Research Article

An Integrated CoCoSo-CRITIC-Based Decision-Making Framework for Quality Evaluation of Innovation and Entrepreneurship Education in Vocational Colleges with Intuitionistic Fuzzy Information

Chang Gou

Department of Admission and Employment (School of Innovation & Entrepreneurship), Chengdu Vocational & Technical College of Industry, Chengdu 610000, Sichuan, China

Correspondence should be addressed to Chang Gou; gouchang15@sina.com

Received 11 June 2022; Revised 4 August 2022; Accepted 30 August 2022; Published 10 September 2022

Academic Editor: Dragan Pamučar

Copyright © 2022 Chang Gou. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

This paper proposes a multiattribute group decision-making (MAGDM) based on the CoCoSo method under the intuitionistic fuzzy sets (IFSs) environment for quality evaluation of innovation and entrepreneurship education (IEE) in vocational colleges. First of all, this paper extends the CoCoSo to the IFSs environment. Second, a new MAGDM model for quality evaluation of IEE in vocational colleges based on the CoCoSo algorithm is built. In this algorithm, the attribute weight is derived by subjective weight and objective weight, and the objective weights are defined by using the CRITIC method. At the end of this given study, some comparisons are given to verify the decision effectiveness of the algorithm.

1. Introduction

Along with daily growing decision complications and ambiguity and things’ fuzziness of contemporary human subjective information cognition, there are new and increasingly arduous for DMs to offer real exact assessments [1–3]. So as to derive a better decision choice of MADM which depicted qualitative decision choice [4, 5], Zadeh [6] built the fuzzy sets (FSs) to study not exact information [7, 8]. Furthermore, the intuitionistic fuzzy sets (IFSs) [9] were built. The most common intuitionistic fuzzy decision methods are the GRA method [10], TOPSIS method [11], EDAS method [12], and so on. Different from the above methods, there are three different aggregation strategies to derive better results in the CoCoSo method [13]. In addition, each strategy will give a score index and then get a complete ranking through the score of each data [13]. Zavadskas et al. [14] studied new operational research technologies and MADM tools. No one has adopted the CoCoSo method to solve the decision-making of TPD. Consequently, the CoCoSo method was employed in this study. This study presents a given MAGDM model which determines the objective of the criteria weight through improved CRITIC and selects the most suitable public charging service sections by the CoCoSo. This study proposes three contributions as follows: This paper presents a new MAGDM with the CoCoSo method and CRITIC methods under IFSs. Both the weights of subjective information of experts and objective information of schemes are considered in the operator. The attributes of the decision scheme and their weights can be changed. This model is still applicable if the decision-maker’s preference for the scheme changes with the change in time and development trend. The new MAGDM model for quality evaluation of IEE in vocational colleges based on the IF-CoCoSo algorithm is built.

The whole studies thread is as follows: Section 2 gives a literature review; Section 3 introduces the IFSs; Section 4 builds the MAGDM based on the CoCoSo method under IFSs; Section 5 illustrates a fresh example for quality
evaluation of IEE in vocational colleges to prove the decision practicability; Section 6 gives the comparison analysis.

2. Literature Review

2.1. IFSs. Zadeh [15] designed the FSs. Atanassov [9] proposed the IFSs. The IFSs represented the membership, nonmembership, and hesitation [16–19]. Gou et al. [20] proposed the exponential algorithm for IFSs and proved its effectiveness. Based on the Dombi operations, Liu et al. [21] extended the BM operator and then obtained some feasible intuitionistic fuzzy operators. Gupta et al. [22] extended the BM operator and then obtained some feasible intuitionistic fuzzy operators. Gupta et al. [22] extended the BM operator and then obtained some feasible intuitionistic fuzzy operators. Gupta et al. [22] extended the BM operator and then obtained some feasible intuitionistic fuzzy operators. Gupta et al. [22] extended the BM operator and then obtained some feasible intuitionistic fuzzy operators. Gupta et al. [22] extended the BM operator and then obtained some feasible intuitionistic fuzzy operators. Gupta et al. [22] extended the BM operator and then obtained some feasible intuitionistic fuzzy operators. Gupta et al. [22] extended the BM operator and then obtained some feasible intuitionistic fuzzy operators. Gupta et al. [22] extended the BM operator and then obtained some feasible intuitionistic fuzzy operators.

2.2. CoCoSo. The CoCoSo method was first suggested by Yazdani et al. [13] in 2018; it is based on a comprehensive product model of simple additive weighting and exponential weighting. The CoCoSo was generalized to many practical cases. Feng et al. [33] not only used the CoCoSo and CRITIC method to evaluate the 5G information industry but also adopted the novel q-ROF score function and CoCoSo methods [34] for financial risk evaluation. Yazdani et al. [13] utilized the CoCoSo information method to study logistics centers’ locations. Yazdani et al. [35] put forward a compromise method that combines the grey number and CoCoSo method to objectively measure supplier performance. Erceg et al. [36] proposed the interval rough CoCoSo for inventory management in storage systems. However, we still encounter some practical decision problems with complex data during the real decision process. In order to handle these complex information, the CoCoSo method is successfully proposed under the IFSs soft decision environment [37], hesitant fuzzy soft decision environment [38], and bipolar complex fuzzy sets environment [39].

3. Preliminaries

3.1. IFSs. Atanassov [9] proposed the IFSs.

Definition 1 (see [40]). Let X be the nonempty information set; the IFS is defined as

\[ A = \{< ax_i, \mu_A(ax_i), \nu_A(ax_i) > | ax_i \in X \}, \]

where \( \mu_A(ax_i) \in [0, 1] \) and \( \nu_A(ax_i) \in [0, 1] \) represent the membership and given nonmembership of \( ax_i \in X \) to A, and

\[ 0 \leq \mu_A(ax_i) + \nu_A(ax_i) \leq 1, ax_i \in X. \]

Definition 2 (see [41]). Let \( \alpha = (a_\mu, a_\nu) \) be the IFN, then the defined score function is

\[ SF(\alpha) = 2a_\mu + a_\nu - 1, SF(\alpha) \in [0, 1]. \]

Definition 3 (see [42]). Let \( \alpha = (a_\mu, a_\nu) \) be IFN, then the accuracy function is

\[ AF(\alpha) = a_\mu + a_\nu, AF(\alpha) \in [0, 1]. \]

Definition 4 (see [43]). \( \alpha_1 = (a_{\mu_1}, a_{\nu_1}) \) and \( \alpha_2 = (a_{\mu_2}, a_{\nu_2}) \) are two IFSs; then,

\[ \alpha_1 \otimes \alpha_2 = (a_{\mu_1} + a_{\nu_2} - a_{\mu_2}a_{\nu_2}, a_{\mu_1}a_{\nu_2}), \]

\[ \alpha_1 \otimes \alpha_2 = (a_{\mu_1}a_{\mu_2}, a_{\nu_1} + a_{\nu_2} - a_{\nu_1}a_{\nu_2}), \]

\[ \lambda \alpha = (1 - (1 - a_\mu^\lambda)a_\nu^\lambda), \lambda > 0, \]

\[ a^\lambda = (a_\mu^\lambda, 1 - (1 - a_\nu^\lambda)), \lambda > 0. \]

Definition 5 (see [44]). \( \alpha_1 = (a_{\mu_1}, a_{\nu_1}) \) and \( \alpha_2 = (a_{\mu_2}, a_{\nu_2}) \) are two IFSs; the Hamming distance is

\[ HD(\alpha_1, \alpha_2) = \frac{1}{2}(|a_{\mu_1} - a_{\mu_2}| + |a_{\nu_1} - a_{\nu_2}| + |a_{\nu_1} - a_{\nu_2}|). \]

Definition 6 (see [45]). Suppose that \( \alpha_j = (a_{\mu_j}, a_{\nu_j}), j = 1, 2, \ldots, s \); let IFWA: \( Q_n \rightarrow Q \), then

\[ IFWA_{xw}(\alpha_1, \alpha_2, \ldots, \alpha_s) = \frac{s}{s} \left( xw_j \alpha_j \right) \]

\[ = \left( 1 - \prod_{j=1}^s \left(1 - a_{\mu_j}^x \right) \right) \sum_{j=1}^s \frac{a_{\nu_j}^x}{xw_j}. \]

\( x = (xw_1, xw_2, \ldots, xw_s) \) is weight of \( \alpha_j = (a_{\mu_j}, a_{\nu_j}) \), and \( xw_j > 0, \sum_{j=1}^s xw_j = 1. \)

Definition 7 (see [46]). Suppose that \( \alpha_j = (a_{\mu_j}, a_{\nu_j}), j = 1, 2, \ldots, s \); let IFWG: \( Q_n \rightarrow Q \), then
\[ IFWG_{xw}(\alpha_1, \alpha_2, \ldots, \alpha_s) = \sum_{j=1}^{s} (a_j^{xw_j}) \]
\[ = \left( \sum_{j=1}^{s} a_{\mu_j}^{xw_j}, 1 - \sum_{j=1}^{s} (1 - a_{v_j})^{xw_j} \right). \tag{9} \]
\[ xw = (xw_1, xw_2, \ldots, xw_s)^T \text{ is weight of } \alpha_j = (a_{\mu_j}, a_{v_j}), \text{ and } xw_j > 0, \sum_{j=1}^{s} xw_j = 1. \]

4. Approach to the Intuitionistic Fuzzy MAGDM-Based CoCoSo Method with CRITIC

Let \( XA = \{XA_1, XA_2, \ldots, XA_n\} \) be the alternatives set, \( XT = \{XT_1, XT_2, \ldots, XT_n\} \) the chosen attributes set with corresponding weight \( xw = (xw_1, xw_2, \ldots, xw_n) \), where \( xw_j \in [0, 1], \sum_{j=1}^{n} xw_j = 1 \) and a experts group \( XE = \{XE_1, XE_2, \ldots, XE_m\} \) with weight vector \( xw = (xw_1, xw_2, \ldots, xw_m) \), where \( xw_k \in [0, 1], \sum_{k=1}^{m} xw_k = 1. \) Assume that decision matrix \( A^{(k)} = (a_{\mu_j}^{(k)})_{n \times m}, a_{\nu_j}^{(k)} = (a_{\mu_j}^{(k)}, a_{\nu_j}^{(k)})_{n \times m} \) (i = 1, 2, \ldots, n, j = 1, 2, \ldots, m, k = 1, 2, \ldots, t). The IF-CoCoSo method is used to solve MAGDM problems, which includes the following steps:

\( \text{Step 1.} \text{ The matrix under IFSs is described:} \)
\[ A^{(k)} = \left( \begin{array}{cccc}
\alpha_{\mu_1}^{(k)} & \cdots & \alpha_{\mu_n}^{(k)} \\
\vdots & \ddots & \vdots \\
\alpha_{\nu_1}^{(k)} & \cdots & \alpha_{\nu_m}^{(k)}
\end{array} \right) = (a_{\mu_j}^{(k)})_{n \times m}. \tag{10} \]

\( \text{Step 2.} \text{ Calculate the overall matrix } X = (xx_{ij})_{n \times m}, xx_{ij} = (a_{\mu_j}, a_{\nu_i})_{n \times m} \text{ by the IFWA operator.} \)
\[ xx_{ij} = IFWA_w(a_{\mu_j}^{(1)}, a_{\mu_j}^{(2)}, \ldots, a_{\mu_j}^{(t)}) \]
\[ = \left( 1 - \prod_{k=1}^{t} (1 - a_{\mu_j}^{(k)}), \prod_{k=1}^{t} (a_{\nu_j}^{(k)})^{xw_k} \right). \tag{11} \]

\( \text{Step 3.} \text{ Normalize the defined overall matrix } X = (xx_{ij})_{n \times m} \text{ to } NX = (nx_{ij})_{n \times m}. \)
\[ nx_{ij} = \begin{cases} (a_{\mu_j}, a_{\nu_i}), & \text{if } XT_j \text{ is a benefit criterion,} \\ (a_{\nu_i}, a_{\mu_j}), & \text{if } XT_j \text{ is a cost criterion.} \end{cases} \tag{12} \]

\( \text{Step 4.} \text{ Calculate the defined weight through the CRITIC method.} \)

The CRITIC is usually used to obtain the objective weight [47]. Mukhametzyanov [48] studied specific character for determining weights. Žižović et al. [49] studied the objective weight coefficients. The initial matrix is

\[ NX = \left( \begin{array}{c}
nx_{11} \\ \vdots \\ nx_{in} \\ \vdots \\ nx_{mn}
\end{array} \right) = (nx_{ij})_{n \times m} = (a_{\mu_j}, a_{\nu_i})_{n \times m}. \tag{13} \]

\( \text{(1) Depending on the NX, the score function is defined.} \)
\[ SF(nx_{ij}) = 2a_{\mu_j} + a_{\nu_i} - 1. \tag{14} \]

\( \text{(2) Calculate the defined correlation coefficient } (\rho_{jk}): \)
\[ n\bar{x}_j = \frac{1}{m} \sum_{i=1}^{m} SF(nx_{ij}), \]
\[ \rho_{jk} = \frac{\sum_{i=1}^{m}(SF(nx_{ij}) - n\bar{x}_j)(SF(nx_{ik}) - n\bar{x}_k)}{\sqrt{\left( \sum_{i=1}^{m}(SF(nx_{ij}) - n\bar{x}_j)^2 \right) \sum_{i=1}^{m}(SF(nx_{ik}) - n\bar{x}_k)^2}}. \tag{15} \]

\( \text{(3) Obtain the built standard deviation } (\sigma_j) \text{ and the index } (C_j) \text{ for given attributes:} \)
\[ \sigma_j = \sqrt{\frac{1}{m-1} \sum_{i=1}^{m} (SF(nx_{ij}) - n\bar{x}_j)^2}, \tag{16} \]
\[ C_j = \sigma_j \sum_{k=1}^{n} (1 - \rho_{jk}). \tag{17} \]

\( \text{(4) Obtain the objective weight:} \)
\[ xw_j = \frac{C_j}{\sum_{j=1}^{n} C_j}, \quad j = 1, \ldots, n. \tag{18} \]

\( \text{Step 5.} \text{ Obtain the weighted comparability sequence } IFS_i. \)
\[ IFS_i = \sum_{j=1}^{n} xw_j \times SF(nx_{ij}). \tag{19} \]

\( \text{Step 6.} \text{ The sum of weights of comparability series } IFP_i. \)
\[ IFP_i = \sum_{j=1}^{n} (SF(nx_{ij}))^{xw_j}. \tag{20} \]

\( \text{Step 7.} \text{ The three aggregation modes are utilized to comprehensively calculate the given relative importance by the following equations} \)
\[ IFK_i = \frac{IFP_i + IFS_i}{\sum_{i=1}^{m} (IFP_i + IFS_i)}. \tag{21} \]
\[ IFKC_i = \frac{\lambda IFKA_i + (1 - \lambda) IFKB_i}{\lambda \text{max}_i IFSA_i + (1 - \lambda) \text{max}_i IFPS_i}, \quad 0 \leq \lambda \leq 1, \]  

where \( IFKA_i \) is the given arithmetic mean, \( IFKB_i \) is the sum of the given relative scores, and \( IFKC_i \) is the given balanced compromise.

**Step 8.** Obtain the assessment value \( IFK_i \) by the following equation.

\[ IFK_i = \sqrt{IFKA_i IFKB_i IFKB_i + IFKA_i + IFKB_i + IFKB_i} \]

**Step 9.** Sort the designed alternatives through \( IFK_i \), and the higher the \( IFK_i \), the better the designed alternative is.

### 5. Numerical Example and Some Comparative Studies

**5.1. Numerical Example.** Nowadays, many higher vocational colleges have many outstanding problems in the process of carrying out IEE, which seriously affect the effectiveness of IEE. The main reason for these problems is that in some higher vocational colleges still insufficient attention has been paid to the given development of IEE, the popularity of IEE is not high, and a good cultural atmosphere of innovation and entrepreneurship has not yet been formed. In addition, the concept of IEE in some higher vocational colleges lags behind slightly, and IEE has not been integrated into the talent training system of higher vocational colleges. The links are out of touch, resulting in the lack of continuity and systematization of the entire educational practice. There are also some higher vocational colleges whose IEE activities are mere formalities. The lack of teachers and the lack of IEE awareness and educational ability have also led to the failure of higher vocational colleges to form a good innovation and entrepreneurship system. The key to the root cause of this problem is that higher vocational colleges lack a feasible evaluation index system for innovation and entrepreneurship quality, so they cannot guide the development direction of IEE in vocational colleges and cannot guarantee the quality of IEE in higher vocational colleges. This is because education evaluation itself is an effective way to control the quality of IEE. Only through scientific and reasonable education evaluation work can we timely find out whether the IEE work in vocational colleges deviates from the actual development direction so as to give corrective measures in a timely manner. To ensure that all IEE activities are always centered on the expected educational goals, while improving the effectiveness of IEE activities in higher vocational colleges, it also promotes the healthy and stable development of IEE in higher vocational colleges. A point in case that the quality evaluation of IEE in vocational colleges under IFNs is used to depict the built methods. There are five vocational colleges \( VC_i \) (\( i = 1, 2, 3, 4, 5 \)) to choose from. The experts found four selected attributes to depict these vocational colleges: \( XT_1 \) represents course teaching quality; \( XT_2 \) means practical teaching; \( XT_3 \) represents the quality of the teaching staff; and \( XT_4 \) means the IEE achievements. The quality evaluation of IEE in vocational colleges is evaluated with IFNs (whose weight \( xw = (0.35, 0.40, 0.25) \)); the five vocational colleges is evaluated by four DMs \( XE_k \) (expert’s weight \( xw_k = (0.18, 0.34, 0.26, 0.22)^T \)) using four criteria in the context of IFSs.

Then, we employ the developed algorithm (\( \lambda = 0.5 \)) to choose outstanding vocational colleges under IFSs. The specific calculation steps are given.

**Step 10.** The assessed matrix \( A^{(k)} = (a_{ij}^{(k)})_{5 \times 4} \) is shown in Tables 1–3.

**Step 11.** Calculate the overall information matrix (Table 4) by equation (12).

**Step 12.** The given cost attributes are transformed into given benefit attributes (Table 5).

**Step 13.** The normalized score information are given in Table 6.

**Step 14.** The defined \( \rho_{jk} \) is

\[
\rho_{ij} = \begin{bmatrix}
1.00 & 0.68 & -0.04 & -0.32 \\
0.68 & 1.00 & 0.69 & 0.14 \\
-0.42 & 0.69 & 1.00 & 0.46 \\
0.31 & 0.14 & 0.46 & 1.00
\end{bmatrix}.
\]

**Step 15.** The defined standard deviation is

\[
\sigma_1 = 0.10, \sigma_2 = 0.06, \sigma_3 = 0.07, \sigma_4 = 0.18.
\]

The \( C \) is determined:

\[
C_1 = 0.25, C_2 = 0.09, C_3 = 0.13, C_4 = 0.49.
\]

**Step 16.** The final weight is calculated.

\[
xw_1 = 0.258, xw_2 = 0.096, xw_3 = 0.139, xw_4 = 0.507.
\]

**Step 17.** The \( IFS_i \) is obtained.

\[
IFS_1 = 0.30, IFS_2 = 0.44, IFS_3 = 0.43, IFS_4 = 0.42, IFS_5 = 0.57.
\]

**Step 18.** The \( IFP_i \) is obtained.
Table 2: The assessed matrix through the second DM.

| Alternatives | XT₁ | XT₂ | XT₃ | XT₄ |
|--------------|-----|-----|-----|-----|
| VC₁          | (0.6, 0.3) | (0.8, 0.1) | (0.8, 0.1) | (0.7, 0.2) |
| VC₂          | (0.7, 0.2) | (0.7, 0.2) | (0.7, 0.2) | (0.6, 0.4) |
| VC₃          | (0.8, 0.1) | (0.6, 0.3) | (0.6, 0.3) | (0.5, 0.5) |
| VC₄          | (0.7, 0.1) | (0.5, 0.4) | (0.5, 0.4) | (0.7, 0.2) |
| VC₅          | (0.6, 0.3) | (0.7, 0.3) | (0.7, 0.3) | (0.6, 0.3) |

Step 19. The $IFK_{A_{i}}, IFK_{B_{i}}, IFK_{C_{i}}$ are obtained (Table 7).

Step 20. The $IFK_{i}$ is obtained.

\[ IFK_{1} = 1.61, IFK_{2} = 2.05, IFK_{3} = 2.00, IFK_{4} = 1.99, \]
\[ IFK_{5} = 2.34. \]  \hspace{1cm} (29)

Step 21. The ranking of alternatives is as follows (the higher the $IFK_{i}$, the better the alternative $i$).

\[ VC_{5} \succ VC_{4} \succ VC_{3} \succ VC_{2} \succ VC_{1}. \]  \hspace{1cm} (30)

Table 3: The assessed matrix through the third DM.

| Alternatives | XT₁ | XT₂ | XT₃ | XT₄ |
|--------------|-----|-----|-----|-----|
| VC₁          | (0.7, 0.2) | (0.6, 0.2) | (0.5, 0.3) | (0.6, 0.4) |
| VC₂          | (0.8, 0.1) | (0.6, 0.4) | (0.4, 0.5) | (0.7, 0.1) |
| VC₃          | (0.9, 0.1) | (0.8, 0.1) | (0.6, 0.3) | (0.8, 0.1) |
| VC₄          | (0.6, 0.3) | (0.7, 0.2) | (0.8, 0.1) | (0.5, 0.4) |
| VC₅          | (0.7, 0.3) | (0.7, 0.2) | (0.7, 0.3) | (0.7, 0.2) |

Table 4: The overall matrix.

| Alternatives | XT₁ | XT₂ | XT₃ | XT₄ |
|--------------|-----|-----|-----|-----|
| VC₁          | (0.72, 0.21) | (0.72, 0.14) | (0.69, 0.21) | (0.24, 0.51) |
| VC₂          | (0.71, 0.19) | (0.62, 0.28) | (0.53, 0.46) | (0.37, 0.57) |
| VC₃          | (0.80, 0.14) | (0.71, 0.22) | (0.59, 0.47) | (0.29, 0.60) |
| VC₄          | (0.64, 0.17) | (0.62, 0.28) | (0.68, 0.28) | (0.37, 0.59) |
| VC₅          | (0.69, 0.25) | (0.70, 0.25) | (0.69, 0.32) | (0.47, 0.53) |

Table 5: The normalized score matrix $NX$.

| Alternatives | XT₁ | XT₂ | XT₃ | XT₄ |
|--------------|-----|-----|-----|-----|
| VC₁          | (0.72, 0.21) | (0.72, 0.14) | (0.69, 0.21) | (0.24, 0.51) |
| VC₂          | (0.71, 0.19) | (0.62, 0.28) | (0.53, 0.46) | (0.37, 0.57) |
| VC₃          | (0.80, 0.14) | (0.71, 0.22) | (0.59, 0.47) | (0.29, 0.60) |
| VC₄          | (0.64, 0.17) | (0.62, 0.28) | (0.68, 0.28) | (0.37, 0.59) |
| VC₅          | (0.69, 0.25) | (0.70, 0.25) | (0.69, 0.32) | (0.47, 0.53) |

$\begin{align*}
IFP_{1} &= 2.79, \quad IFP_{2} = 3.29, \quad IFP_{3} = 3.23, \quad IFP_{4} = 3.25, \quad I \\
FP_{5} &= 3.49.
\end{align*}$  \hspace{1cm} (28)

5.2. Comparative Analyses. For this research, five college stadiums are selected to assess. This paper applied the IF-CoCoSo method to solve MAGDM. In order to certify the superiority of the IF-CoCoSo method more efficiently, we employed some previous decision methods (the IFWA operator [45], IFWG operator [46], IF-TOPSIS method [50], IF-GRAs method [51], and IF-taxonomy method [52]). The ranking of given alternatives was recorded and is given in Table 8.

Compared with the result of the CoCoSo method to other methods, consequently, Table 8 shows that the results of the five application methods are basically consistent with the IF-CoCoSo algorithm.

6. Conclusion

Deepening the IEE in higher vocational colleges is not only an urgent important need to really improve the quality of our country’s market economy but also a powerful measure to really promote higher education reform and improve graduates’ entrepreneurship. Therefore, major higher vocational colleges need to proceed from the actual situation, further strengthen the design of the school’s IEE quality evaluation information system, timely correct and improve inappropriate codes of conduct, and ensure that the IEE can always focus on education. The goal is to provide effective services for improving the effectiveness of IEE activities and to ensure the healthy development of IEE. The quality evaluation of IEE in vocational colleges is looked as MAGDM. Thus, in this paper, the IF-CoCoSo method is
proposed to solve MADM problems for quality evaluation of IEE in vocational colleges.

In the future, the IF-CoCoSo method will be expanded to some other existing fuzzy environment, such as the Q-rung orthopair fuzzy set, Pythagorean fuzzy set, and interval-valued IFs, or expanded to study some other existing decision-making issues [53–56]. At the same time, the novel logarithm method of additive weights [57] shall be our future works for uncertain MAGDM problems.

**Data Availability**

The data used to support the findings of this study are included within the article.

**Conflicts of Interest**

The author declares that there are no conflicts of interest.

**References**

[1] J. Roy, H. K. Sharma, S. Kar, E. K. Zavadskas, and J. Saparauskas, “An extended COPRAS model for multi-criteria decision-making problems and its application in web-based hotel evaluation and selection,” *Economic Research-Ekonomska Istraživanja*, vol. 32, no. 1, pp. 219–253, 2019.

[2] M. Keshavarz-Ghorabaee, M. Amiri, E. K. Zavadskas, Z. Turskis, and J. Antucheviciene, “Simultaneous evaluation of criteria and alternatives (SECA) for multi-criteria decision-making,” *Informatica*, vol. 29, no. 2, pp. 265–280, 2018.

[3] B. Ning, G. Wei, R. Lin, and Y. Guo, “A novel MADM technique based on extended power generalized Maclaurin symmetric mean operators under probabilistic dual hesitant fuzzy setting and its application to sustainable suppliers selection,” *Expert Systems with Applications*, vol. 204, Article ID 117419, 2022.

[4] T. Rashid, S. Faizi, and S. Zafar, “Outranking method for intuitionistic 2-tuple fuzzy linguistic information model in group decision making,” *Soft Computing*, vol. 23, no. 15, pp. 6145–6155, 2019.

[5] H. Zhang, G. Wei, and X. Chen, “SF-GRA method based on cumulative prospect theory for multiple attribute group decision making and its application to emergency supplies supplier selection,” *Engineering Applications of Artificial Intelligence*, vol. 110, Article ID 104679, 2022.

[6] L. A. Zadeh, “Fuzzy sets,” *Information and Control*, vol. 8, no. 3, pp. 338–353, 1965.

[7] A. Bhaumik, S. K. Roy, and D. F. Li, “Analysis of triangular intuitionistic fuzzy matrix games using robust ranking,” *Journal of Intelligent and Fuzzy Systems*, vol. 33, no. 1, pp. 327–336, 2017.

[8] D. Banerjee, B. Dutta, D. Guha, and L. Martinez, “SMAAQUALIFLEX methodology to handle multicriteria decision-making problems based on q-rung fuzzy set with hierarchical structure of criteria using bipolar Choquet integral,” *International Journal of Intelligent Systems*, vol. 35, no. 3, pp. 401–431, 2020.

[9] K. T. Atanassov, “Intuitionistic fuzzy sets,” *Fuzzy Sets and Systems*, vol. 20, no. 1, pp. 87–96, 1986.

[10] S. Zhang, H. Gao, G. Wei, and X. Chen, “Grey relational analysis method based on cumulative prospect theory for intuitionistic fuzzy multi-attribute group decision making,” *Journal of Intelligent and Fuzzy Systems*, vol. 41, no. 2, pp. 3783–3795, 2021.

[11] Y. J. Lai, T. Y. Liu, and C. L. Hwang, “TOPSIS for MODM,” *European Journal of Operational Research*, vol. 76, no. 3, pp. 486–500, 1994.

[12] D. Stanužič, E. K. Zavadskas, M. Keshavarz-Ghorabaee, and Z. Turskis, “An extension of the EDAS method based on the use of interval grey numbers,” *Studies in Informatics and Control*, vol. 26, no. 1, pp. 5–12, 2017.

[13] M. Yazdani, P. Zarate, E. K. Zavadskas, and Z. Turskis, “A Combined Compromise solution (CoCoSo) Method for Multi-Criteria Decision-Making Problems,” *Management Decision*, vol. 57, 2018.

[14] E. K. Zavadskas, J. Saparauskas, and Z. Turskis, “Selection of façade’s alternatives of commercial and public buildings based on multiple criteria/Komercinës Ir Viešosių paskirties PASTATŲ fasado Alternatyvų Daugiakriterinė atranka,” *International Journal of Strategic Property Management*, vol. 15, no. 2, pp. 189–203, 2011.

[15] L. A. Zadeh, *Fuzzy Sets*, pp. 338–356, Information and Control, Singapore, 1965.

[16] A. Bryniarska, “Mathematical models of diagnostic information granules generated by scaling intuitionistic fuzzy sets,” *Applied Sciences*, vol. 12, no. 5, p. 2597, 2022.

[17] O. Dogan, O. F. Seymen, and A. Hiziroglu, “Customer behavior analysis by intuitionistic fuzzy segmentation: comparison of two major cities in Turkey,” *International Journal of Information Technology and Decision Making*, vol. 21, no. 2, pp. 707–727, 2022.

[18] H. Garg and D. Rani, “Novel distance measures for intuitionistic fuzzy sets based on various triangle centers of isosceles triangular fuzzy numbers and their applications,” *Expert Systems with Applications*, vol. 191, Article ID 116228, 2022.

[19] A. Hussain, H. Al Sulami, and U. Ishitaq, “Some new aspects in the intuitionistic fuzzy and neurostochastic fixed point theory,” *Journal of Function Spaces*, vol. 2022, Article ID 3138740, 14 pages, 2022.

[20] X. J. Gou, Z. S. Xu, and Q. Lei, “New operational laws and aggregation method of intuitionistic fuzzy information,” *Journal of Intelligent and Fuzzy Systems*, vol. 30, no. 1, pp. 129–141, 2015.

[21] P. Liu, J. Liu, and S.-M. Chen, “Some intuitionistic fuzzy Dombi Bonferroni mean operators and their application to multi-attribute group decision making,” *Journal of the Operational Research Society*, vol. 69, pp. 1–24, 2018.

[22] P. Gupta, H. D. Arora, and P. Tiwari, “Generalized entropy for intuitionistic fuzzy sets,” *Malaysian Journal of Mathematical Sciences*, vol. 10, pp. 209–220, 2016.

[23] L. Zhang and Y. D. He, “Extensions of intuitionistic fuzzy geometric interaction operators and their application to cognitive microcredit origination,” *Cognitive Computation*, vol. 11, no. 5, pp. 748–760, 2019.

[24] Y. D. He, Z. He, and H. Huang, “Decision making with the generalized intuitionistic fuzzy power interaction averaging operators,” *Soft Computing*, vol. 21, no. 5, pp. 1129–1144, 2017.

[25] M. Li and C. Wu, “A Distance Model of Intuitionistic Fuzzy Cross Entropy to Solve Preference Problem on Alternatives,” *Mathematical Problems in Engineering*, vol. 2016, Article ID 8324124, 9 pages, 2016.

[26] T. T. Bao, X. L. Xie, P. Y. Long, and Z. K. Wei, “MADM method based on prospect theory and evidential reasoning approach with unknown attribute weights under intuitionistic
fuzzy environment," Expert Systems with Applications, vol. 88, pp. 305–317, 2017.

[27] S. M. Chen, S. H. Cheng, and T. C. Lan, "Multicriteria decision making based on the TOPSIS method and similarity measures between intuitionistic fuzzy values," Information Sciences, vol. 367, pp. 279–295, 2016.

[28] J. W. Gan and L. Luo, "Using DEMATEL and intuitionistic fuzzy sets to identify critical factors influencing the recycling rate of end-of-life vehicles in China," Sustainability, vol. 9, no. 10, p. 1873, 2017.

[29] P. Gupta, M. K. Mehlawat, N. Grover, and W. Chen, "Modified intuitionistic fuzzy SIR approach with an application to supplier selection," Journal of Intelligent and Fuzzy Systems, vol. 32, no. 6, pp. 4431–4441, 2017.

[30] B. D. Rouyendehg, "The intuitionistic fuzzy ELECTRE model," International Journal of Management Science and Engineering Management, vol. 13, no. 2, pp. 139–145, 2018.

[31] P. Phochanikorn and C. Q. Tan, "A new extension to a multi-criteria decision-making model for sustainable supplier selection under an intuitionistic fuzzy environment," Sustainability, vol. 11, no. 19, p. 5413, 2019.

[32] R. Krishankumar, K. Ravichandran, and A. B. Saeid, "A new extension to PROMETHEE under intuitionistic fuzzy enviroment for solving supplier selection problem with linguistic preferences," Applied Soft Computing, vol. 60, pp. 564–576, 2017.

[33] X. Peng, X. Zhang, and Z. Luo, "Pythagorean Fuzzy MCDM Method Based on CoCoSo and CRITIC with Score Function for 5G Industry Evaluation," Artificial Intelligence Review, vol. 53, 2019.

[34] X. Peng and H. Huang, "Fuzzy decision making method based on cococo with critric for financial risk evaluation," Technological and Economic Development of Economy, vol. 26, no. 4, pp. 695–724, 2020.

[35] M. Yazdani, Z. Wen, H. C. Liao, A. Banaitis, and Z. Turskis, "A grey combined compromise solution (COCOSO-G) method for supplier selection in construction management," Journal of Civil Engineering and Management, vol. 25, no. 8, pp. 858–874, 2019.

[36] Z. Erceg, V. Starcevic, D. Pamucar, G. Mitrovic, Z. Stevic, and S. Zikic, "A new model for stock management in order to rationalize costs: ABC-FUCOM-Interval rough CoCoSo model," Symmetry, vol. 11, no. 12, p. 1527, 2019.

[37] X. Peng and H. Garg, "Intuitionistic Fuzzy Soft Decision Making Method Based on CoCoSo and CRITIC for CCN Cache Placement Strategy Selection," Artificial Intelligence Review, vol. 55, 2021.

[38] X. Peng, H. Garg, and Z. Luo, "Hesitant fuzzy soft combined compromise solution method for IoT E companies’ evaluation," International Journal of Fuzzy Systems, vol. 24, no. 1, pp. 457–473, 2021.

[39] J. Baidya, H. Garg, A. Saha, A. R. Mishra, P. Rani, and D. Dutta, "Selection of third party reverses logistic providers: an approach of BCF-CRITIC-MULTIMOORA using Archimedean power aggregation operators," Complex & Intelligent Systems, vol. 7, no. 5, pp. 2503–2530, 2021.

[40] K. T. Atanassov, "More on intuitionistic fuzzy sets," Fuzzy Sets and Systems, vol. 33, no. 1, pp. 37–45, 1989.

[41] S. Zeng, S.-M. Chen, and L.-W. Kuo, "Multiattribute decision making based on novel score function of intuitionistic fuzzy values and modified VIKOR method," Information Sciences, vol. 488, pp. 76–92, 2019.

[42] J. Wu and Q.-w. Cao, "Same families of geometric aggregation operators with intuitionistic trapezoidal fuzzy numbers," Applied Mathematical Modelling, vol. 37, no. 1-2, pp. 318–327, 2013.

[43] K. T. Atanassov, "New operations defined over the intuitionistic fuzzy sets," Fuzzy Sets and Systems, vol. 61, no. 2, pp. 137–142, 1994.

[44] P. Grzegorzewski, "Distances between intuitionistic fuzzy sets and/or interval-valued fuzzy sets based on the Hausdorff metric," Fuzzy Sets and Systems, vol. 148, no. 2, pp. 319–328, 2004.

[45] X. Zeshui, "Intuitionistic fuzzy aggregation operators," IEEE Transactions on Fuzzy Systems, vol. 15, no. 6, pp. 1179–1187, 2007.

[46] Z. Xu and R. R. Yager, "Some geometric aggregation operators based on intuitionistic fuzzy sets," International Journal of General Systems, vol. 35, no. 4, pp. 417–433, 2006.

[47] D. Diakoulaki, G. Mavrotas, and L. Papayannakis, "Determining Objective Weights In Multiple Criteria Problems The Critic Method," Elsevier Science, vol. 22, pp. 767–770, 1995.

[48] I. Mukhametzyanov, "Specific character of objective methods for determining weights of criteria in MCDM problems: entropy, CRITIC and SD," Decision Making Applications in Management and Engineering, vol. 4, no. 2, pp. 76–105, 2021.

[49] M. Žiković, B. Miljković, and D. Marinković, "Objective methods for determining criteria weight coefficients: a modification of the CRITIC method," Decision Making: Applications in Management and Engineering, vol. 3, no. 2, pp. 149–161, 2020.

[50] Z. Yue, "TOPSIS-based group decision-making methodology in intuitionistic fuzzy setting," Information Sciences, vol. 277, pp. 141–153, 2014.

[51] G.-W. Wei, "GRA method for multiple attribute decision making with incomplete weight information in intuitionistic fuzzy setting," Knowledge-Based Systems, vol. 23, no. 3, pp. 243–247, 2010.

[52] T. T. He, G. W. Wei, J. P. Lu, C. Wei, and R. Lin, "Pythagorean 2-tuple linguistic Taxonomy method for supplier selection in medical instrument industries," International Journal of Environmental Research and Public Health, vol. 16, no. 23, pp. 4875, 2019.

[53] G. F. Yu, D. F. Li, and W. Fei, "A novel method for heterogeneous multi-attribute group decision making with preference deviation," Computers & Industrial Engineering, vol. 124, pp. 58–64, 2018.

[54] D. F. Li, Y. T. Wang, A. Madden et al., "Analyzing stock market trends using social media user moods and social influence," Journal of the Association for Information Science and Technology, vol. 70, no. 9, pp. 1000–1013, 2019.

[55] K. Hayat, M. Ali, B.-Y. Cao, F. Karasaaln, and X.-P. Yang, "Another view of aggregation operators on group-based generalized intuitionistic fuzzy soft sets: multi-attribute decision making methods," Symmetry, vol. 10, no. 12, p. 753, 2018.

[56] M. Zhao, H. Gao, G. Wei, C. Wei, and Y. Guo, "Model for network security service provider selection with probabilistic uncertain linguistic TODIM method based on prospect theory," Technological and Economic Development of Economy, vol. 28, no. 3, pp. 638–654, 2022.