Location Selection of Electric Vehicle Charging Stations Through Employing the Spherical Fuzzy CoCoSo and CRITIC Technique

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Abstract. Energy conservation and emission reduction are important policies vigorously promoted in China. With the continuous popularization of the concept of green transportation, electric vehicles have become a green transportation tool with good development prospects, greatly reducing the pressure on the environment and resources caused by rapid economic growth. The development status of electric vehicles has a significant impact on urban energy security, environmental protection, and sustainable development in China. With the widespread application of new energy vehicles, charging piles have become an important auxiliary infrastructure necessary for the development of electric vehicles. They have significant social and economic benefits, so it is imperative to build electric vehicle charging piles. There are many factors to consider in the scientific layout of electric vehicle charging stations, and the location selection problem of electric vehicle charging stations is a multiple-attribute group decision-making (MAGDM) problem. Recently, the Combined Compromise Solution (CoCoSo) technique and CRITIC technique have been utilized to deal with MAGDM issues. Spherical fuzzy sets (SFSs) can uncover the uncertainty and fuzziness in MAGDM more effectively and deeply. In this paper, on basis of CoCoSo technique, a novel spherical fuzzy number CoCoSo (SFN-CoCoSo) technique based on spherical fuzzy number cosine similarity measure (SFNCSM) and spherical fuzzy number Euclidean distance (SFNED) is conducted for dealing with MAGDM. Moreover, when the attribute weights are completely unknown, the CRITIC technique is extended to SFSs to acquire the attribute weights based on the SFNCSM and SFNED. Finally, the SFN-CoCoSo technique is utilized for location selection problem of electric vehicle charging stations to prove practicability of the developed technique and compare the SFN-CoCoSo technique with existing techniques to further demonstrate its superiority.

Key words: multiple-attribute group decision-making (MAGDM), spherical fuzzy sets (SFSs), CoCoSo technique, CRITIC technique, location selection.
1. Introduction

Traditional cars consume energy and cause pollution, so electric vehicles have become a key focus of industry development (Wang et al., 2013; Zhang et al., 2014). A survey shows that the concern of users about the range of electric vehicles greatly hinders the development of electric vehicles. In order to promote the development of electric vehicles, we need to establish sufficient and reasonably arranged electric vehicle charging facilities (Lin and Hua, 2015; Kong et al., 2017). In 2009, the planning and layout of charging facilities in the United States began construction projects in multiple states. In February 2022, the US Department of Energy announced that it would spend $5 billion to build a charging network for electric vehicles. In order to significantly promote the development of the electric vehicle industry, Japan is expected to reach 30,000 fast charging stations by 2030 (Zhang and Wei, 2023; Zhao et al., 2023). According to data from the National Energy Administration, the annual growth of charging facilities in China in 2022 is about 2.6 million units, a year-on-year increase of nearly 100%. New energy electric vehicle charging stations refer to various charging facilities that provide charging services for electric vehicles, mainly including dedicated charging stations, public charging stations, and personal charging stations (Zhang and Shi, 2023; Sisman, 2023). Among them, dedicated charging stations are mainly used for passenger car services and provide fast charging services to meet the travel needs of car owners; public charging stations mainly provide services for public transportation such as buses, taxis, and shared cars; personal charging stations are mainly used for private cars, personal taxis, and personal ride-hailing services (Zu and Sun, 2022; Banegas and Mamkhezri, 2023). Currently, developing a low-carbon economy has become a trend in global economic development and an inevitable way to achieve sustainable development. A low-carbon economy is an economic form based on low energy consumption, low pollution, and low emissions. Its core lies in the innovation of energy-saving and emission reduction technologies, as well as the innovation of industrial structure and system (Seikh and Mandal, 2022; Wang et al., 2022; Wei et al., 2022). At present, China is in a period of accelerated industrialization and urbanization, and the demand for energy is constantly increasing. At the same time, China’s energy-intensive and high emission industries account for a large proportion of the entire industry, and there is a rough development model (Liang et al., 2022). Therefore, in the process of developing a low-carbon economy, it is necessary to focus on energy conservation and emission reduction. In the process of developing a low-carbon industry, more attention should be paid to “industrial carbon reduction” in order to save energy, reduce pollution, and alleviate pressure on resources, energy, environment, and other aspects. The automotive industry is a high energy consuming industry, and while the number of motor vehicles continues to grow, the exhaust gases it produces are a major source of pollution (Li et al., 2022a, 2022b). Compared with traditional fuel vehicles, electric vehicles have advantages such as high efficiency, low environmental pollution, and low noise. Therefore, it is an inevitable trend to transform the energy drive system of vehicles (Bian et al., 2022). Electric vehicles are a transportation vehicle with great development prospects, and their development is of great strategic significance for ensuring energy security, achieving energy
conservation and emission reduction, and comprehensively promoting the transformation of economic development mode. This is an important historical opportunity for China to revitalize the automotive industry and build a strong automotive country (Yazdekhasti et al., 2021; Asna et al., 2022).

Since 2015, the sales of new energy vehicles in China have continued to rise. In 2018, the sales of new energy vehicles reached 1.256 million units, a year-on-year increase of 61.7%. In 2022, the production and sales of new energy vehicles reached 7.058 million and 6.887 million, respectively, with year-on-year growth of 96.9% and 93.4%, maintaining the world’s first place for 8 consecutive years (He et al., 2022; Huang et al., 2022). Meanwhile, the construction of charging facilities is also accelerating. According to data from the Ministry of Industry and Information Technology, as of the end of 2022, a total of 5.21 million charging stations and 1973 swapping stations have been built nationwide. Among them, 2.593 million new charging stations and 675 swapping stations were added in 2022, and the construction speed of charging and swapping infrastructure has significantly accelerated. In order to ensure the safety of electric vehicle charging in China, the National Development and Reform Commission and 10 other departments have clearly stated that by the end of the 14th Five Year Plan, China’s charging infrastructure system can meet the charging needs of over 20 million electric vehicles (Li et al., 2021; Rani and Mishra, 2021; Wang et al., 2021). It is expected that by 2025, the number of new energy vehicles in China will reach 26.72 million, pure electric vehicles will reach 23.24 million, and the total number of charging stations in China will reach 6.543 million. The relevant factors involved in the site selection process of charging piles mainly include the construction cost, construction period, and operation and maintenance cost of charging piles, and other factors need to be considered, such as market demand, power supply situation, transportation convenience, etc. (Karasan et al., 2020; Liu et al., 2020; Luo et al., 2020; Bao and Xie, 2021). Therefore, the selection of charging station locations needs to comprehensively consider multiple factors, and then determine the optimization plan for charging station locations based on the relationship between each factor (Yang and Cao, 2019; Yi et al., 2019; Jiang and Wan, 2020). The main evaluation indicator in optimizing the location of charging stations is the demand of new energy electric vehicles for existing charging infrastructure. In addition, it is necessary to consider multiple aspects such as power supply, transportation convenience, parking charging, and operation and maintenance costs (Ju et al., 2019; Kizhakkkan et al., 2019). The evaluation indicators for the demand for charging infrastructure construction mainly include the number of public parking lots, the number of charging stations in public parking lots, the number of taxi charging stations, and the number of bus charging stations. The number of public parking lots is generally determined based on the actual situation of the city, but can also be obtained through survey statistics, while the number of charging stations is calculated based on the number of new energy electric vehicles in the city. The number of charging stations in public parking lots needs to take into account the construction cost of charging facilities, power supply, and operation and maintenance costs. The number of taxi charging stations can be determined based on the existing number of taxis. Bus charging stations are generally set up in bus stops to meet the charging needs of new energy electric buses. Based on the evaluation
indicators for the construction needs of charging piles, the optimization plan for the site selection of charging piles can be determined, and corresponding conclusions can be drawn (Liu et al., 2018; Ahn et al., 2019; Fredriksson et al., 2019). For the optimization problem of charging station location, multiple methods such as fuzzy comprehensive evaluation, analytic hierarchy process, and expert consultation can be combined to obtain the optimal solution (Li et al., 2017; Cui et al., 2018; Erbas et al., 2018). With the development of the national new energy vehicle industry and the continuous progress of electric vehicle technology, charging stations have become a key link and infrastructure in the development of the electric vehicle industry, and also an important infrastructure to promote the rapid development of the electric vehicle industry. As one of the key links in the construction of new energy electric vehicle charging stations, reasonable site selection planning plays a decisive role in the construction of charging stations. It can not only reduce resource waste, but also lower investment costs, improve service quality and efficiency, and increase user stickiness (Liu et al., 2019; Wang et al., 2019).

In practical life, people often face various decision-making problems, ranging from personal clothing, food, housing, and transportation to national policies and guidelines (Chen et al., 2021; Dong et al., 2021; Verma and Alvarez-Miranda, 2023; Saghari et al., 2023). Multiple-attribute group decision-making (MAGDM), as an important branch of modern decision science, refers to the process, where a group of experts is sorting and selecting a finite number of options under the consideration of multiple attribute constraints (Garg, 2021; Garg et al., 2021a; Liao et al., 2021). The theory and methods of MAGDM have been widely applied in various fields such as engineering design, economics, management, medicine, and military, such as investment decision-making, project evaluation, factory site selection, medical diagnosis, supply chain selection, and weapon system performance evaluation (Shabu et al., 2023; Sankar et al., 2023; Palanikumar et al., 2023). In order to portray the fuzzy information, in 1965, Zadeh (1965) put forward the fuzzy sets (FSs) to portray the ambiguity of things. As a new extended form of FSs, spherical fuzzy sets (SFSs) (Mahmood et al., 2019; Gundogdu and Kahraman, 2019) combined the advantages of PFSs (Yager and Abbasov, 2013) and picture fuzzy sets (Cuong, 2014), expressing the ambiguity of things from four aspects. The location selection problem of electric vehicle charging stations could be solved as MAGDM. Mahmood et al. (2019) and Gundogdu and Kahraman (2019) used the spherical fuzzy sets (SFSs) which could consist of the uncertainty and fuzziness during the location selection problem of electric vehicle charging stations. Yazdani et al. (2018) put forward the CoCoSo technique for MAGDM issues. Compared with other techniques, the main advantages of CoCoSo technique consisted of high efficiency and low computational complexity. More and more scholars have studied the CoCoSo technique based on different uncertain MAGDM (Yazdani et al., 2019; Peng and Smarandache, 2020; Torkayesh et al., 2021; Kharwar et al., 2022; Lai et al., 2022; Turskis et al., 2022). Unfortunately, we have not been able to find efficient research works for CoCoSo technique (Yazdani et al., 2018) based on the cosine similarity measure (Ye, 2016) and Euclidean distance under SFSs in the existing MADM and MAGDM. Therefore, it is of great significance to investigate the novel CoCoSo technique based on the cosine similarity measure (Ye, 2016) and Euclidean distance based
on the CRITIC technique (Diakoulaki et al., 1995; Badi et al., 2023; Narang et al., 2022; Pamucar et al., 2022) under SFSs. The basic main goal of this research is to put forward the spherical fuzzy number CoCoSo (SFN-CoCoSo) technique based on the cosine similarity measure and Euclidean distance that can address MAGDM based on the CRITIC technique (Diakoulaki et al., 1995) under SFSs more efficiently. Finally, a numerical example is presented to demonstrate the SFN-CoCoSo technique and several comparative analyses are utilized to verify the advantages of SFN-CoCoSo technique. Therefore, the research motivations and aims of this research work are outlined: (1) the CRITIC technique (Diakoulaki et al., 1995) is utilized to derive the attribute’s weight; (2) the novel CoCoSo technique is extended to the SFSs environment; (3) the novel spherical fuzzy number CoCoSo (SFN-CoCoSo) technique based on the Cosine similarity measure and Euclidean distance is put forward to solve the MAGDM; (4) a numerical example for location selection problem of electric vehicle charging stations is presented to demonstrate the SFN-CoCoSo technique and several comparative analyses are utilized to verify the advantages of SFN-CoCoSo technique.

The remaining framework of this paper proceeds as follows. The SFSs are used in Section 2. The SFN-CoCoSo technique is put forward to solve the MAGDM in Section 3. A numerical example for location selection problem of electric vehicle charging stations and several comparative analysis are utilized to verify the advantages of SFN-CoCoSo technique in Section 4. Lastly, a useful conclusion is presented in Section 5.

2. Preliminaries

Mahmood et al. (2019) and Gundogdu and Kahraman (2019) used the SFSs.

**Definition 1** (Mahmood et al., 2019; Gundogdu and Kahraman, 2019). The SFSs $EE$ in $\Theta$ are used:

$$EE = \{(\theta, ET(\theta), EI(\theta), EF(\theta)) | \theta \in \Theta\},$$

where $ET(\theta), EI(\theta), EF(\theta)$ is the truth-membership, indeterminacy-membership and falsity-membership, $ET(\theta), EI(\theta), EF(\theta) \in [0, 1]$ and satisfies $0 \leq ET^2(\theta) + EI^2(\theta) + EF^2(\theta) \leq 1$. The spherical fuzzy number (SFN) is used as $EE = (ET, EI, EF)$, where $ET, EI, EF \in [0, 1]$, and $0 \leq ET^2 + EI^2 + EF^2 \leq 1$.

**Definition 2** (Mahmood et al., 2019; Gundogdu and Kahraman, 2019). Let $EA = (ET_A, EI_A, EF_A)$ be the SFN, a score value is determined:

$$SV(EA) = (ET_A - EI_A)^2 - (EF_A - EI_A)^2, \quad SV(EA) \in [0, 1].$$

**Definition 3** (Mahmood et al., 2019; Gundogdu and Kahraman, 2019). Let $EA = (ET_A, EI_A, EF_A)$ be the SFN, an accuracy value is determined:

$$AV(EA) = (ET_A)^2 + (ET_A)^2 + (EF_A)^2, \quad AV(EA) \in [0, 1].$$
Mahmood et al. (2019) and Gundogdu and Kahraman (2019) determined the order relation for SFNs.

**Definition 4** (Mahmood et al., 2019; Gundogdu and Kahraman, 2019). Let $DA = (DT_A, DI_A, DF_A)$ and $DB = (DT_B, DI_B, DF_B)$ be SFNs, let $SV(EA) = (ET_A - EI_A)^2 - (EF_A - EI_A)^2$ and $SV(EB) = (ET_B - EI_B)^2 - (EF_B - EI_B)^2$, and let $AV(EA) = (ET_A)^2 + (ET_A)^2 + (EF_A)^2$ and $AV(EB) = (ET_B)^2 + (ET_B)^2 + (EF_B)^2$, respectively, then if $SV(EA) < SV(EB)$, then $EA < EB$; if $SV(EA) = SV(EB)$, then (1) if $AV(EA) = AV(EB)$, then $EA = EB$; (2) if $AV(EA) < AV(EB)$, then $EA < EB$.

**Definition 5** (Gundogdu and Kahraman, 2019; Sharaf, 2021). Let $EA = (ET_A, EI_A, EF_A)$ and $EB = (ET_B, EI_B, EF_B)$ be two SFNs, the basic operations are conducted:

1. $EA \oplus EB = (ET_A + ET_B - ET_A ET_B, EI_A EI_B, EF_A EF_B)$;
2. $EA \otimes EB = (ET_A ET_B, EI_A + EI_B - EI_A EI_B, EF_A + EF_B - EF_A EF_B)$;
3. $\lambda EA = (1 - (1 - ET_A)^\lambda, (EI_A)^\lambda, (EF_A)^\lambda)$, $\lambda > 0$;
4. $(EA)^\lambda = ((ET_A)^\lambda, (EI_A)^\lambda, 1 - (1 - EF_A)^\lambda)$, $\lambda > 0$.

The SFN weighted averaging (SFNWA) technique and SFN weighted geometric (SFNWG) technique are used.

**Definition 6** (Mahmood et al., 2019; Gundogdu and Kahraman, 2019). Let $EA_j = (ET_j, EI_j, EF_j)$ ($j = 1, 2, \ldots, n$) be a family of SFNs, the SFNWA technique is used:

$$\text{SFNWA}_{e\omega}(EA_1, EA_2, \ldots, EA_n) = \bigoplus_{j=1}^{n} (e\omega_j EA_j)$$

$$= \left( \sqrt{1 - \prod_{j=1}^{n} (1 - ET_j^{2})^{e\omega_j}}, \prod_{j=1}^{n} (1 - ET_j^{2})^{e\omega_j} - \prod_{j=1}^{n} (1 - ET_j^{2} - EF_j^{2})^{e\omega_j}, \prod_{j=1}^{n} (EF_j)^{e\omega_j} , \right),$$

where $e\omega = (e\omega_1, e\omega_2, \ldots, e\omega_n)^T$ is the weight of $EA_j$ ($j = 1, 2, \ldots, n$) and $e\omega_j > 0$, $\sum_{j=1}^{n} e\omega_j = 1$.

**Definition 7** (Mahmood et al., 2019; Gundogdu and Kahraman, 2019). Let $EA_j = (ET_j, EI_j, EF_j)$ ($j = 1, 2, \ldots, n$) be a family of SFNs, the SVNNWG technique is used:
Definition 8 (Aydin and Kahraman, 2020). Let 
\[ \text{SFNWG}_{e\omega}(EA_1, EA_2, \ldots, EA_n) = \bigotimes_{j=1}^{n}(EA_j)^{e\omega_j} \]
\[ = \left( \prod_{j=1}^{n}(ET_j)^{e\omega_j}, \right. \]
\[ \sqrt{\frac{\prod_{j=1}^{n}(1 - EF_j^2)^{e\omega_j} - \prod_{j=1}^{n}(1 - EF_j^2 - EI_j^2)^{e\omega_j}}{1 - \prod_{j=1}^{n}(1 - EF_j^2)^{e\omega_j}}}, \] (5)

where \( e\omega = (e\omega_1, e\omega_2, \ldots, e\omega_n)^T \) is the weight of \( EA_j \) \( (j = 1, 2, \ldots, n) \) and \( e\omega_j > 0 \), \( \sum_{j=1}^{n} e\omega_j = 1 \).

Definition 9 (Kutlu Gündoğdu and Kahraman, 2021). Let \( EA = (ET_A, EI_A, EF_A) \) and \( EB = (ET_B, EI_B, EF_B) \), then the SFN cosine similarity measure (SFNCSM) between \( EA = (ET_A, EI_A, EF_A) \) and \( EB = (ET_B, EI_B, EF_B) \) is constructed:

\[ \text{SFNCSM}(EA, EB) \]
\[ = \frac{1}{2} \left( \cos \left( \frac{\pi}{6} \left( |ET_A^2 - ET_B^2| + |EI_A^2 - EI_B^2| + |EF_A^2 - EF_B^2| \right) \right) \right. \]
\[ + \cos \left( \frac{\pi}{2} \max (|ET_A^2 - ET_B^2|, |EI_A^2 - EI_B^2|, |WF_A - WF_B|) \right) \left. \right) \), (6)

3. SFN-CoCoSo Technique for MAGDM Based on the CRITIC with SFNs

In this section, SFN-CoCoSo technique is used for MAGDM. Let \( EA = \{EA_1, EA_2, \ldots, EA_m\} \) be alternatives. Let \( EG = \{EG_1, EG_2, \ldots, EG_n\} \) be attributes with weight information \( e\omega = \{e\omega_1, e\omega_2, \ldots, e\omega_n\} \), where \( e\omega_j \in [0, 1] \), \( \sum_{j=1}^{n} e\omega_j = 1 \). Assume \( EE = \{EE_1, EE_2, \ldots, EE_l\} \) be a family of DMs with weight values \( ew = \{ew_1, ew_2, \ldots, ew_l\} \), where \( ew_k \in [0, 1] \), \( \sum_{k=1}^{l} ew_k = 1 \). And \( EE^{(k)} = (EE_{ij}^{(k)})_{m \times n} = (ET_{ij}^{(k)}, EI_{ij}^{(k)}, EF_{ij}^{(k)})_{m \times n} \) is the SFN-matrix, \( EE_{ij}^{(k)} = (ET_{ij}^{(k)}, EI_{ij}^{(k)}, EF_{ij}^{(k)}) \) means the SFNs of \( EA_i \) for the attribute \( EG_j \) through \( EE_k \). Subsequently, the calculating steps are carried out (see Fig. 1).
**Fig. 1. SFN-CoCoSo technique for MAGDM based on the CRITIC with SFNs.**

**SFN-CoCoSo technique for MAGDM based on the CRITIC with SFNs**

**Step 1.** Conduct the group SFN-matrix and overall SFN matrix

**Step 2.** Normalize the Overall SFN matrix into normalized Overall SFN matrix

**Step 3.** Conduct the SFN positive ideal solution (SFNPIS) and SFN negative ideal solution (SFNNIS)

**Step 4.** Construct the SFNCSM between NEE and SFNPIS

**Step 5.** Construct the SFNED between NEE and SFNNIS

**Step 6.** Conduct the weight values through employing the CRITIC technique

**Step 7.** Conduct the SFN weighted arithmetic values (SFNWAV)

**Step 8.** Conduct the SFN weighted geometric values (SFNWGV)

**Step 9.** The following three SFN decision strategies (SFNDS) are employed to conduct the relative importance

**Step 10.** Compute the SFN overall decision strategies (SFNODS)

**Step 11.** Sort the alternatives in line with SFNODS, and the higher the SFNODS, the better the alternative is
**Step 1.** Determine the group SFN-matrix $EE^{(k)} = (EE_{ij}^{(k)})_{m \times n} = (ET_{ij}^{(k)}, EI_{ij}^{(k)}, EF_{ij}^{(k)})_{m \times n}$ and the overall SFN matrix $EE = (EE_{ij})_{m \times n}$ using the SFNWG technique.

$$EE^{(k)} = [EE_{ij}^{(k)}]_{m \times n} = \begin{bmatrix} EE_{11}^{(k)} & EE_{12}^{(k)} & \ldots & EE_{1n}^{(k)} \\ EE_{21}^{(k)} & EE_{22}^{(k)} & \ldots & EE_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ EE_{m1}^{(k)} & EE_{m2}^{(k)} & \ldots & EE_{mn}^{(k)} \end{bmatrix},$$

(8)

$$EE = [EE_{ij}]_{m \times n} = \begin{bmatrix} EE_{11} & EE_{12} & \ldots & EE_{1n} \\ EE_{21} & EE_{22} & \ldots & EE_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ EE_{m1} & EE_{m2} & \ldots & EE_{mn} \end{bmatrix},$$

(9)

$$EE_{ij} = (ET_{ij}, EI_{ij}, EF_{ij})$$

$$= \left( \prod_{k=1}^{l} (ET_{ij}^{(k)})^{2} e_{wk} \right)^{\frac{1}{\prod_{k=1}^{l} (1 - (ET_{ij}^{(k)})^{2}) e_{wk} - \prod_{k=1}^{l} (1 - (EF_{ij}^{(k)})^{2}) e_{wk} - \prod_{k=1}^{l} (1 - (EI_{ij}^{(k)})^{2}) e_{wk}}},$$

(10)

**Step 2.** Normalize the $EE = (EE_{ij})_{m \times n}$ to $NEE = [NEE_{ij}]_{m \times n}$.

$$NEE_{ij} = (NET_{ij}, NEI_{ij}, NEF_{ij})$$

$$= \{ (ET_{ij}, EI_{ij}, EF_{ij}), \ EG_{j} \text{ is a benefit criterion,} \}$$

$$= \{ (EF_{ij}, EI_{ij}, ET_{ij}), \ EG_{j} \text{ is a cost criterion.} \}$$

(11)

**Step 3.** Determine the SFN positive ideal solution (SFNPIS) and SFN negative ideal solution (SFNNIS):

$$SFNPIS_{j} = (NET_{j}^{+}, NEI_{j}^{+}, NEF_{j}^{+}),$$

(12)

$$SFNNIS_{j} = (NET_{j}^{-}, NEI_{j}^{-}, NEF_{j}^{-}),$$

(13)

$$SV(SFNPIS_{j}) = \max_{i} SV(NET_{ij}, NEI_{ij}, NEF_{ij}),$$

(14)

$$SV(SFNNIS_{j}) = \min_{i} SV(NET_{ij}, NEI_{ij}, NEF_{ij}).$$

(15)

**Step 4.** Construct the SFNCSM between $NEE_{ij} = (NET_{ij}, NEI_{ij}, NEF_{ij})$ and $SFNPIS_{j} = (NET_{j}^{+}, NEI_{j}^{+}, NEF_{j}^{+})$. 
\[
\text{SFNCSM}(\text{NEE}_{ij}, \text{SFNPIS}_j) = \frac{1}{2} \left( \cos \left[ \frac{\pi}{6} \left( (\text{NET}_{ij})^2 - (\text{NET}_j^+)^2 \right) + (\text{NEI}_{ij})^2 - (\text{NEI}_j^+)^2 \right] \right) + \cos \left[ \frac{\pi}{2} \max \left( (\text{NET}_{ij})^2 - (\text{NET}_j^+)^2, (\text{NEI}_{ij})^2 - (\text{NEI}_j^+)^2, (\text{NEF}_{ij})^2 - (\text{NEF}_j^+)^2 \right) \right].
\]

**Step 5.** Construct the SFNED between \(\text{NEE}_{ij} = (\text{NET}_{ij}, \text{NEI}_{ij}, \text{NEF}_{ij})\) and \(\text{SFNNIS}_j = (\text{NET}_j^-, \text{NEI}_j^-, \text{NEF}_j^-)\).

\[
\text{SFNED}(\text{NEE}_{ij}, \text{SFNNIS}_j) = \sqrt{\frac{1}{2} \left( (\text{NET}_{ij})^2 - (\text{NET}_j^-)^2 + (\text{NEI}_{ij})^2 - (\text{NEI}_j^-)^2 + (\text{NEF}_{ij})^2 - (\text{NEF}_j^-)^2 \right)}. \tag{17}
\]

**Step 6.** Compute the weight values through employing the CRITIC technique.

The CRITIC technique (Diakoulaki et al., 1995) is employed to compute the weight values.

(1) The SFN correlation coefficient values (SFNCCV) are determined.

\[
\text{SFNCCV}_{jt} = \frac{\sum_{i=1}^{m} (\varphi(\text{SFN}_{ij}) - \varphi(\text{SFN}_j))(\varphi(\text{SFN}_{it}) - \varphi(\text{SFN}_t))}{\sqrt{\sum_{i=1}^{m} (\varphi(\text{SFN}_{ij}) - \varphi(\text{SFN}_j))^2 \sqrt{\sum_{i=1}^{m} (\varphi(\text{SFN}_{it}) - \varphi(\text{SFN}_t))^2}},
\]

where

\[
\varphi(\text{SFN}_j) = \frac{1}{2m} \sum_{i=1}^{m} (\text{SFNCSM}(\text{NEE}_{ij}, \text{SFNPIS}_j) + \text{SFNED}(\text{NEE}_{ij}, \text{SFNNIS}_j)),
\]

\[
\varphi(\text{SFN}_t) = \frac{1}{2m} \sum_{i=1}^{m} (\text{SFNCSM}(\text{NEE}_{it}, \text{SFNPIS}_t) + \text{SFNED}(\text{NEE}_{it}, \text{SFNNIS}_t)),
\]

\[
\varphi(\text{SFN}_{ij}) = \frac{1}{2} (\text{SFNCSM}(\text{NEE}_{ij}, \text{SFNPIS}_j) + \text{SFNED}(\text{NEE}_{ij}, \text{SFNNIS}_j)),
\]

\[
\varphi(\text{SFN}_{it}) = \frac{1}{2} (\text{SFNCSM}(\text{NEE}_{it}, \text{SFNPIS}_t) + \text{SFNED}(\text{NEE}_{it}, \text{SFNNIS}_t)).
\]

(2) Compute the SFN standard deviation values (SFNSDV).

\[
\text{SFNSDV}_j = \sqrt{\frac{1}{m-1} \sum_{i=1}^{m} (\varphi(\text{SFN}_{ij}) - \varphi(\text{SFN}_j))^2}. \tag{19}
\]
(3) Compute the attribute weight values.

\[ e_{\omega j} = \frac{SFNSDV_j \sum_{t=1}^{n}(1 - SFNCCV_{jt})}{\sum_{j=1}^{n}(SFNSDV_j \sum_{t=1}^{n}(1 - SFNCCV_{jt}))}, \]  

where \( e_{\omega j} \in [0, 1] \), \( \sum_{j=1}^{n} e_{\omega j} = 1 \).

**Step 7.** Compute the SFN weighted arithmetic values (SFNWAV).

\[ SFNWAV_i = \sum_{j=1}^{n} e_{\omega j} \times \left( \frac{1}{2} \left( SFNCSM(NEE_{ij}, SFNPIS_j) + SFNED(NEE_{ij}, SFNNIS_j) \right) \right). \]  

**Step 8.** Compute the SFN weighted geometric values (SFNWGV).

\[ SFNWGV_i = \sum_{j=1}^{n} \left( \frac{1}{2} \left( SFNCSM(NEE_{ij}, SFNPIS_j) + SFNED(NEE_{ij}, SFNNIS_j) \right) \right)^{e_{\omega j}}. \]

**Step 9.** The following three SFN decision strategies (SFNDS) are employed to compute the relative importance:

\[ SFNDS_{ia} = \frac{SFNWAV_i + SFNWGV_i}{\sum_{i=1}^{m}(SFNWAV_i + SFNWGV_i)}, \]

\[ SFNDS_{ib} = \frac{SFNWAV_i}{\min_i SFNWAV_i} + \frac{SFNWGV_i}{\min_i SFNWGV_i}, \]

\[ SFNDS_{ic} = \frac{\lambda SFNWAV_i + (1 - \lambda)SFNWGV_i}{\lambda \max_i SFNWAV_i + (1 - \lambda) \max_i SFNWGV_i}, \quad 0 \leq \lambda \leq 1, \]

where \( SFNDS_{ia} \) is the arithmetic sum of \( SFNWAV_i, SFNWGV_i \); \( SFNDS_{ib} \) is the relative score of \( SFNWAV_i, SFNWGV_i \), and \( SFNDS_{ic} \) is the computed compromise of \( SFNWAV_i, SFNWGV_i \).

**Remark 1.** \( \lambda \) (usually \( \lambda = 0.5 \)) is chosen by DMs. The higher the \( \lambda \), the higher the each alternative.

**Step 10.** Compute the SFN overall decision strategies (SFNODS).

\[ SFNODS_i = \frac{3SFNDS_{ia}SFNDS_{ib}SFNDS_{ic}}{SFNDS_{ia} + SFNDS_{ib} + SFNDS_{ic}}. \]

**Step 11.** Sort the alternatives in line with \( SFNODS_i \) \( (i = 1, 2, \ldots, m) \), and the higher the \( SFNODS_i \), the better the alternative is.
4. Numerical Example and Comparative Analysis

4.1. Numerical Example

The traditional operation mode of vehicles driven by energy sources such as gasoline and diesel has drawbacks such as high energy consumption and pollution. With the increasing accessibility of urban transportation and the significant increase in the proportion of vehicles in transportation, a large amount of exhaust from fuel powered vehicles will exacerbate air pollution in urban areas, leading to the depletion of non-renewable energy sources. The electric energy resources used by new energy vehicles have good cleanliness and renewability, and the energy consumption cost and pollution gas volume generated during vehicle operation are relatively small, which is an important direction for the transformation and upgrading of the automotive industry. The new energy charging station is a workstation that provides electricity replenishment for new energy vehicles. With the increase of the proportion of new energy electric vehicles in the total ownership of vehicles, the planning, construction, and later operation and maintenance management of new energy charging piles are directly related to the operating income of new energy charging piles and their contribution to new energy vehicles. The charging piles for new energy electric vehicles are mainly electronic products. They are located in the external environment for a long time and have a high frequency of use, which can easily lead to aging or damage to the charging pile equipment and facilities. It is necessary to promptly investigate and repair the fault problems to avoid insufficient operation and maintenance time, which may affect the use of new energy electric vehicle owners. At the same time, limited human resources for inspection, operation, and maintenance make it difficult to monitor the charging piles of new energy electric vehicles 24/7, and there is a lag in emergency response and fault maintenance. In addition, in many regions, the operation and maintenance of electric vehicle charging piles are the responsibility of manufacturers, who arrange on-site inspection personnel to discover defects and faults in the operation of the charging piles. Under the constraints of operation and maintenance labour costs, the inspection strength of manufacturers is weak, and the real-time and timely management of operation and maintenance is insufficient. On the contrary, the operation and maintenance management costs of new energy electric vehicle charging piles have increased. The operation and maintenance management of new energy electric vehicle charging piles mainly includes daily operation status inspection of charging piles, defect detection feedback, defect maintenance and fault handling, etc. Through daily operation status inspections, they can comprehensively and timely grasp the operation status and abnormal situations of new energy electric vehicle charging piles, discover defects in charging pile equipment and facilities, as well as safety hazards timely, so that maintenance personnel can promptly go to the site to handle defects and eliminate hidden dangers, and improve the safety of the operation of new energy electric vehicle charging piles. The defect repair and troubleshooting of charging piles require the charging pile manufacturer to arrange personnel to the site for defect confirmation and equipment maintenance. The process involves many engineering task orders, such as defect dispatch forms, maintenance confirmation forms,
process control forms, etc. Through standardized and procedural management, it promotes the operation and maintenance management of new energy electric vehicle charging piles to form an organic whole. The traditional operation and maintenance management of new energy electric vehicle charging piles is mainly manual, and there is a certain time lag in the closed-loop management of the process from discovering faults or defects during daily inspections of new energy electric vehicle charging piles to reporting faults or defects, arranging maintenance personnel for review and repair by manufacturers, and providing feedback on maintenance situations. By utilizing information technology and information management systems, the process of closed-loop management for the operation and maintenance of new energy electric vehicle charging piles is commercialized. Real time online filling of inspection and discovery of faults or defects, online approval and dispatch of defective orders, acceptance and on-site maintenance of defective orders, and feedback on defective order maintenance are utilized to promote closed-loop management of the operation and maintenance process of new energy electric vehicle charging piles. The closed-loop management of the operation and maintenance of new energy electric vehicle charging piles can avoid equipment failures or defects found during daily inspections that are not repaired in a timely manner. It can also improve the efficiency of the operation and maintenance of new energy electric vehicle charging piles. By leaving traces in intermediate processes such as dispatching orders, maintenance, and feedback, it ensures that each process task is clearly decomposed and responsibilities are assigned to individuals, achieving online traceability of relevant responsible persons and work effectiveness. The location selection problem of electric vehicle charging stations could be deemed as the MAGDM problem. In this section, an empirical example for location selection problem of electric vehicle charging stations is provided using SFN-CoCoSo technique. In order to choose the most suitable electric vehicle charging stations, some traffic departments invite three experts (transportation department officials, transportation department management personnel, university professors) to evaluate the five electric vehicle charging stations $E_A_i$ ($i = 1, 2, 3, 4, 5$) in line with four attributes: $E_{G_1}$ is the demand for charging infrastructure construction, $E_{G_2}$ is the urban transportation convenience, $E_{G_3}$ is the construction cost of electric vehicle charging stations, $E_{G_4}$ is the urban power supply situation. Among them, only $E_{G_3}$ is cost attribute. Furthermore, $\mathbf{w} = (0.2346, 0.3233, 0.4421)^T$ denotes experts’ weight information. The evaluation information from $\mathbf{EE} = (EE_1, EE_2, EE_3)$ with linguistic scale (see Table 1, Gundogdu and Kahraman, 2019) are displayed in Tables 2–4. Then, the SFN-CoCoSo technique is utilized to help the traffic management department select the best electric vehicle charging station.

**Step 1.** Put forward the group SFN matrix $EE^{(k)} = (EE_{ij}^{(k)})_{5 \times 4}$ ($k = 1, 2, 3$) as in Tables 2–4. The overall SFN-matrix is calculated by SFNWG technique. The results are calculated in Table 5.

**Step 2.** Normalize the SFN-matrix $EE = [EE_{ij}]_{5 \times 4}$ to $NEE = [NEE_{ij}]_{5 \times 4}$ (see Table 6).

**Step 3.** Obtain the SFNPIS and SFNNIS (Table 7).

**Step 4.** Conduct the SFNCSM between $NEE_{ij} = (NET_{ij}, NEI_{ij}, NEF_{ij})$ and $SFNPIS_j = (NET_j^+, NEI_j^+, NEF_j^+)$ (Table 8):
Table 1
Linguistic scales and their corresponding SFNs.

<table>
<thead>
<tr>
<th>Linguistic terms</th>
<th>SFNs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exceedingly Terrible-EET</td>
<td>(0.9, 0.1, 0.1)</td>
</tr>
<tr>
<td>Very Terrible-EVT</td>
<td>(0.7, 0.3, 0.3)</td>
</tr>
<tr>
<td>Terrible-ET</td>
<td>(0.6, 0.4, 0.4)</td>
</tr>
<tr>
<td>Medium-EM</td>
<td>(0.5, 0.5, 0.5)</td>
</tr>
<tr>
<td>Well-EW</td>
<td>(0.4, 0.4, 0.6)</td>
</tr>
<tr>
<td>Very Well-EVW</td>
<td>(0.3, 0.3, 0.7)</td>
</tr>
<tr>
<td>Exceedingly Well-EEW</td>
<td>(0.1, 0.1, 0.9)</td>
</tr>
</tbody>
</table>

Table 2
Linguistic scale from $EE_1$.

<table>
<thead>
<tr>
<th>EG1</th>
<th>EG2</th>
<th>EG3</th>
<th>EG4</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA1</td>
<td>EVT</td>
<td>EM</td>
<td>EW</td>
</tr>
<tr>
<td>EA2</td>
<td>EM</td>
<td>EVT</td>
<td>EVT</td>
</tr>
<tr>
<td>EA3</td>
<td>EM</td>
<td>ET</td>
<td>EVW</td>
</tr>
<tr>
<td>EA4</td>
<td>EVT</td>
<td>EVW</td>
<td>EW</td>
</tr>
<tr>
<td>EA5</td>
<td>EVW</td>
<td>EW</td>
<td>EM</td>
</tr>
</tbody>
</table>

Table 3
Linguistic scale from $EE_2$.

<table>
<thead>
<tr>
<th>EG1</th>
<th>EG2</th>
<th>EG3</th>
<th>EG4</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA1</td>
<td>EVT</td>
<td>EM</td>
<td>EVW</td>
</tr>
<tr>
<td>EA2</td>
<td>EVT</td>
<td>EVW</td>
<td>EM</td>
</tr>
<tr>
<td>EA3</td>
<td>EVW</td>
<td>EW</td>
<td>EM</td>
</tr>
<tr>
<td>EA4</td>
<td>EVW</td>
<td>ET</td>
<td>EVT</td>
</tr>
<tr>
<td>EA5</td>
<td>EM</td>
<td>EVW</td>
<td>ET</td>
</tr>
</tbody>
</table>

Table 4
Linguistic scale from $EE_3$.

<table>
<thead>
<tr>
<th>EG1</th>
<th>EG2</th>
<th>EG3</th>
<th>EG4</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA1</td>
<td>ET</td>
<td>EM</td>
<td>EM</td>
</tr>
<tr>
<td>EA2</td>
<td>ET</td>
<td>EM</td>
<td>EW</td>
</tr>
<tr>
<td>EA3</td>
<td>EM</td>
<td>EW</td>
<td>EVT</td>
</tr>
<tr>
<td>EA4</td>
<td>EVW</td>
<td>EW</td>
<td>EM</td>
</tr>
<tr>
<td>EA5</td>
<td>EVT</td>
<td>ET</td>
<td>EW</td>
</tr>
</tbody>
</table>

**Step 5.** Conduct the SFNED between $NEE_{ij} = (NET_{ij}, NEI_{ij}, NEF_{ij})$ and $SFNNIS_j = (NET^-_j, NEI^-_j, NEF^-_j)$ (Table 9).

**Step 6.** Conduct the weight values utilizing the CRITIC technique (Table 10).

**Step 7.** Conduct the SFNWAV (Table 11).

**Step 8.** Conduct the SFNWGV (Table 12).

**Step 9.** Conduct the $SFNDS_{ia}$, $SFNDS_{ib}$, $SFNDS_{ic}$ (see Table 13).
### Table 5
Overall SFNs information.

<table>
<thead>
<tr>
<th></th>
<th>$\text{EG}_1$</th>
<th>$\text{EG}_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{EA}_1$</td>
<td>(0.3712, 0.1436, 0.4287)</td>
<td>(0.4376, 0.3418, 0.4276)</td>
</tr>
<tr>
<td>$\text{EA}_2$</td>
<td>(0.4328, 0.1425, 0.4324)</td>
<td>(0.3778, 0.1659, 0.4398)</td>
</tr>
<tr>
<td>$\text{EA}_3$</td>
<td>(0.4434, 0.1618, 0.3584)</td>
<td>(0.4736, 0.1658, 0.3549)</td>
</tr>
<tr>
<td>$\text{EA}_4$</td>
<td>(0.4497, 0.2436, 0.2564)</td>
<td>(0.4325, 0.1857, 0.2439)</td>
</tr>
<tr>
<td>$\text{EA}_5$</td>
<td>(0.4315, 0.2775, 0.3435)</td>
<td>(0.3217, 0.2513, 0.4439)</td>
</tr>
</tbody>
</table>

### Table 6
The $\text{NEE} = [\text{NEE}_{ij}]_{5 \times 4}$.

<table>
<thead>
<tr>
<th></th>
<th>$\text{EG}_1$</th>
<th>$\text{EG}_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{EA}_1$</td>
<td>(0.2143, 0.2657, 0.5443)</td>
<td>(0.5454, 0.3524, 0.3376)</td>
</tr>
<tr>
<td>$\text{EA}_2$</td>
<td>(0.3354, 0.2276, 0.5635)</td>
<td>(0.3473, 0.4564, 0.5476)</td>
</tr>
<tr>
<td>$\text{EA}_3$</td>
<td>(0.3354, 0.2875, 0.5536)</td>
<td>(0.2576, 0.1958, 0.5324)</td>
</tr>
<tr>
<td>$\text{EA}_4$</td>
<td>(0.5347, 0.3764, 0.3349)</td>
<td>(0.6426, 0.3369, 0.3873)</td>
</tr>
<tr>
<td>$\text{EA}_5$</td>
<td>(0.3725, 0.4126, 0.5347)</td>
<td>(0.3724, 0.4376, 0.5213)</td>
</tr>
</tbody>
</table>

### Table 7
The SFNPIS and SFNNIS.

<table>
<thead>
<tr>
<th></th>
<th>SFNPIS</th>
<th>SFNNIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{EG}_1$</td>
<td>(0.4497, 0.2436, 0.2564)</td>
<td>(0.3712, 0.1436, 0.4287)</td>
</tr>
<tr>
<td>$\text{EG}_2$</td>
<td>(0.4736, 0.1658, 0.3549)</td>
<td>(0.3217, 0.2513, 0.4439)</td>
</tr>
<tr>
<td>$\text{EG}_3$</td>
<td>(0.5347, 0.3764, 0.3349)</td>
<td>(0.2143, 0.2657, 0.5443)</td>
</tr>
<tr>
<td>$\text{EG}_4$</td>
<td>(0.6426, 0.3369, 0.3873)</td>
<td>(0.3473, 0.4564, 0.5476)</td>
</tr>
</tbody>
</table>

### Table 8
The SFNCSM between $\text{NEE}_{ij} = (\text{NET}_{ij}, \text{NEI}_{ij}, \text{NEF}_{ij})$ and $\text{SFNPIS}_{ij} = (\text{NET}^+_j, \text{NEI}^+_j, \text{NEF}^+_j)$.

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>$\text{EG}_1$</th>
<th>$\text{EG}_2$</th>
<th>$\text{EG}_3$</th>
<th>$\text{EG}_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{EA}_1$</td>
<td>0.5820</td>
<td>0.5722</td>
<td>0.5685</td>
<td>0.7699</td>
</tr>
<tr>
<td>$\text{EA}_2$</td>
<td>0.8563</td>
<td>0.7917</td>
<td>0.7875</td>
<td>0.4265</td>
</tr>
<tr>
<td>$\text{EA}_3$</td>
<td>0.6916</td>
<td>1.0000</td>
<td>0.5899</td>
<td>0.6578</td>
</tr>
<tr>
<td>$\text{EA}_4$</td>
<td>1.0000</td>
<td>0.7155</td>
<td>1.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>$\text{EA}_5$</td>
<td>0.8175</td>
<td>0.5401</td>
<td>0.8091</td>
<td>0.7496</td>
</tr>
</tbody>
</table>
Table 9
The SFNED between $NEE_{ij} = (NET_{ij}, NEI_{ij}, NEF_{ij})$ and $SFNNIS_{j} = (NET_{j}', NEI_{j}', NEF_{j}')$.

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>EG1</th>
<th>EG2</th>
<th>EG3</th>
<th>EG4</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA1</td>
<td>0.4016</td>
<td>0.2476</td>
<td>0.0000</td>
<td>0.3188</td>
</tr>
<tr>
<td>EA2</td>
<td>0.0000</td>
<td>0.3282</td>
<td>0.3611</td>
<td>0.0000</td>
</tr>
<tr>
<td>EA3</td>
<td>0.3672</td>
<td>0.3739</td>
<td>0.3245</td>
<td>0.2942</td>
</tr>
<tr>
<td>EA4</td>
<td>0.4524</td>
<td>0.2765</td>
<td>0.5322</td>
<td>0.4404</td>
</tr>
<tr>
<td>EA5</td>
<td>0.4239</td>
<td>0.0000</td>
<td>0.3880</td>
<td>0.3972</td>
</tr>
</tbody>
</table>

Table 10
The attribute weight.

<table>
<thead>
<tr>
<th></th>
<th>EG1</th>
<th>EG2</th>
<th>EG3</th>
<th>EG4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>0.1760</td>
<td>0.3281</td>
<td>0.2751</td>
<td>0.2208</td>
</tr>
</tbody>
</table>

Table 11
The SFNWAV.

<table>
<thead>
<tr>
<th></th>
<th>EA1</th>
<th>EA2</th>
<th>EA3</th>
<th>EA4</th>
<th>EA5</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFNWAV</td>
<td>0.4194</td>
<td>0.4642</td>
<td>0.5494</td>
<td>0.6603</td>
<td>0.4891</td>
</tr>
</tbody>
</table>

Table 12
The SFNWGV.

<table>
<thead>
<tr>
<th></th>
<th>EA1</th>
<th>EA2</th>
<th>EA3</th>
<th>EA4</th>
<th>EA5</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFNWGV</td>
<td>0.4074</td>
<td>0.4346</td>
<td>0.5410</td>
<td>0.6491</td>
<td>0.4596</td>
</tr>
</tbody>
</table>

Table 13
Three aggregation strategies.

<table>
<thead>
<tr>
<th></th>
<th>SFNDS_{ia}</th>
<th>SFNDS_{ib}</th>
<th>SFNDS_{ic}</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA1</td>
<td>0.1630</td>
<td>2.0000</td>
<td>0.6315</td>
</tr>
<tr>
<td>EA2</td>
<td>0.1771</td>
<td>2.1733</td>
<td>0.6864</td>
</tr>
<tr>
<td>EA3</td>
<td>0.2149</td>
<td>2.6377</td>
<td>0.8328</td>
</tr>
<tr>
<td>EA4</td>
<td>0.2581</td>
<td>3.1674</td>
<td>1.0000</td>
</tr>
<tr>
<td>EA5</td>
<td>0.1870</td>
<td>2.2942</td>
<td>0.7245</td>
</tr>
</tbody>
</table>

Step 10. Conduct the assessment value $SFNODS_{i}$ (see Table 14).

Step 11. In line with the $SFNODS_{i}$ ($i = 1, 2, 3, 4, 5$), the order is $EA_{4} > EA_{3} > EA_{5} > EA_{2} > EA_{1}$ and the optimal electric vehicle charging station is $EA_{4}$.

Table 14
The $SFNODS_{i}$.

<table>
<thead>
<tr>
<th></th>
<th>EA1</th>
<th>EA2</th>
<th>EA3</th>
<th>EA4</th>
<th>EA5</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFNODS</td>
<td>1.5219</td>
<td>1.6540</td>
<td>2.0071</td>
<td>2.4101</td>
<td>1.7459</td>
</tr>
</tbody>
</table>
Table 15
Order results for these different techniques.

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Ranking order</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFNWA technique (Gundogdu and Kahraman, 2019)</td>
<td>$EA_4 &gt; EA_3 &gt; EA_5 &gt; EA_2 &gt; EA_1$</td>
</tr>
<tr>
<td>SFNWG technique (Gundogdu and Kahraman, 2019)</td>
<td>$EA_4 &gt; EA_3 &gt; EA_2 &gt; EA_5 &gt; EA_1$</td>
</tr>
<tr>
<td>SFPWA technique (Garg et al., 2021b)</td>
<td>$EA_4 &gt; EA_3 &gt; EA_5 &gt; EA_2 &gt; EA_1$</td>
</tr>
<tr>
<td>SFPWG technique (Garg et al., 2021b)</td>
<td>$EA_4 &gt; EA_3 &gt; EA_2 &gt; EA_5 &gt; EA_1$</td>
</tr>
<tr>
<td>SFGWMSM technique (Liu et al., 2019)</td>
<td>$EA_4 &gt; EA_3 &gt; EA_5 &gt; EA_2 &gt; EA_1$</td>
</tr>
<tr>
<td>SFN-VIKOR technique (Aydogdu and Gul, 2020)</td>
<td>$EA_4 &gt; EA_3 &gt; EA_5 &gt; EA_2 &gt; EA_1$</td>
</tr>
<tr>
<td>SFN-GRA technique (Zhang et al., 2022)</td>
<td>$EA_4 &gt; EA_3 &gt; EA_5 &gt; EA_2 &gt; EA_1$</td>
</tr>
<tr>
<td>SFN-TODIM technique (Zhang et al., 2023)</td>
<td>$EA_4 &gt; EA_3 &gt; EA_5 &gt; EA_2 &gt; EA_1$</td>
</tr>
<tr>
<td>SFN-CoCoSo technique</td>
<td>$EA_4 &gt; EA_3 &gt; EA_5 &gt; EA_2 &gt; EA_1$</td>
</tr>
</tbody>
</table>

Fig. 2. Order for different techniques.

4.2. Comparative Analysis

The SFN-CoCoSo technique is compared with some existing techniques, such as SFNWA technique (Gundogdu and Kahraman, 2019), SFNWG technique (Gundogdu and Kahraman, 2019), spherical fuzzy power weighted averaging (SFPWA) technique (Garg et al., 2021b), spherical fuzzy power weighted geometric (SFPWG) technique (Garg et al., 2021b), spherical fuzzy generalized weighted MSM (SFGWMSM) technique (Liu et al., 2019), SFN-VIKOR technique (Aydogdu and Gul, 2020), SFN-GRA technique (Zhang et al., 2022) and SFN-TODIM technique (Zhang et al., 2023). Then, the results of these techniques are depicted in Table 15 and Fig. 2.

In accordance with WS coefficient technique (Salabun and Urbaniak, 2020; Salabun et al., 2020), the WS coefficient information between the SFNWA technique (Gundogdu and Kahraman, 2019), SFNWG technique (Gundogdu and Kahraman, 2019), SFPWA technique (Garg et al., 2021b), SFPWG technique (Garg et al., 2021b), SFGWMSM technique (Liu et al., 2019), SFN-VIKOR technique (Aydogdu and Gul, 2020), SFN-GRA
technique (Zhang et al., 2022), SFN-TODIM technique (Zhang et al., 2023) and the proposed SFN-CoCoSo technique is 1.0000, 0.7266, 1.0000, 0.7266, 1.0000, 1.0000, 1.0000, respectively. Therefore, the proposed SFN-CoCoSo technique is effective and reliable MAGDM model. The main advantages of SFN-CoCoSo technique combined the weighted arithmetic technique and weighted geometric technique to construct the compromise solution of combining different fused decision strategies, then ranked the alternatives based on the SFNCSM and SFNED. The main limits of the results obtained in this paper hasn’t mentioned the psychological behaviour of DMs.

5. Conclusion

New energy electric vehicles use electricity as their energy source, and the use of clean energy can reduce the pollution caused by the operation of new energy electric vehicles. The new energy electric vehicle charging station is a device that provides electrical energy supply for new energy electric vehicles. In the current stage of rapid development of new energy electric vehicles, the operation and maintenance management level of the charging station is directly related to the practicality of new energy electric vehicles. At present, there are problems with uneven regional distribution and untimely operation and maintenance management of new energy electric vehicle charging piles, which affect the actual usage rate and operation and management costs of charging piles. In view of this, it is necessary to introduce computer technology, digital technology, and information technology to innovate the operation and maintenance management mode of new energy electric vehicle charging piles, sort out and digitize the operation and maintenance management process and content, achieve all-weather monitoring of the operation status of new energy electric vehicle charging pile equipment, equipment inspection and maintenance process control, fault or defect diagnosis and early warning, and extend the service life of new energy electric vehicle charging piles. The location selection problem of electric vehicle charging stations could be deemed as the MAGDM problem. In this paper, on basis of CoCoSo technique, a novel SFN-CoCoSo technique based on SFNCSM and SFNED is conducted for dealing with MAGDM. Moreover, when the attribute weights are completely unknown, the information entropy technique is extended to SFSs to acquire the attribute weights. Finally, SFN-CoCoSo technique is used for location selection problem of electric vehicle charging stations to prove practicability of the developed technique and compare SFN-CoCoSo technique with existing techniques to further demonstrate its superiority. Hence, the main research achievements are obtained: (1) the CRITIC technique is extended to SFSs to acquire the attribute weights; (2) the novel CoCoSo technique is extended to the SFSs environment; (3) the novel SFN-CoCoSo technique based on the SFNCSM and SFNED is used to deal with MAGDM; (4) a numerical example for location selection problem of electric vehicle charging stations is presented to verify the SFN-CoCoSo technique and several comparative analysis are utilized to verify the advantages of SFN-CoCoSo technique.

There may be some possible limitations for location selection problem of electric vehicle charging stations, which could be further managed in our future research for location
selection problem of electric vehicle charging stations: (1) It is a worthwhile research work to manage consensus (Wu et al., 2023; Xu et al., 2023; Zhang and Dai, 2023) to deal with location selection problem of electric vehicle charging stations under SFSs; (2) It is also a worthwhile research to manage regret theory to deal with the location selection problem of electric vehicle charging stations under SFSs (Tian et al., 2021; Lin et al., 2017).

References


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