Evaluation System and Method of Electric Vehicle Development Based on Analytic Hierarchy Process

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Abstract. Due to the economic and environmental factors, electric vehicles are developing. In order to evaluate the development of electric vehicles, we established a comprehensive evaluation system through AHP to evaluate the future development of electric vehicles. The factors mainly include construction cost, utilization, report back and electricity price. The sensitivity analysis: we verified the stability of the model. The main factor is the rate of the growth of electric vehicles. Regardless of the variation of the data, the trend remains. Finally, the main factors affecting the development of electric vehicles are obtained, and specific evaluation is given.

1. Introduction
Reducing the use of fossil fuels has drawn global attention since the development of economic and the changing environment. In order to complete the transition of charging network from zero charger to all-electric vehicle system, a series of energy-saving products and policies are trying to protect the earth homeland. The rise of electric vehicles has a great significance to solve these problems.

In this paper, we try to model the electric vehicle charging stations and refine the mode. We apply comprehensive evaluation model by AHP algorithm to solve the question that the order of building chargers in different area. We use comprehensive evaluation model with analytic hierarchy process. The factors mainly include construction cost, utilization, report back and electricity price.

2. Comprehensive evaluation model structure
We establish a hierarchical model of hierarchical structure. According to the theory, the application of AHP can be divided into three levels: the highest level, the middle layer and the bottom layer.

Next, we construct all judgement matrices at all levels. We know that factors of the hierarchy have a certain proportion. We say that I want to compare factors, which number is n. For example:

\[ X = \{x_1, x_2, x_3, \ldots, x_n\} \]

They influence on a factor Z. We compare pairs of factors to establish a pair comparison matrix. The definition of positive reciprocal matrices is given that \( A = (a_{ij})_{n \times n} \) must obey two conditions.

\[ a_{ij} > 0 \]

\[ \sum_{j=1}^{n} a_{ij} = 1 \]
\[ a_{ij} = \frac{1}{a_{ji}} \quad (i,j=1,2,\ldots,n) \]  

We can easily get that. The diagonal elements are all 1. For how to determine the value of \( a_{ij} \), Saaty and his group suggested that the number 1-9 and its inverse can be used as the scale. The following chart lists the scale meaning of 1-9.

**Table 1. The meaning of scale**

| Scale | Meaning                                      |
|-------|----------------------------------------------|
| 1     | Two factors are equally important            |
| 3     | The former is slightly more important than the latter |
| 5     | The former is obviously more important than the latter |
| 7     | The former is strongly more important than   |
| 2,4,6,8 | The middle value of the above adjudication   |
|       | Reciprocal If the ratio of the importance of factor i and factor j is \( a_{ij}, a_{ji} = 1/a_{ij} \) |

To start hierarchical single ordering and consistency checking, let’s review some theories of matrix. The process of hierarchical single ordering is that find the maximum eigenvalues and eigenvectors to normalize. The results are the ranking weight of the relative importance of a factor at the same level.

Although the above method can reduce interference from other factors, there is inconsistency existing in some way after comparing total results. If the comparison results are completely consistent, the elements of matrix A should also obey that \( a_{ij}a_{jk} = a_{ik}, \forall i,j,k = 1,2,\ldots,n \). Besides, if we accept A, we should judge whether matrix A is seriously inconsistent or not.

The maximum eigenvalue of the positive reciprocal matrix A is positive real numbers, all of its corresponding eigenvectors are positive real numbers, too. The modulus of \( \lambda_{\text{max}} \).

The corresponding eigenvector \( \omega = (\omega_1, \omega_2, \ldots, \omega_n)^T \) means that \( a_{ij} = \omega_i / \omega_j, \forall i,j = 1,2,\ldots,n \). A is as follows:

\[
\begin{bmatrix}
\omega_1 & \omega_1 & \ldots & \omega_1 \\
\omega_2 & \omega_2 & \ldots & \omega_2 \\
\omega_3 & \omega_3 & \ldots & \omega_3 \\
\vdots & \vdots & \ddots & \vdots \\
\omega_n & \omega_n & \ldots & \omega_n 
\end{bmatrix}
\]

A theorem points that the n-order positive reciprocal matrix A is the uniform matrix when and only if its maximum eigenvalue is \( \lambda_{\text{max}} = n \), and when the positive reciprocal matrix A is not consistent, there must be exiting \( \lambda_{\text{max}} > n \).

Therefore, we can test whether the matrix A is a consistent matrix by whether the \( \lambda_{\text{max}} > n \) is equal to n. It is necessary for decision-makers to make a consistency test to determine whether they can accept it. Steps go like this:

• Calculate the consistency index.
• Find the corresponding average random consistency index RI. Saaty and his group give the value of RI.
• Calculate the consistency ratio \( CR = CI / RI \). When \( CR < 0.1 \), it is considered that the consistency of the matrix is acceptable. Otherwise, we should correct the matrix.

**Table 2. RI**

| n   | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| RI  | 0   | 0   | 0.58| 0.90| 1.12| 1.24| 1.32| 1.41| 1.45|
At last, we make overall ranking and consistency test. We finally get the weights for the goals sorted by each of the elements, especially the lowest level. Thus carrying on the plan choice. The total weight of the order of the top-down, which is under the weight of a single criterion synthesis.

3. Investment charger location

Through above AHP algorithm, we get the following analysis results.

![Hierarchical structure model](image)

**Figure 1.** Hierarchical structure model

| S.L.S.W.Work3 | 0.2969 | 0.2385 | 0.2970 | 0.2869 |
|---------------|--------|--------|--------|--------|

**Table 3.** Criterion layer judgement matrix

|   | B1  | B2  | B3  | B4  |
|---|-----|-----|-----|-----|
| B1 | 1   | 1   | 3   | 5   |
| B2 | 1   | 1   | 2   | 4   |
| B3 | 1/3 | 1/2 | 1   | 1   |
| B4 | 1/5 | 1/4 | 1   | 1   |

**Table 4.** Criterion layer judgement matrix

| B1   | C1  | C2  | C3  | B2   | C1  | C2  | C3  |
|------|-----|-----|-----|------|-----|-----|-----|
| C1   | 1   | 3   | 1/2 | C1   | 1   | 4   | 3   |
| C2   | 1/3 | 1/2 | 1   | C2   | 1   | 4   | 1   |
| C3   | 2   | 1/2 | 1   | C3   | 1/3 | 2   | 1   |

**Table 5.** The total hierarchy of synthetic table

| Criterion   | Construction cost | Utilization | Reward | Electricity Price |
|-------------|-------------------|-------------|--------|-------------------|
| C.L.W.      | 0.4114            | 0.3535      | 0.1352 | 0.0999            |
| S.L.S.W.Work1 | 0.1634          | 0.6250      | 0.5396 | 0.2000            |
| S.L.S.W.Work2 | 0.5396          | 0.1365      | 0.1634 | 0.5130            |
L.W. is the abbreviation of Criterion layer weight. S.L.S.W. is the abbreviation of Scheme layer single sort weight.

Table 6. Total Sort Weight

| Work  | Total Sort Weight |
|-------|-------------------|
| Work1 | 0.3811            |
| Work2 | 0.3436            |
| Work3 | 0.2753            |

The urban area is the symbol of work1 and C1. The Rural area is the symbol of work2 and C2. The Urban area and the Rural area existing at the same time are the symbol of work3 and C3. From the figure we can easily know Korea should build electric charging stations in the Urban area, only in this way their benefits can be maximized.

4. Conclusion

4.1. Conclusion of problem
We choose South Korea to analyze, and the key factors, which affect the development process and made clear to increase the number of cars and development of the charging order problem of pile, and forecasts the whole time of electrochemical process.

4.2. Strengths
Using the comprehensive evaluation model, through the Analytic Hierarchy Process (AHP) to the problem of charging pile construction of planning for data analysis and finishing, with the help of matlab and mathematica software, we achieve the optimum construction plan, for the purpose of the problem been solved to a certain extent, on the basis of the reference for the similar model in order to establish a more reasonable one.

4.3. Weaknesses
In the process of model establishment, there is no comprehensive consideration of the constraint conditions, and the artificial data is processed in a certain way, so there may be a gap with the optimal result.

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