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Optimizing The Location of Electric Car Charging Stations Using TOPSIS and Fuzzy TOPSIS Method

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Abstract
Selecting the most suitable location for electric car charging stations plays a significant role in encouraging the utilization of electric cars. Multi-criteria Decision Making (MCDM) is applied to manage several criteria and order preferences in evaluating the best option among the alternatives of electric vehicle charging station (EVCS). This study focuses on four randomly assigned places (EVCS1, EVCS2, EVCS3, EVCS4) and uses the technique for order performance by similarity to ideal solution (TOPSIS) and fuzzy TOPSIS to optimize the allocation of electric car charging stations. According to the analysis using the TOPSIS method, EVCS1 achieved the highest-ranking score, while the fuzzy TOPSIS method revealed that EVCS2 obtained the highest-ranking score. These methods propose distinct optimal sites for constructing electric car charging stations, considering specific criteria that were emphasized. The study concludes that when precise performance ratings are available, the TOPSIS method provides an effective and objective approach for allocating electric vehicle charging stations. However, when dealing with imprecise or uncertain ratings, Fuzzy TOPSIS is preferred as it can handle fuzzy or vague information, allowing for more flexible decision-making.
Keywords: location selection, Multi-criteria Decision Making (MCDM), TOPSIS, fuzzy TOPSIS, EVCS

Introduction
The selection of a suitable location for electric car charging stations plays a significant role in encouraging the utilization of electric cars, with a higher likelihood of their use in the future. This process leads to determining the best allocation of electric car charging stations. A strategic location is necessary to encourage the use of electric cars to be more efficient and encounter no difficulties such as limiting the moving range. Such a decision would be helpful for electric vehicle owners, which might ease the problem of locating an electric vehicle charging station [1].

A revolution in the transportation industry can aid in lowering pollution levels, particularly those brought on by car emissions that impair air quality and threaten the health of humans and living things. The idea is to establish electric vehicle charging stations at optimal locations as an indirect measure to encourage the use of electric vehicles in transport systems dominated by fuel cars [2]. Based on the information obtained, electric vehicles have been recognized as one of the best options for drastically reducing traffic pollution and dependency on petroleum. [3] Building an electric vehicle charging station requires cooperation with investors to be financially supported because it needs to be installed in the best places to guarantee long-term user pleasure. A complete and correct appraisal of the location is considered based on the specific criteria that the result will provide the area for building a charging station for electric vehicles [4].

The selection of optimal locations involves finding zones within the city with a higher suitability index for the potential development of electric car charging infrastructure based on multidimensional criteria. Multi-criteria Decision Making (MCDM) is applied to manage several criteria and order preferences in evaluating and selecting the best option among many alternatives based on the desired outcomes [5]. There are some existing and well-known MDCM methods such as technique for order performance by similarity to ideal solution (TOPSIS), fuzzy TOPSIS and fuzzy analytical hierarchy process, (AHP).

Nowadays, the use of electric vehicles is increasing along with the development of technology. However, the lack of charging stations for electric cars is the main issue that makes it inconvenient to use electric cars. This problem arises when the local community doubts that they can survive their journey with electric vehicles on the road for a long period. They need to plan their route well to overcome the issues, therefore they prefer cars that use petrol fuel over electric powered cars because the number of petrol pumps is very high compared to the limited number of electric car charging stations. Based on the current usage of electric cars, the number of electric vehicles charging stations is still low. Therefore, the allocation of electric vehicle charging stations (EVCS) is important for electric car users as well as in encouraging the utilization of electric cars, with a higher likelihood of their use in the future. The optimal selection of location needs to consider qualitative and quantitative criteria. It is not necessary to involve only cost, there are further standards as well.

The objective of this study is to study multi-criteria decision-making methods in the allocation of electric vehicle charging stations and determine the ranking of allocation for charging stations using TOPSIS and fuzzy TOPSIS methods. Then, compare the performance of TOPSIS and fuzzy TOPSIS in the allocation problem. The first section is the introduction of the study. The second section contains the literature review of TOPSIS method and Fuzzy TOPSIS method. Next, section three is the methodology of TOPSIS and Fuzzy TOPSIS method. Section four displays the results and discussion. The fifth section comprises the conclusion and recommendations of the research. Lastly, the sixth section has the acknowledgement.

Literature Review

This section includes the literature review of recent approach for the application of charging stations, TOPSIS method and Fuzzy TOPSIS method.

Numerous research studies have been conducted to identify appropriate sites for electric vehicle charging stations. These investigations primarily focus on employing optimization methods and multi-criteria decision-making approaches. While certain studies consider both electricity and transportation networks, others utilize point-based and flow-based models to assess the demand for charging stations. The selection of charging station locations was evaluated using MCDM tools such as fuzzy techniques for order of preference by similarity to ideal solution (FTOPSIS) and fuzzy complex proportional assessment (FCOPRAS) [6].

The utilization of sustainable technologies, which can reduce dependence on oil, holds the potential to not only stabilize the climate but also promote energy independence and improve quality of life. To select the most suitable locations for electric vehicle charging stations, the fuzzy analytical hierarchy process (AHP) and the technique for order preference by similarity to ideal solution (TOPSIS) methods have been employed. A four-step approach was developed to address various aspects of the 15 criteria, considering different perspectives. This approach involved utilizing Geographic Information System (GIS) to assign scores indicating the availability of electric vehicle charging station sites, prioritizing the criteria through fuzzy AHP, and ultimately ranking the potential sites using TOPSIS [7]. Furthermore, in a separate study by, [8] different policies influencing the growth of electric vehicles in Tehran were evaluated and ranked. The proximity coefficient for each policy scenario was then estimated using fuzzy TOPSIS.

[9] recognized Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) fuzzy approach, which is a popular method in Multi-Criteria Decision Making (MCDM), to determine the optimal location for an electric vehicle charging station. They consider several factors such as the environment, economy, society, electricity, and transport system. Furthermore, a hybrid optimization algorithm that combines the multi-objective particle swarm optimization (MOPSO) algorithm and the TOPSIS method is involved in solving this model. The proposed optimization framework is applied to a specific case study in Inner Mongolia, China, which focuses on a multi-objective optimization model for fast electric vehicle charging stations incorporating wind, Photovoltaic (PV) power, and energy storage by [10].

Hence, conducting a study on the location of electric vehicle charging stations holds great significance for sustainable cities and society. Based on fuzzy TOPSIS method [11] allocate the planning of smart charging station. The promotion of electric vehicles in a metropolitan area has a substantial impact, proven to reduce carbon emissions and mitigate environmental pollution. Previous studies have proposed various methods to identify appropriate locations for electric vehicle charging stations.

TOPSIS

Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) is a Multi-Criteria Decision Making (MCDM) method created by Hwang and Yoon (1981). TOPSIS is the idea that the chosen alternative should be the one with the shortest distance from the positive ideal solution and the opposite with the longest distance from the negative ideal solution. It is a compensatory aggregation approach that analyzes many alternatives by determining weights for each criterion, then normalizing scores for the criteria and calculating the distance between the ideal alternative [12]. This solution has all the best attribute values acquired, whereas the negative solution contains all the unfavorable attribute values. As a result, the objective of TOPSIS method is to provide a solution that is closest to the ideal solution. Finally, the alternatives are ranked using a closeness coefficient calculated based on the distance from the ideal solution [13].

Fuzzy TOPSIS

The fuzzy TOPSIS is a modified version of the conventional TOPSIS approach that is used to ensure that any candidate material with the smallest distance to the ideal solution also has the greatest distance to the negative ideal solution. TOPSIS only considers crisp values, whereas human judgments are usually uncertain and could not be evaluated using fixed numbers. Despite this, fuzzy numbers are used to replace all the crisp values in TOPSIS. In decision-making is difficult to give a certain judgement, hence by integrating fuzzy logic and TOPSIS it will eliminate the uncertainty of the decision making [14].

Methodology

This section presents the frameworks of TOPSIS and Fuzzy TOPSIS method including the data collection for this study.

TOPSIS framework

TOPSIS method is a technique for order preference by similarity to the ideal solution that maximizes the benefit criteria and minimizes the cost criteria, while the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria. The ranking of alternatives is determined by an overall index that is computed by considering the proximity to the ideal solution. The TOPSIS procedure encompasses the following sequential steps.

STEP 1: Establish a decision matrix for the ranking. The structure of the matrix can be expressed as follows:

$$D = \begin{matrix} \\ B_1 \\ \vdots \\ B_m \end{matrix} \begin{matrix} F_1 & F_2 & \cdots & F_n \\ \left(\begin{matrix} x_{11} \\ \vdots \\ x_{m1} \end{matrix} \right. & \begin{matrix} x_{12} \\ \dots \\ x_{m2} \end{matrix} & \begin{matrix} \cdots \\ \dots \\ \cdots \end{matrix} & \left. \begin{matrix} x_{1n} \\ \vdots \\ x_{mn} \end{matrix} \right) \end{matrix} \qquad (3.1)$$

Where B_i denotes the alternative i^{th}; F_j represents the j^{th} attribute or criteria, x_{ij} is a crisp value indicating the performance rating of each alternative B_i with respect to each criterion F_j.

STEP 2: Calculate the normalized decision matrix. The normalized value N_{ij} calculated as:

$$N_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, i = 1,2, \dots, n; \ j = 1,2, \dots, m \qquad (3.2)$$

where x_{ij} is the score of the i^{th} alternative with respect to the j^{th} criteria.

STEP 3: Calculate the weighted normalized decision matrix by multiplying the normalized decision matrix by its associated weights. The weighted normalized value is V_{ij} calculated as:

$$V_{ij} = W_j * N_{ij}, i = 1,2, \dots, n, j = 1,2, \dots, m \quad (3.3)$$

where W_j represents the weight of the j^{th} attribute or criteria, and $\sum_{j=1}^{m} W = 1$.

STEP 4: Determine the positive ideal solution (PIS) and the negative ideal solution (NIS) respectively:

$$A^* = \left\{\left(\max_J v_{ij} \middle| i \in I\right), \left(\min_J v_{ij} \middle| i \in J\right)\right\} = \{v_1^*, v_2^*, \dots, v_n^*\} \quad (3.4)$$

$$A^- = \left\{\left(\min_J v_{ij} \middle| i \in I\right), \left(\max_J v_{ij} \middle| i \in J\right)\right\} = \{v_1^-, v_2^-, \dots, v_n^-\} \quad (3.5)$$

Where I is a set of benefit criteria and J is a set of cost criteria. A^* indicates the most preferable solution and similarly A^- indicates the least preferable solution.

STEP 5: Calculate the separation measures, using then m-dimensional Euclidean distance. The separation of each alternative from the ideal solution is given as:

The separation from the positive ideal solution:

$$d_i^* = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^*\right)^2}, i = 1,2, \dots, n \quad (3.6)$$

Similarly, separation from the negative ideal solution:

$$d_i^- = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^-\right)^2}, i = 1,2, \dots, n \quad (3.7)$$

STEP 6: Calculate the relative closeness of each alternative to the ideal solution. The relative closeness of the alternative A_i with respect to A^* is defines as follows:

$$C_i = \frac{d_i^-}{d_i^* + d_i^-}, i = 1,2, \dots, n \quad (3.8)$$

Note that, $0 \le C_i \le 1$, where $C_i = 0$ when $A_i = A^-$, and $C_i = 1$ when $A_i = A^*$.

STEP 7: Rank preference order. Rank alternatives according to C_i in descending order.

Fuzzy TOPSIS framework

Fuzzy TOPSIS is an extension of the TOPSIS method that incorporates fuzzy sets and linguistic variables to handle uncertainties and vagueness in decision-making problems. It allows for the consideration of subjective judgments and linguistic terms in the evaluation process. By using fuzzy membership functions and fuzzy similarity measures, Fuzzy TOPSIS provides a more flexible and comprehensive approach to decision-making, particularly in situations where the criteria and alternatives are not precisely defined or the data is imprecise. The following sequential steps are involved in the Fuzzy TOPSIS procedure.

STEP 1: Design the hierarchical diagram.

STEP 2: Conduct the data scaling process for criteria and alternatives. The decision makers assigned the importance to the criteria and rated the alternatives using linguistic variables.

STEP 3: Compute the aggregated fuzzy weight of each criterion, $\widetilde{w}_j$ of the kth decision maker described as:

$$\widetilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$$

where

$$w_{j1} = \min_k\{w_{j1}^k\}, w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{j2}^k, w_{j3} = \max_k\{w_{j3}^k\} \tag{3.9}$$

and the weight of criterion C_j is denoted $\widetilde{w}_{ij}^k = (w_{j1}^k, w_{j2}^k, w_{j3}^k)$.

STEP 4: Design the fuzzy decision matrix, $\widetilde{D}$ which made up of alternatives, i and criteria, j as follows:

$$\widetilde{D} = \begin{matrix} \\ A_1 \\ \vdots \\ A_m \end{matrix} \begin{matrix} C_1 & C_2 & \cdots & C_n \\ \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \vdots & \cdots & \cdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{matrix} \tag{3.10}$$

Let $\tilde{x}_{ij}$ be the aggregated fuzzy ratings of alternative, i with respect to each criterion, j in a group of K decision makers whereas $\tilde{x}_{ij}$ is calculated as follows:

$$\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$$

where

$$a_{ij} = \min_k\{a_{ij}^k\}, b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ij}^k, c_{ij} = \max_k\{c_{ij}^k\} \tag{3.11}$$

and

$$\tilde{x}_{ij}^k = (a_{ij}^k, b_{ij}^k, c_{ij}^k)$$

STEP 5: Normalize the fuzzy decision matrix using:
For benefit-type criteria, the normalization processing is expressed as:

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \text{ and } c_j^* = \max_i\{c_{ij}\} \text{ (benefit-criteria)} \tag{3.12}$$

For cost-type criteria, the normalization processing is expressed as:

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \text{ and } c_j^- = \min_i\{a_{ij}\} \text{ (cost-criteria)} \tag{3.13}$$

STEP 6: Develop the weighted normalized fuzzy decision matrix, $\widetilde{V}$ by multiplying the normalized fuzzy decision matrix, $\tilde{r}_{ij}$ with the weights of evaluation criteria, $\widetilde{w}_j$ as follows:

$$\widetilde{V} = (\tilde{v}_{ij}), \text{ where } \tilde{v}_{ij} = \tilde{r}_{ij} \times \widetilde{w}_j \tag{3.14}$$

STEP 7: Find the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS), using:

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_n^*), \text{where } \tilde{v}_j^* = \max_i\{v_{ij3}\} \tag{3.15}$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-), \text{where } \tilde{v}_j^- = \min_i\{v_{ij1}\} \tag{3.16}$$

STEP 8: Compute the distance of each alternative, (d_i^*, d_i^-) where $i = 1,2,3,..,m$ from the FPIS and the FNIS by applying the equation below:

$$d_i^* = \sum_{j=1}^{n} d\ (\tilde{v}_{ij}, \tilde{v}_j^*) \tag{3.17}$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-) \tag{3.18}$$

where the distance between two fuzzy numbers $\tilde{a}$ and $\tilde{b}$, $d(\tilde{a}, \tilde{b})$ can be calculated using:

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3}[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]} \tag{3.19}$$

STEP 9: Compute the closeness coefficient, CC_i for each alternative using:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*}\ , i = 1,2,3, .., m \tag{3.20}$$

STEP 10: Rank the alternative based on the closeness coefficient of each alternative to the ideal solution in decreasing order.

Description of the data criteria

In this study, seven criteria were used for the allocation of electric vehicle charging stations. These criteria were selected from the studies by [11]. The definitions of the criteria are summarized as follows:

1. Construction cost (C_1): Construction cost is the investment cost of smart charging station during the construction period, including engineering investment cost and equipment purchase cost, etc.
2. Operation and maintenance costs (C_2): Operation and maintenance costs are used to ensure the normal operation of charging stations and equipment maintenance.
3. Investment payback period (C_3): The payback period refers to the time during which the total cost of the investment can be recovered through income. Specifically, it is the ratio between the total of cost investment and monthly income.
4. Coordination ability (C_4): Coordination ability refers to the ability of power network to provide stable power supply to charging stations.
5. Traffic conditions (C_5): Traffic conditions refer to road conditions and vehicle flow near charging stations, which will affect the operating volume of charging stations.
6. Service ability (C_6): The service capacity of a charging station refers to the number of electric cars it can serve and the maximum amount of charging.
7. Impact on Resident's lives (C_7): Noise from charging stations may affect resident's lives.

Results and analysis

Choosing the best allocation of electric vehicle charging stations randomly is a highly challenging task. The available options can be confusing when attempting to select the optimal charging stations. To address this issue, this research will discuss decision support systems by utilizing predetermined criteria. The methods employed to determine the alternative decision for the best allocation of electric vehicle charging stations are TOPSIS and Fuzzy TOPSIS. The selection of this method is based on the concept that the best alternative should not only have the shortest distance from the ideal solution but also the longest distance from it. This approach will yield the best charging station recommendations in accordance with the expected results.

Allocation of charging stations using TOPSIS

Four alternatives and seven criteria are given below. The alternatives refer to four suitable locations of electric vehicle charging stations. The criteria have been selected to make the decision. The initial three criteria fall under the non-beneficial category, commonly called cost criteria, whereas the remaining four are considered beneficial criteria. The weight of criteria is given below. Here are the criteria and weights used in the TOPSIS calculation process. Criteria and weight are a requirement that must be determined by decision makers in the decision-making process.

Table 1: The criteria and weight

Criteria	Weight	Type
C_1	0.2	Cost
C_2	0.2	Cost
C_3	0.15	Cost
C_4	0.125	Benefit
C_5	0.15	Benefit
C_6	0.075	Benefit
C_7	0.1	Benefit

After determining the criteria and weights in table 4.1, the decision maker determines the alternatives to be selected. The alternative is known as EVCS 1, EVCS 2, EVCS 3 and EVCS 4. The table below shows the performance rating of each electric vehicle charging station (EVCS) against the seven criteria.

Table 2: The performance rating of each electric vehicle charging stations allocations.

	A1	A2	A3	A4
C1	33000	32000	40000	35000
C2	16500	16000	20000	17500
C3	3	2	5	4
C4	13	10	12	11
C5	42	40	50	48
C6	40	50	35	45
C7	35	20	60	40

Then, calculate using the step and finally the rank of the solutions obtained.

Table 3: The ranking of electric vehicle charging stations

	Ci	Rank
A1	0.5812	1
A2	0.5674	2
A4	0.4490	3
A3	0.4255	4

Hence, the relative closeness coefficients are computed, and the four allocations of electric vehicle charging stations are ranked accordingly, EVCS 1 >EVCS 2> EVCS 4 > EVCS 3. A higher value of the closeness coefficient indicates a closer proximity to the ideal solution for the alternatives. Consequently, the obtained result reveals that EVCS 1 achieves the highest score among the four allocations with a value of 0.5812. Microsoft Excel is utilized to solve this problem. Thus, the result of the ranking refers to the criteria involved.

Allocation of charging stations using fuzzy TOPSIS

In the context of the Fuzzy TOPSIS method, we consider a similar scenario to the TOPSIS method but with addition in number of decision makers which involved three decision makers. There are four alternatives and seven criteria provided below. These alternatives represent four potential locations for electric vehicle charging stations. The criteria have been chosen to facilitate the decision-making process. The initial three criteria fall under the non-beneficial category, commonly called cost criteria, whereas the remaining four are considered beneficial criteria.

The conversion scales are applied to transform the linguistic terms into fuzzy numbers. Apply a scale of 0 to 1 for rating the criteria and the alternatives. The intervals are chosen to have a uniform representation from 0 to 1 for the fuzzy triangular numbers used for the five linguistic ratings.

Table 4: Linguistic terms for criteria ratings

Linguistic terms	Membership function
Very Low (VL)	(0,0,0.3)
Low (L)	(0,0.3,0.5)
Medium (M)	(0.2,0.5,0.8)
High (H)	(0.5,0.7,1)
Very High (VH)	(0.7,1,1)

Table 5: Linguistic terms for alternative ratings

Linguistic terms	Membership function
Very Poor (VP)	(0,0,0.2)
Poor (P)	(0,0.2,0.4)
Fair (F)	(0.3,0.5,0.7)
Good (G)	(0.6,0.8,1)
Very Good (VG)	(0.8,1,1)

There are four alternatives such as EVCS 1, EVCS 2, EVCS 3 and EVCS 4 for comparison with seven criteria such as C1, C2, C3, C4, C5 C6 and C7 also we have three decision makers namely DM 1, DM 2 and DM 3. Calculate using the framework as shown in the methodology. Finally, the ranked could be obtained as table below.

Table 6: Rank of alternatives according to its closeness coefficient

	CCi	Rank
A2	0.564	1
A1	0.523	2
A4	0.476	3
A3	0.366	4

Hence, the ranking order of allocation for electric car charging station are EVCS 2 > EVCS 1 > EVCS 4 > EVCS 3. Therefore, alternative EVCS 2 is recommended as the best allocation of electric vehicle charging stations.

Analysis

The TOPSIS and fuzzy TOPSIS concludes with the different order of ranking. For TOPSIS method the ranking is EVCS1> EVCS2> EVCS4> EVCS3 and for fuzzy TOPSIS method the ranking is EVCS2> EVCS1>EVCS4> EVCS3. According to the TOPSIS and fuzzy TOPSIS methods, the preference order of the alternatives shows a contrast between EVCS 1 and EVCS 2. It is evident that TOPSIS method leads to the choice of EVCS 1 due to balance of performance rating for all criteria and fuzzy TOPSIS method leads to the choice of EVCS 2 due to alternative rating shown that EVCS 2 selected as the most suitable location by the decision makers. Based on the results of this study, systematic evaluation of the MADM problem can reduce the risk of poor service quality selection.

When precise performance ratings are available, the TOPSIS method is considered a viable approach for allocating electric vehicle charging stations due to its reliance on quantitative measurements. Precise performance ratings provide accurate and measurable data on various criteria such as proximity, infrastructure availability, charging speed, cost-effectiveness, and environmental impact. The TOPSIS method utilizes these precise ratings to calculate the distances of alternatives from the ideal solution.

On the other hand, when dealing with imprecise or uncertain performance ratings, Fuzzy TOPSIS becomes a preferred choice for allocating electric vehicle charging stations. Fuzzy TOPSIS accommodates imprecise performance ratings by allowing decision-makers to express their judgments in a more flexible manner. It captures the inherent fuzziness and ambiguity in the decision-making process and provides a robust framework for ranking the alternatives. This makes it suitable for solving the proposed service quality problem in situations where precise ratings may be difficult to obtain or where subjective judgments play a significant role.

In summary, when precise performance ratings are available, the TOPSIS method provides an effective and objective approach for allocating electric vehicle charging stations. However, when dealing with imprecise or uncertain ratings, Fuzzy TOPSIS is a preferred choice as it can handle fuzzy or vague information, allowing for more flexible and robust decision-making.

Conclusion and limitation of study

TOPSIS and fuzzy TOPSIS method are applied for the allocation of electric vehicle charging station. In conclusion, electric vehicles are the nearest solution to lead to an environmentally friendly environment in the future. The TOPSIS method aims to identify an ideal solution that maximizes performance in criteria selection. By calculating the closeness coefficients to the ideal solution, the optimal location is EVCS 1. The TOPSIS calculation process is characterized by its simplicity and clarity. The evaluation results are minimally influenced by subjective factors, resulting in a higher level of objectivity. The fuzzy TOPSIS method application for site selection of the electric vehicle charging station, effectively handling the fuzziness in the criteria selection. By calculating the closeness coefficients to the ideal solution, the optimal location is EVCS 2. However, based on the calculation results the application of the weight integrating process during the aggregation results in inaccurate rankings. This aspect will be advantageous for decision makers who are uncertain about choosing between these two methods, as it will help eliminate any confusion.This study does not encompass the sensitivity analysis of the weight for the electric vehicle charging station selection, which could potentially distinguish between these two methods. This will be considered in future study.

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