.09 & 0.11 & 0.34 & 0.46 \\ 0.14 & 0.29 & 0.37 & 0.2 \end{pmatrix} = (0.14, 0.29, 0.1, 0.1)$$

According to maximum membership principle, S1 belong to “excellent” while S2 belong to “good”. As a result, there is a greater demand in Florida than Maine. We can assign an evaluation, and make a judgment according to the weighted average principle. We can get the results: S1=87.621, S2 =36.573 and so on. In this way, we can sort out the degree of demand in each state in turn.

Table 2 The Number of Charging Station in US

State Name	Population Density	The Number of Charge Station	State Name	Population Density	The Number of Charge Station
California	37.3	49623.61	Oregon	3.8	5055.489
Texas	25.1	33392.83	South Carolina	4.6	6119.802
New York	19.4	25809.6	Kentucky	4.3	5720.685
Florida	18.8	25011.37	Oklahoma	3.8	5055.489
Illinois	12.8	17029.02	Iowa	3	3991.175
Pennsylvania	12.7	16895.98	Kansas	2.9	3858.136
New Jersey	8.8	11707.45	Nevada	2.7	3592.058
Ohio	11.5	15299.51	Utah	2.8	3725.097
Virginia	8	10643.13	Arkansas	2.9	3858.136
North Carolina	9.5	12638.72	D.Columbia	0.6	798.2351
Georgia	9.7	12904.8	Mississippi	3	3991.175
Massachusetts	6.5	8647.547	Nebraska	1.8	2394.705

Michigan	9.9	13170.88	New Mexico	2.1	2793.823
Washington	6.7	8913.625	Hawaii	1.4	1862.549
Maryland	5.8	7716.273	West Virginia	1.9	2527.744
Indiana	6.5	8647.547	Delaware	0.9	1197.353
Minnesota	5.3	7051.077	New hampshise	1.3	1729.509
Arizona	6.4	8514.508	Idaho	1.6	2128.627
Colorado	5	6651.959	Maine	1.3	1729.509
Wisconsin	5.7	7583.233	Rhode	1.1	1463.431
Tennessee	6.3	8381.468	Alaska	0.7	931.2743
Missouri	6	7982.351	South Dakota	0.8	1064.313
Connecticut	3.6	4789.411	Wyoming	0.6	798.2351
Louisiana	4.5	5986.763	Montana	1	1330.392
Alabama	4.8	6385.881	North Dakota	0.7	931.2743

4. Problem extension of FAHP in other countries

4.1 The Establishment of Classification System

According to the establishment of charging Station location Index system based on FAHP, we can also get the assessment indicators of each countries. As different countries have different geographical conditions, the evaluation index and its corresponding standards will change accordingly. Except the four factors (Population, Economic, Traffic and Policy), we should lead into other factors, these other factors related to the specific conditions of various countries, thus we establish a classification system. Because of the differences in different conditions, the weight of each index is bound to be different from country to country. So, we constructing a new weight vector

$$W' = \{W_1, W_2, W_3, W_4, W^*\} \quad (3)$$

Where

$$W^* = \{W_1^*, W_2^*, \ldots, W_m^*\} \quad (4)$$

4.2 The Assessment of the Needs of Individual Countries

In China, due to different economic systems, the government tends to have greater intervention in the market, so the weight of policy factors is relatively large. In Saudi Arabia, where the oil industry remains the mainstay of the country's development, energy (and other factors) will account for a bigger share, so people prefer cars to electric vehicles. In addition, it is necessary to construct different judgment functions for different countries. We get weight vector of these 5 countries.

Australia: Australia is a sparsely populated area, residents travel mostly by car, so the other factors W_1^*= {travel mode}.

China: the introduction of shared bikes in China in recent years and the promotion of health have made it more difficult for electric vehicles to compete in the market, W_2^*= {market competition}.

Indonesia: in South Asia, the topography of the archipelago makes it more difficult to popularize for electric vehicles, W_3^* = {geographical features}.

Singapore: for countries with small area, the consumption of electric energy reserves will affect the normal operation of the whole country to some extent, W_4^*= {Resource consumption}.

Saudi Arabia: for an oil-rich country, there is a certain difficulty in popularizing electric energy travel methods, W_5^*= {industrial structure}.

The new judgment matrix is composed of new influencing factors, and the new weight vector is obtained after consistency checking.

Table 3 Weight Vector in Different Country

country	Australia	China	Indonesia
weight vector	(0.2,0.2,0.3,0.1,0.2)	(0.3,0.2,0.1,0.4,0.1)	(0.3,0.1,0.3,0.1,0.2)
country	Singapore	Saudi Arabia	
weight vector	(0.2,0.2,0.2,0.3,0.1)	(0.2,0.2,0.1,0.1,0.4)	

Then follow the same steps to calculate the needs and ranking of each country.

Table 4 Evaluation Value in Different Country

country	Australia	China	Indonesia	Singapore	Saudi Arabia
Evaluation results	70.436	92.688	62.890	60.020	58.307

5. Conclusion

It is not difficult to see that the location of electric vehicles should first tend to choose China. By consulting the background information of various countries, we can see that China has vigorously advocated green and sustainable development in recent years, especially in reaching the full tram coverage plan in 2040. Tesla's initiative to actively build more charging stations in China has made China the country with the most charging facilities outside the United States. Through a comprehensive analysis of various factors, it can be seen that the evaluation results are basically in line with the future development of countries.

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