ISSN: 2688-9323

Using the Analytic of Hierarchy Process to Choose Site for a Supercharger Station

-- A Case Study of Tesla

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Abstract

For today's new-energy vehicle enterprises, the construction of charging stations is the top priority to maintain after-sales service. Indeed, a scientific charging station location facilitates users, increases profits and establishes a high reputation. This paper takes the site of supercharger station as the research object and Tesla brand vehicles as the case. Three alternative locations are provided according to the reality. Using the Analytic Hierarchy Process(AHP) included in the Management Decision Model, the factors that have the greatest impact on choosing the site and the most suitable site for the construction of supercharger station is obtained.

Keywords

Site Selection; The Analytic of Hierarchy Process; The Management Decision Model; Supercharger Station.

1. Introduction

As the automobile industry booms, many new energy brands have emerged in order to meet the increasing needs of consumers and respond to the environmental protection policies of "China VI vehicle emission standards". At present, the Battery Replacement Service is not widely used in China, and charging is still the mainstream for new energy vehicles to obtain energy. Therefore, the location of charging point is particularly important. A scientific location greatly facilitates the travel of new energy owners, which can not only meet the charging needs of surrounding resident vehicles, but also avoid the embarrassment of insufficient driving range for other car owners.

At the same time, charging is both after-sales service and value-added service, which has a great impact on the reputation of an automobile brand. Good location and service can promote the brand and attract customers, so as to improve the profitability of the enterprise.

This report is mainly based on the site selection and business model of Tesla's Supercharger Station. Here are three alternatives for constructing a Supercharger Station:

A is set up in the basement on the ground floor of the business center, and an area is set aside for Tesla vehicle charging.

B is set up in the international community, opposite the sporting goods supermarket, surrounded by many catering and entertainment facilities.

C is set up in the suburb of the city, close to the motor city and the super factory of Tesla.

ISSN: 2688-9323

2. Literature Review

2.1. The Analytic of Hierarchy Process

This method is proposed by Thomas L. Saaty to determine the weight of each objective in multi-objective decision-making. The Analytic Hierarchy Process not only plays an important role in management decision-making, but also has many important applications in other disciplines other than management.

In multi-objective decision-making, the weight of each objective has an important impact on the analysis results, but it is difficult to determine the weight. The basis of the Analytic Hierarchy Process is the stratification of objectives and the pairwise comparison of the importance of each objective at the same level, so that the task of determining the weight of each objective is operable.

2.2. Site Selection

Site selection refers to the process of demonstrating and making decisions on the address before the construction. Firstly, it refers to the set area, the environment of the area and the basic requirements that should be met. Secondly, it refers to the specific location and orientation. With the progress of social development, "site selection" has been applied to more industrial enterprises, and there are more choices of chain national terminals. Many enterprises will choose appropriate sites according to their company's strategic planning.

In this paper, the criteria affecting the site selection are divided into: convenience, economy and space, and the factors are divided into: location, floor, unit price, area and flow-rate.

3. Methods

3.1. Basic Ideas

The title of this paper includes the research object and research method. This paragraph will take three real alternative locations as an example, calculate the data through the Analytic Hierarchy Process, compare and obtain the optimal scheme.

3.2. Steps of the AHP

1. Build a hierarchical model of the problem. That is to define the target layer, criterion layer and sub criterion layer of the problem. Determine the factors of each layer and the relationship between each factor and the factors of the previous layer.

2. Construct the importance pairwise comparison judgment matrix of each factor constituting the goal.

3. Find the eigenvector of the judgment matrix and the corresponding maximum eigenvalue.

4. The consistency test of judgment matrix, which includes the following steps:

(1) Calculate the consistency index(C.I.). Comparing the size of the maximum eigenvalue λ of the judgment matrix reflects the consistency of the judgment matrix, but the matrix theory shows that the larger the matrix is, the larger the maximum eigenvalue λ is. In order to eliminate the influence of matrix dimension on consistency, it is necessary to calculate the consistency index C.I.:

$$\mathbf{C.I.} = \frac{\boldsymbol{\lambda} - \mathbf{n}}{\mathbf{n} - \mathbf{1}}$$

In this way, the C.I. of two judgment matrices with different dimensions are comparable.

(2) Calculate the random index(R.I.). This index is the average of the eigenvalues of randomly generated judgment matrices with different dimensions.

ISSN: 2688-9323

Saaty used a large number of random numbers in the computer to form the judgment matrix. They all met the two principles that the factors on the diagonal are 1 and the factors symmetrical on the diagonal were reciprocal to each other, but they were not required to meet the consistency principle. Therefore, the consistency of such random judgment matrix was very poor. At the same time, he calculated the C.I. of these matrices and the R.I. of random judgment matrices with the same dimension.

We can speculate that if a judgment matrix of pairwise comparison is given after careful consideration, the C.I. of this matrix will be much smaller than the R.I. of the same dimension. Therefore, Saaty believes that if the ratio of two C.I. was less than 0.1, it can be considered that the inconsistency of the constructed pairwise comparison judgment matrix is very small, and this judgment matrix can be considered to be effective.

Table 1. The R.I. of different dimensions

n	1	2	3	4	5	6	7	8
R.I.	--	--	0.52	0.89	1.12	1.26	1.36	1.41

From above, n=1 is meaningless. When n=2, the judgment matrix must be completely consistent, and there is no need for consistency test.

(3) Calculate the consistency ratio (C.R.):

$$\mathbf{C.R.} = \frac{\mathbf{C.I.}}{\mathbf{R.I.}}$$

(4) When C.R. < 0.1, it is considered that the consistency of the judgment matrix is acceptable.

5. If the consistency test is passed, the feature vector obtained is the weight of each factor.

6. Use the weight of each level to calculate the gross weight of the bottom scheme to the top goal.

3.3. Construction of the Research Model

Based on the business model of Tesla super charging station, an ideal new energy vehicle super charging station should meet the characteristics of convenient transportation, economical management and large space.

Build a hierarchical model according to the influencing factors mentioned in 2.2 and steps of AHP mentioned in 3.2.

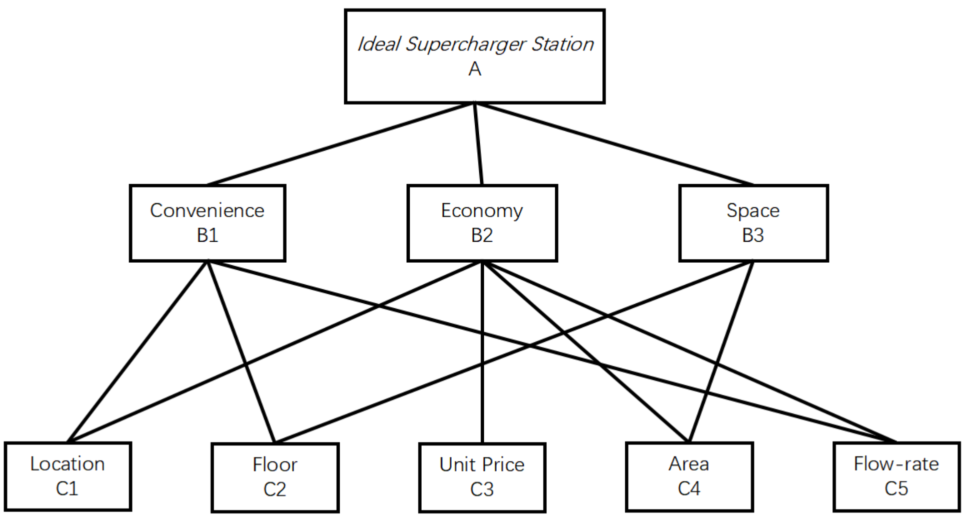

Fig 1. The AHP of site selection

ISSN: 2688-9323

4. Calculations based on the Analytic Hierarchy Process

4.1. Weight Calculation of the Second Level Indexes

Compare the importance to the overall goal and analyze the judgment matrix, as shown in the figure below:

Table 2. Calculation of index weight of overall goal

Ideal Supercharger Station	Convenience B1	Economy B2	Space B3	Weight W	Product of judgment matrix and eigenvector AW	Maximum Eigenvalue λ
Convenience B1	1	2	8	0.6821	1.9227	3.0804
Economy B2	0.5	1	2	0.2171	0.7598	
Space B3	0.1250	0.5	1	0.1008	0.2946	
C.I.=0.0402 R.I.=0.52 C.R.=0.0773<0.1 Passes the consistency test.						

4.2. Weight Calculation of the Third Level Indexes

Table 3. Pairwise comparison of factors on convenience

Convenience B1	Location C1	Floor C2	Flow-rate C5	W	AW	λ
Location C1	1	4	6	**0.6911**	2.1361	3.0126
Floor C2	0.25	1	2	**0.2042**	0.5864	
Flow-rate C5	0.1667	0.5	1	**0.1047**	0.3220	
C.I.=0.0063 R.I.=0.52 C.R.=0.0121<0.1 Passes the consistency test.						

As can be seen from Table 3, the convenience criterion passes the consistency test. The location factor has the greatest impact on the convenience criterion, and its weight reaches 0.6911.

Table 4. Pairwise comparison of factors on economy

Economy B2	Location C1	Unit Price C3	Area C4	Flow-rate C5	W	AW	λ
Location C1	1	2	4	6	**0.5166**	2.2252	4.1733
Unit Price C3	0.5	1	1.25	2	**0.1887**	0.8725	
Area C4	0.25	0.8	1	4	**0.2185**	0.8033	
Flow-rate C5	0.1667	0.5	0.25	1	**0.0762**	0.3113	
C.I.=0.0578 R.I.=0.89 C.R.=0.0649<0.1 Passes the consistency test.							

As can be seen from Table 4, the economy criterion passes the consistency test. The location factor has the greatest impact on the convenience criterion, and its weight reaches 0.5166.

Table 5. Pairwise comparison of factors on space

Space B3	Floor C2	Area C4	W	AW	λ
Floor C2	1	0.25	**0.2**	0.4	2
Area C4	4	1	**0.8**	1.6	

Since only two factors affect the spatial criterion, there is no need for consistency test.

4.3. Calculation of Total Weight of Indexes

Mark the weight of each factor of each layer calculated previously on the figure:

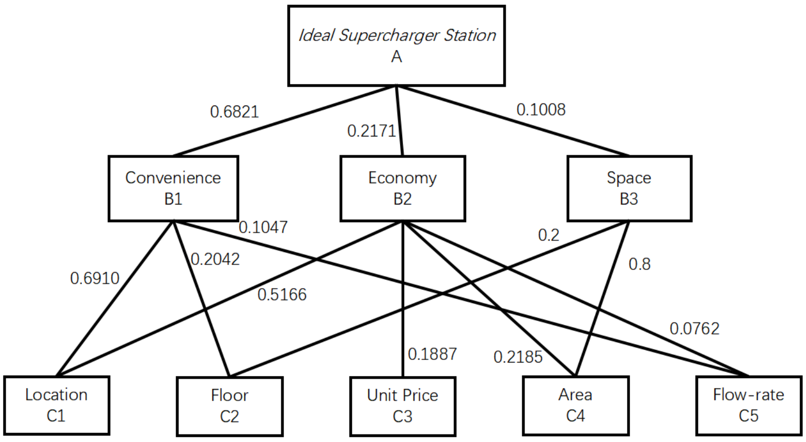

Fig 2. Calculation of site selection weight of the ideal supercharger station

The paths from C1 to A: C1-B1-A, C1-B2-A
The total weight of C1 to A is 0.6910*0.6821+ 0.5166*0.2171=0.5835

The paths from C2 to A: C2-B1-A, C2-B3-A
The total weight of C2 to A is 0.2042*0.6821+0.2*0.1008=0.1594

The path from C3 to A: C3-B2-A
The total weight of C3 to A is 0.1887*0.2171=0.0410

The path from C4 to A: c4-b2-a, c4-b3-a
The total weight of C4 to A is 0.2185*0.2171+0.8*0.1008=0.1280

The paths from C5 to A: C5-B1-A, C5-B2-A
The total weight of C5 to A is 0.1047*0.6821+0.0762*0.2171=0.0880

To sum up, the order of weight of each factor in Layer C is:

C1 > C2 > C4 > C5 > C3

5. Ranking the Alternatives

Table 6. Weighted score and ranking of three alternative sites

Layer C	Weight to A	Site A	Site B	Site C
Location C1	0.5835	0.8	0.6	0.2
Floor C2	0.1594	0.5	0.7	0.7
Unit Price C3	0.0410	0.6	0.5	0.8
Area C4	0.1280	0.8	0.5	0.7
Flow-rate C5	0.0880	1	0.7	0.7
Weighted Score		0.7615	0.6078	0.4123
Ranking		1	2	3

ISSN: 2688-9323

6. Conclusion and Analysis

This paper uses the AHP to choose site for a supercharger station of Tesla. After the statistical analysis of the data of each index with Excel, all the above results are obtained.

According to the Analytic Hierarchy Process, the weighted scores of alternative site A, B and C are 0.7615, 0.6078 and 0.4123 respectively. It can be seen that site A has the highest score and is more suitable for building super charging stations for new energy vehicles than the other two.

Through the analysis of this example, it can be concluded that the AHP is a decision-making method that decomposes the elements related to decision-making into objectives, criteria, schemes and other levels, and carries out qualitative and quantitative analysis on this basis. The advantages of the AHP can be summarized as follows:

1. Systematic analysis method. The weight setting of each layer in the AHP will directly or indirectly affect the results, and the influence degree of each factor in each layer on the results is quantified and very clear. This method can especially be used for the systematic evaluation of unstructured characteristics and the systematic evaluation of multi-objective, multi criteria and multi period.

2. Concise and practical decision-making method. The AHP Organically combines qualitative and quantitative methods to decompose complex systems, and turn decision-making problems with multiple objectives and criteria that are difficult to be fully quantified into multi-level single objective problems. After determining the quantitative relationship between the elements of the same level and the elements of the previous level through pairwise comparison, simple mathematical operation is carried out.

3. Less quantitative data information is required. The AHP mainly starts from the evaluators' understanding of the essence and elements of the evaluation problem, and pays more attention to qualitative analysis and judgment than general quantitative methods.

When people systematically analyze the problems in the fields of society, economy and management, they often face a complex system composed of many interrelated and mutually restrictive factors. The AHP provides a new, concise and practical decision-making method for the study of such complex systems.

The AHP not only meets the needs of professional fields, but also is used to guide and solve the problems encountered in personal life. It can clarify the working ideas and obtain the optimal solution through simple modeling. Although the AHP can not provide new solutions and seems to be qualitative, we must admit that this is a simple and efficient method, which is suitable for wide popularization. We also hope that it can be accepted and improved by more people.

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