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Research article

Complex intuitionistic fuzzy soft SWARA - COPRAS approach: An application of ERP software selection

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Abstract: In this manuscript, we propose an integrated framework based on COmplex PRoportional ASsessment and Step-wise Weight Assessment Ratio Analysis approach within the complex intuitionistic fuzzy soft (CIFS) context. This context is an ideal technique with complex fuzzy foundation that means to denote multi-dimensional data in a concise. In this framework, criteria weights are evaluated by the SWARA technique, and the ranking of alternatives is determined by the COPRAS method using CIFSs. Further, to illustrate the applicability of the presented technique, an empirical case study of ERP software selection problem is taken. A comparative study and sensitivity analysis is presented to verify the strength of the presented methodology.

Keywords: complex intuitionistic fuzzy soft set; ERP software selection; multi criteria decision-making; COPRAS; SWARA
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1. Introduction

Uncertainties and vagueness are characteristics that are prevalent in problems which occurring in science, engineering, medical science, economics, decision making, etc. To exceed these, some of the theories were designated like fuzzy set (FS) [38], intuitionistic fuzzy set (IFS) [2], soft set (SS) [23] and intuitionistic fuzzy soft set (IFSS) [18]. MCDM problems often require the decision makers to give evaluation information about the alternative and the criteria with a FS, soft set, IFS and other extended sets [12, 15, 20, 36, 37]. Under these existing sets, there is a difficulty to handle the seasonality or periodicity that to be in many real life problems. The complex numbers can be used to model the periodicity of the elements by its phase term and also complex numbers can represent the two dimensional information. The complex valued models have been widely used in various fields of applications [3, 34, 35].

In this regard, Ramot et al. [28] introduced a novel concept known as complex fuzzy sets (CFSs), which included the amplitude and phase terms. By adding the degree of non-belongingness to CFSs, Alkouri et al. [1] proposed the idea of complex intuitionistic fuzzy sets (CIFSs). Further, Kumar et al. [13] defined the CIFSSs (complex intuitionistic fuzzy soft sets) concept. In recent times, CIFS is a powerful context means to represent the two dimensional data arisen in natural complicated problems [6, 29]. Consequently, numerous methodologies and theories have been established under the CFSs extensions [9, 16, 17, 19, 24–27, 32]. In this work, a novel MCDM technique is proposed to select the ideal choice in which the data is represented in the form of CIFSS environment.

Zavadskas et al. [39] defined a novel approach known as COPRAS (COmplex PRoportional ASsessment), which is a realistic decision making framework. The advantages of the COPRAS framework are: (i) it contains the ratios of benefit and cost solutions simultaneously; (ii) it is a valuable and flexible method to solve the problems. Several works have extended the COPRAS method in various uncertain contexts. Recently, Garg [7] proposed the COPRAS method in possibility intuitionistic fuzzy soft sets environment for the decision problem. Also, Mishra et al. [14, 22] introduced the COPRAS Method in various fuzzy extensions to solve the decision making. The weights of the criteria are key factors in the decision process. There are two kinds of criteria weights: (i) subjective; (ii) objective. The objective weights are computed from the data given in decision matrices and the subjective weights are evaluated based on the data given by the experts. To evaluate the subjective criteria weights, Kersuliene et al. [11] introduced a novel approach called SWARA, which has a least computational complexity. The SWARA and fuzzy COPRAS approach was integrated by Ighravwe and Oke [4] to select the maintenance technician. Further, the combined SWARA and COPRAS approach is developed in various domain such as hesitant fuzzy sets [30] and intuitionistic fuzzy sets (IFSs) [21]. These approaches had their own significance in the evaluation of weight and preference ranking of an alternative, respectively.

The existing studies such as IFS, IFSS etc., have been widely applicable in many fields, although it has been restricted in nature. In such theories, the information collected related to the object is deal with only one dimension information at a time, which may result to loss of some information at a particular time. In everyday life, we come across complex phenomena where it becomes necessary to add the other dimension to the membership and non-membership grades. By defining this other dimension, the complete information can be projected in single set, and hence, information loss can be ignored. To illustrate the importance of the phase term, consider an automotive manufacturing company in India, where they decide to select the ERP software for improving their business activities. The company consults an expert team regarding (i) overall rating about an alternative; (ii) corresponding latest version of ERP software. This is a two-dimensional problem and this is unable to done accurately using IFS and IFSS [2, 18] structure. To the best of our knowledge, this work develops a new framework called Complex Intuitionistic Fuzzy Soft-SWARA-COPRAS (CIFS-SWARA-COPRAS) with CIFSS domain for solving the two dimensional problem. In CIFSS atmosphere, the amplitude term represents the expert's decision with respect to the alternative and the phase term represents the expert's decision with respect to the current version of ERP software.

An ERP system is the brain of the company's technology system. Because ERP combines all features of a business involving development of product, manufacturing, retail and sales. ERP software selection is one of the most important decision making issues covering both qualitative and quantitative criterion for organizations. The authors of [10], in their conjoint work of 1008 calculation completed in 126 organizations state that reliability, functionality, ease of use and ease of customization are considered as the most important criteria. Based on these criteria, an automotive manufacturing company in India, where they decides to select the ERP software by using CIFS-SWARA-COPRAS technique.

The main contributions of this paper include:

1) A new framework named as CIFS-SWARA-COPRAS is introduced in the work. In this framework, criteria weights are evaluated by the SWARA technique, and the ranking of alternatives is determined by the COPRAS method using CIFSs information.

2) In the proposed technique, the weights are calculated by using the SWARA method which include the exactness of experts' opinion and the ranking of an alternative is determined by using the COPRAS approach.

3) To illustrate the applicability of the presented framework, an empirical case study of ERP software selection problem is examined under CIFSSs environment. The problem is two dimensional, that is to find the ideal ERP software with its current version.

4) A sensitivity analysis and comparative study are presented to show the validity and stability of the defined methodology.

The rest of this paper is organized as follows: Section 2 describes the notion of complex fuzzy sets and complex intuitionistic fuzzy soft sets. Section 3 proposes the CIFS-SWARA-COPRAS method under the CIFSS-environment. The applicability of the stated method is demonstrated through a case study of ERP software selection in Section 4. Also, a comparative study and sensitivity analysis is conducted to strengthen the results over the existing studies results. At last, Section 5 concludes the work.

2. Preliminaries

In this section, we review the notions of CFS, CIFS and CIFSS.

Definition 2.1. [28] A complex fuzzy set (CFS) C over U is distinguished by a membership function $\mu_C(u)$ that belongs to the unit circle in the complex plane and is denoted by $\mu_C(u) = r_C(u)e^{is_C(u)}$, where $r_C(u)$ and $s_C(u)$ are both real-valued, $r_C(u) \in [0, 1]$ and $i = \sqrt{-1}$. A CFS C is represented by,

$$\begin{aligned} C &= \{(u, \mu_C(u)) : u \in U\} \\ &= \{(u, r_C(u)e^{is_C(u)}) : u \in U\} \end{aligned} \tag{1}$$

Definition 2.2. [13] Let $CIFS(U)$ denotes the set of all CIFs over U, E be a set of criteria. Then

$$(\widetilde{F}, E) = \left\{(e, \widetilde{F}(e)) : e \in E, \widetilde{F}(e) \in \text{CIFS(U)}\right\}, \tag{2}$$

is a complex intuitionistic fuzzy soft set (CIFSS) over U, where $\widetilde{F} : E \longrightarrow CIFS(U)$.

For all $\epsilon \in E$,

$$\begin{aligned} \widetilde{F}(\epsilon) &= \{(u, \mu_{\widetilde{F}(\epsilon)}(u), \nu_{\widetilde{F}(\epsilon)}(u)) : u \in U\} \\ &= \left\{\left(u, r_{\widetilde{F}(\epsilon)}(u) e^{iw_{\mu_{\widetilde{F}(\epsilon)}}(u)}, k_{\widetilde{F}(\epsilon)}(u) e^{iw_{\nu_{\widetilde{F}(\epsilon)}}(u)}\right) : u \in U\right\} \end{aligned} \tag{3}$$

where $\mu_{\widetilde{F}(\epsilon)} : U \longrightarrow \{a | a \in \mathbb{C}, |a| \leq 1\}$ and $\nu_{\widetilde{F}(\epsilon)} : U \longrightarrow \{a' | a' \in \mathbb{C}, |a'| \leq 1\}$, $|\mu_{\widetilde{F}(\epsilon)}(u) + \nu_{\widetilde{F}(\epsilon)}(u)| \leq 1$.

For convince, we denote $\delta = \left(re^{is}, \tau e^{i\psi}\right)$ and called as CIFN ("complex intuitionistic fuzzy number") with the condition that $r, \tau, s, \psi \in [0, 1]$ and $|\ re^{is} + \tau e^{i\psi}\ | \leq 1$.

Definition 2.3. [6] Let $\delta = \left(re^{is}, \tau e^{i\psi}\right)$ be a CIFN. Then the score function of δ is defined as

$$S(\delta) = (r - \tau) + \frac{1}{2\pi}(s - \psi). \tag{4}$$

and the accuracy function is

$$H(\delta) = (r + \tau) + \frac{1}{2\pi}(s + \psi). \tag{5}$$

It is clearly seen that $S(\delta) \in [-2, 2]$ and $H(\delta) \in [0, 2]$.

Definition 2.4. Let δ be a CIFN. Then the normalized score function of δ is defined as

$$\mathbb{S}^*(\delta) = \frac{1}{4}(S(\delta) + 2), \tag{6}$$

where $S(\delta)$ is the score function of δ and $\mathbb{S}^*(\delta) \in [0, 1]$.

Definition 2.5. [6] Let $\delta_j = \left(r_j e^{is_j}, \eta_j e^{i\psi_j}\right) (j = 1, 2, ..., n)$ be CIFNs. The aggregated value of these CIFNs is obtained by using the complex intuitionistic fuzzy weighted averaging operator (CIFWA) and given as

$$\begin{aligned} \text{CIFWA}(\delta_1, \delta_2, ..., \delta_n) &= \bigoplus_{j=1}^{n} w_j \delta_j \\ &= \left(\left(1 - \prod_{j=1}^{n} (1 - r_j)^{w_j}\right) e^{i2\pi\left(1 - \prod_{j=1}^{n} (1 - s_j)^{w_j}\right)}, \left(\prod_{j=1}^{n} \tau_j^{w_j}\right) e^{i2\pi\left(\prod_{j=1}^{n} \psi_j^{w_j}\right)}\right) \end{aligned} \tag{7}$$

where $w = (w_1, w_2, ..., w_n)^T$ is a weight vector of δ_j with $w_j > 0$ and $\sum_{j=1}^{n} w_j = 1$.

3. Proposed CIFS-SWARA-COPRAS method

In this section, we propose the concept of CIFS-SWARA-COPRAS method and the working framework of it in the following steps:

Step 1: *Originate the data about the alternatives according to the criteria.*

Let $A = \{a_1, a_2, ..., a_m\}$ be a collection of decision criteria and $U = \{x_1, x_2, ..., x_n\}$ denotes the set of alternatives and let $DE = \{E_1, E_2, ..., E_l\}$ be a set of decision experts for the decision process and $W = \{w_1, w_2, ..., w_l\}$ represents the weights for the decision experts. Suppose X be the initial CIFSs decision matrix

$$X = \begin{pmatrix} x_{11}^{(k)} & x_{12}^{(k)} & \cdots & x_{1m}^{(k)} \\ x_{21}^{(k)} & x_{22}^{(k)} & \cdots & x_{2m}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1}^{(k)} & x_{n2}^{(k)} & \cdots & x_{nm}^{(k)} \end{pmatrix} \tag{8}$$

where $x_{ij}^{(k)} = \left(r_{ij}^{(k)} e^{is_{ij}^{(k)}}, \eta_{ij}^{(k)} e^{i\psi_{ij}^{(k)}}\right)$ denotes the initial value for x_i as to the criteria a_j given by the k^{th} expert in terms of CIFS set, for $j = 1, 2, ..., m$, $i = 1, 2, ..., n$ and $k = 1, 2, ..., l$.

Step 2: *Generate the aggregated CIFSS decision matrix.*

Compute the aggregated value of the expert $x_{ij}^{(k)} = \left(r_{ij}^{(k)} e^{is_{ij}^{(k)}}, \eta_{ij}^{(k)} e^{i\psi_{ij}^{(k)}}\right)$ for $k = 1, 2, ..., l$ into CIFSS decision matrix $\widehat{X} = (\widehat{x}_{ij})_{n\times m}$ by utilizing the Definition 2.5. The obtained values of $\widehat{x}_{ij} = \left(r_{ij} e^{is_{ij}}, \eta_{ij} e^{i\psi_{ij}}\right)$ are as follows

$$\begin{aligned} \widehat{x}_{ij} &= \text{CIFWA}\left(x_{jk}^{(1)}, x_{jk}^{(2)}, ..., x_{jk}^{(l)}\right) \\ &= \left(\left(1 - \prod_{k=1}^{l} (1 - r_{jk})^{w_k}\right) e^{i2\pi\left(1 - \prod_{k=1}^{l} (1 - s_{jk})^{w_k}\right)}, \left(\prod_{k=1}^{l} \tau_{jk}^{w_k}\right) e^{i2\pi\left(\prod_{k=1}^{l} \psi_{jk}^{w_k}\right)}\right), i = 1, 2, ..., n \end{aligned} \tag{9}$$

Step 3: *Evaluate the weights for the criteria by using SWARA method.*

The weights of the criteria are computed by using SWARA method, whose steps are summarized as follows.

i) Evaluate the crisp values w_j for the criteria according to the experts' preference and find the normalized score values of w_j (i.e., $\mathbb{S}^*(w_j)$), by using the Definition 2.4.

ii) Order the criteria from the most to the least score value.

iii) Compute the comparative value k_j for the ordered score value, which starts from the second place by differencing the j^{th} value and $(j-1)^{th}$ value.

iv) Calculate the comparative coefficient p_j by

$$p_j = \begin{cases} 1 & \text{if } j = 1 \\ k_j + 1 & \text{if } j > 1. \end{cases} \tag{10}$$

v) Evaluate the recalculated weights q_j by

$$q_j = \begin{cases} 1 & \text{if } j = 1 \\ \frac{q_{(j-1)}}{p_j} & \text{if } j > 1. \end{cases} \tag{11}$$

vi) Estimate the criteria weights w_j by using the following equation

$$w_j = \frac{q_j}{\sum\limits_{j=1}^{m} q_j}. \tag{12}$$

Step 4: *Determine the optimisation indexes α_i^+ and α_i^- for A^+ and A^-, respectively.*

Let us assume $A^+ = \{a_1, a_2, ..., a_r\}$ where $r < m$ be the set of positive (beneficial) criteria. Then we calculate the optimisation index (α_i^+) for each alternative x_i, as follows

$$\alpha_i^+ = \bigoplus_{j=1}^{r} w_j \widehat{x_{ij}},\ i = 1, ..., n \tag{13}$$

Let $A^- = \{a_{r+1}, a_{r+2}, ..., a_m\}$ be the non-beneficial (negative) criteria for the decision problem. Then we determine the optimization index (α_i^-) for each alternative x_i, as

$$\alpha_i^- = \bigoplus_{j=r+1}^{m} w_j \widehat{x_{ij}},\ i = 1, 2, ..., n \tag{14}$$

Step 5: *Calculate the priority value ($\mathbb{Q}_i$), for each x_i.*

By using COPRAS technique, we compute the priority value $\mathbb{Q}_i$, for every x_i as:

$$\mathbb{Q}_i = \mathbb{S}^*(\alpha_i^+) + \frac{\sum\limits_{i=1}^{n} \mathbb{S}^*(\alpha_i^-)}{\mathbb{S}^*(\alpha_i^-) \sum\limits_{i=1}^{n} \left(\frac{1}{\mathbb{S}^*(\alpha_i^-)}\right)}, i = 1, ..., n \quad \text{provided} \quad \mathbb{S}^*(\alpha_i^-) \neq 0 \tag{15}$$

Step 6: *Make the endmost decision based on utility degree γ_i.*

Calculate the utility degree γ_i, for every x_i by

$$\gamma_i = \frac{\mathbb{Q}_i}{Q_{max}} \times 100\%, \tag{16}$$

where $Q_{max} \neq 0$ is the largest value of $\mathbb{Q}_i$. Then, rank the utility degree in which the highest utility degree is ranked as first, while least utility degree is ranked as last. Finally, make the conclusion based on the utility degree γ_i.

The implementation framework of the CIFS-SWARA-COPRAS method is shown in Figure 1.

4. A case study

To demonstrate the working of the proposed CIFS-SWARA-COPRAS method, we provide a numerical example related to ERP software selection, which can be read as follows.

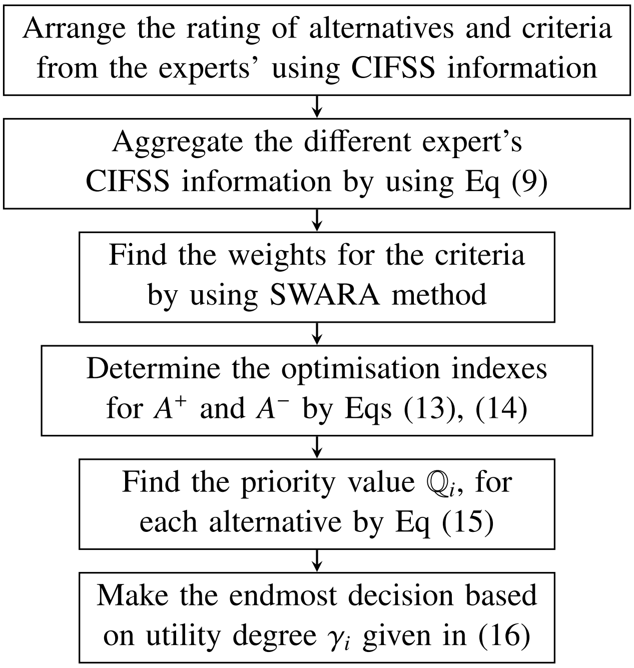

Figure 1. Working process of the proposed CIFS-SWARA-COPRAS method.

4.1. An empirical study: ERP software selection

The proposed CIFS-SWARA-COPRAS algorithm is applied to a Enterprise Resource Planning (ERP) software selection process for the automotive manufacturing company in India. In the manufacturing company, the operation managers need to buy an ERP software system for increasing the day-to-day business activities such as production management, accounting, manufacturing execution, procurement, supply chain operations and compliance. Initially, a decision expert team of 3 $DE = \{E_1, E_2, E_3\}$ consisting of a senior representative and a functional expert and a senior manager was constituted. Then, the expert team decides seven criteria (Functionality, Reliability, Vendor Viability, Cost, Support and Training, Ease of Use and Difficulty in Customization and Implementation) based on their experiences and studies in the literature. Accordingly, the criteria and its direction for the ERP selection process is given in Table 1. In addition, the selection of ERP

Table 1. Criteria and its directions ('+' = Beneficial, '-' = Non-Beneficial).

Criteria	Description	Direction
a_1	Functionality	+
a_2	Reliability	+
a_3	Vendor Viability	+
a_4	Cost	-
a_5	Support and Training	+
a_6	Ease of Use	+
a_7	Difficulty in Customization and Implementation	-

system is not only based on overall average rating about an alternative and it is also based on the recent reviews about an alternative. Because, the average value represents the collected reviews over time do not always give the current customer review - recent reviews about the latest version are more likely to give the current sentiment. Therefore the selection should be based on both overall rating and latest version of an alternative. This can be presented by the amplitude and phase expression of CIFSS. The given each expert needs to select the appropriate ERP software system among the four alternatives x_1, x_2, x_3, and x_4. For this, the steps of the proposed method are implemented to find the desired alternative(s) as follows:

Step 1: The ratings of each expert towards the evaluation of alternatives under the different criteria are provided in terms of linguistic expressions as given in Table 2. In this table, each pair of linguistic intimation represents the amplitude and phase term. The amplitude term means to give an expert's decision with respect to alternative and the phase term can be used to denote an expert's decision with respect to the current version.

Table 2. Linguistic terms given by experts for the criteria.

Criteria	Experts	Alternatives			
		x_1	x_2	x_3	x_4
a_1	E_1	L, SL	H, SH	M, M	H, SH
	E_2	H, SH	M, M	H, SH	VH, EH
	E_3	H, SH	L, SL	L, SL	M, M
a_2	E_1	H, SH	M, M	H, SH	L, SL
	E_2	VH, EH	L, SL	M, M	VL, EL
	E_3	H, SH	VH, EH	H, SH	L, SL
a_3	E_1	M, M	H, SH	VH, EH	M, M
	E_2	H, SH	VH, EH	H, SH	VH, EH
	E_3	VH, EH	L, SL	VL, EL	H, SH
a_4	E_1	H, SH	M, M	L, SL	M, M
	E_2	H, SH	L, SL	L, SL	H, SH
	E_3	L, SL	VL, EL	H, SH	L, SL
a_5	E_1	VL, EL	L, SL	H, SH	VH, EH
	E_2	H, SH	VL, EL	M, M	H, SH
	E_3	M, M	VH, EH	L, SL	VH, EH
a_6	E_1	VH, EH	L, SL	H, SH	M, M
	E_2	M, M	M, M	VH, EH	H, SH
	E_3	H, SH	VH, EH	M, M	VL, EL
a_7	E_1	VL, EL	M, M	H, SH	L, SL
	E_2	L, SL	VL, EL	M, M	H, SH
	E_3	M, M	L, SL	H, SH	M, M

For instance, suppose the expert E_1 thinks that the over all rating about x_1 is "Low" and the rating about the current version of x_1 is "Slightly Low" for the first attribute. So the value of x_1 for the first attribute can be represented as "L, SL". However, the respective ratings of each linguistic term in the form of CIFSS features are summarized in Table 3.

Table 3. Respective values for the linguistic terms in CIFSS.

	r	s	τ	ψ
EH- Extremely high	0.95	$(0.9)2\pi$	0.02	$(0.1)2\pi$
VH- Very High	0.90	$(0.8)2\pi$	0.05	$(0.15)2\pi$
H- High	0.80	$(0.75)2\pi$	0.10	$(0.20)2\pi$
SH- Slightly High	0.70	$(0.7)2\pi$	0.25	$(0.1)2\pi$
M- Medium	0.65	$(0.5)2\pi$	0.30	$(0.4)2\pi$
SL- Slightly Low	0.50	$(0.3)2\pi$	0.45	$(0.6)2\pi$
L- Low	0.40	$(0.25)2\pi$	0.50	$(0.6)2\pi$
VL- Very Low	0.25	$(0.2)2\pi$	0.60	$(0.65)2\pi$
EL- Extremely Low	0.15	$(0.1)2\pi$	0.65	$(0.7)2\pi$

Step 2: By taking the experts' E_1, E_2, E_3 weight as 0.253, 0.621, 0.126, which is provided by the company senior members, we aggregate the different expert preferences into the collective one using Eq. (9). The results corresponding to them are summarized in Table 4.

Table 4. Expert aggregated values.

	x_1	x_2	x_3	x_4
a_1	$\left(0.736e^{i2\pi(0.628)}, 0.150e^{i2\pi(0.157)}\right)$	$\left(0.675e^{i2\pi(0.542)}, 0.243e^{i2\pi(0.296)}\right)$	$\left(0.735e^{i2\pi(0.620)}, 0.162e^{i2\pi(0.178)}\right)$	$\left(0.861e^{i2\pi(0.838)}, 0.075e^{i2\pi(0.119)}\right)$
a_2	$\left(0.870e^{i2\pi(0.848)}, 0.065e^{i2\pi(0.100)}\right)$	$\left(0.582e^{i2\pi(0.497)}, 0.329e^{i2\pi(0.432)}\right)$	$\left(0.717e^{i2\pi(0.588)}, 0.198e^{i2\pi(0.237)}\right)$	$\left(0.291e^{i2\pi(0.155)}, 0.573e^{i2\pi(0.673)}\right)$
a_3	$\left(0.789e^{i2\pi(0.703)}, 0.121e^{i2\pi(0.142)}\right)$	$\left(0.851e^{i2\pi(0.831)}, 0.080e^{i2\pi(0.125)}\right)$	$\left(0.802e^{i2\pi(0.739)}, 0.105e^{i2\pi(0.128)}\right)$	$\left(0.850e^{i2\pi(0.827)}, 0.086e^{i2\pi(0.142)}\right)$
a_4	$\left(0.770e^{i2\pi(0.666)}, 0.123e^{i2\pi(0.125)}\right)$	$\left(0.462e^{i2\pi(0.336)}, 0.450e^{i2\pi(0.552)}\right)$	$\left(0.478e^{i2\pi(0.371)}, 0.408e^{i2\pi(0.479)}\right)$	$\left(0.735e^{i2\pi(0.620)}, 0.162e^{i2\pi(0.178)}\right)$
a_5	$\left(0.700e^{i2\pi(0.578)}, 0.181e^{i2\pi(0.195)}\right)$	$\left(0.450e^{i2\pi(0.360)}, 0.419e^{i2\pi(0.527)}\right)$	$\left(0.675e^{i2\pi(0.542)}, 0.242e^{i2\pi(0.296)}\right)$	$\left(0.846e^{i2\pi(0.802)}, 0.077e^{i2\pi(0.100)}\right)$
a_6	$\left(0.762e^{i2\pi(0.688)}, 0.166e^{i2\pi(0.237)}\right)$	$\left(0.657e^{i2\pi(0.556)}, 0.272e^{i2\pi(0.372)}\right)$	$\left(0.861e^{i2\pi(0.838)}, 0.075e^{i2\pi(0.119)}\right)$	$\left(0.728e^{i2\pi(0.608)}, 0.166e^{i2\pi(0.182)}\right)$
a_7	$\left(0.407e^{i2\pi(0.285)}, 0.491e^{i2\pi(0.593)}\right)$	$\left(0.399e^{i2\pi(0.280)}, 0.492e^{i2\pi(0.596)}\right)$	$\left(0.717e^{i2\pi(0.588)}, 0.198e^{i2\pi(0.237)}\right)$	$\left(0.688e^{i2\pi(0.573)}, 0.188e^{i2\pi(0.201)}\right)$

Step 3: Considering the different experts' preferences weight as given in Table 5 with respect to each criteria, we aggregate their preferences and their result is summarized in the last column of the Table 5.

Table 5. Criteria weights and its aggregated value.

	E_1	E_2	E_3	Aggregated Value
a_1	$\left(0.65e^{i2\pi(0.5)}, 0.30e^{i2\pi(0.4)}\right)$	$\left(0.80e^{i2\pi(0.7)}, 0.10e^{i2\pi(0.1)}\right)$	$\left(0.40e^{i2\pi(0.3)}, 0.50e^{i2\pi(0.6)}\right)$	$\left(0.735e^{i2\pi(0.620)}, 0.162e^{i2\pi(0.178)}\right)$
a_2	$\left(0.80e^{i2\pi(0.7)}, 0.1e^{i2\pi(0.1)}\right)$	$\left(0.90e^{i2\pi(0.9)}, 0.05e^{i2\pi(0.1)}\right)$	$\left(0.90e^{i2\pi(0.9)}, 0.05e^{i2\pi(0.1)}\right)$	$\left(0.881e^{i2\pi(0.868)}, 0.060e^{i2\pi(0.100)}\right)$
a_3	$\left(0.40e^{i2\pi(0.3)}, 0.50e^{i2\pi(0.6)}\right)$	$\left(0.65e^{i2\pi(0.5)}, 0.30e^{i2\pi(0.4)}\right)$	$\left(0.80e^{i2\pi(0.7)}, 0.10e^{i2\pi(0.1)}\right)$	$\left(0.626e^{i2\pi(0.490)}, 0.297e^{i2\pi(0.372)}\right)$
a_4	$\left(0.25e^{i2\pi(0.1)}, 0.60e^{i2\pi(0.7)}\right)$	$\left(0.40e^{i2\pi(0.3)}, 0.50e^{i2\pi(0.6)}\right)$	$\left(0.25e^{i2\pi(0.3)}, 0.50e^{i2\pi(0.6)}\right)$	$\left(0.347e^{i2\pi(0.254)}, 0.524e^{i2\pi(0.624)}\right)$
a_5	$\left(0.65e^{i2\pi(0.5)}, 0.30e^{i2\pi(0.4)}\right)$	$\left(0.80e^{i2\pi(0.7)}, 0.10e^{i2\pi(0.1)}\right)$	$\left(0.80e^{i2\pi(0.7)}, 0.10e^{i2\pi(0.1)}\right)$	$\left(0.770e^{i2\pi(0.659)}, 0.132e^{i2\pi(0.142)}\right)$
a_6	$\left(0.80e^{i2\pi(0.7)}, 0.10e^{i2\pi(0.1)}\right)$	$\left(0.80e^{i2\pi(0.7)}, 0.10e^{i2\pi(0.1)}\right)$	$\left(0.90e^{i2\pi(0.9)}, 0.05e^{i2\pi(0.1)}\right)$	$\left(0.817e^{i2\pi(0.739)}, 0.092e^{i2\pi(0.100)}\right)$
a_7	$\left(0.40e^{i2\pi(0.3)}, 0.50e^{i2\pi(0.6)}\right)$	$\left(0.25e^{i2\pi(0.3)}, 0.50e^{i2\pi(0.6)}\right)$	$\left(0.25e^{i2\pi(0.3)}, 0.50e^{i2\pi(0.6)}\right)$	$\left(0.291e^{i2\pi(0.155)}, 0.573e^{i2\pi(0.673)}\right)$

By using the steps of the SWARA techniques, as mentioned in Step 3 of the proposed method, the values of k_j, p_j and q_j are summarized in Table 6. In this Table, the most significant criteria is ranked as first and the least significant criteria is ranked as last.

Table 6. Criteria weights calculated by the SWARA method.

Criteria	Ordered crisp value k_j	Comparative coefficient p_j	Comparative weights q_j	Recalculated w_j	Criteria weights
a_2	0.897	-	1	1	0.177
a_6	0.841	0.056	1.056	0.947	0.167
a_5	0.789	0.052	1.052	0.900	0.159
a_1	0.754	0.035	1.035	0.870	0.154
a_3	0.612	0.142	1.142	0.762	0.135
a_4	0.363	0.249	1.249	0.610	0.108
a_7	0.300	0.063	1.063	0.574	0.101

Hence, the criteria weights are computed as

$$w_j = \{0.154, 0.177, 0.135, 0.108, 0.159, 0.167, 0.101\}.$$

Step 4: Use Eqs (13), (14), we compute the values of α_i^-, α_i^+ for each alternative $x_i, i = 1, 2, 3, 4$ as

$$\begin{aligned}
\alpha_1^+ &= \left(0.701e^{i2\pi(0.625)}, 0.196e^{i2\pi(0.233)}\right) \quad ; \quad \alpha_1^- = \left(0.200e^{i2\pi(0.141)}, 0.742e^{i2\pi(0.758)}\right) \\
\alpha_2^+ &= \left(0.576e^{i2\pi(0.498)}, 0.329e^{i2\pi(0.413)}\right) \quad ; \quad \alpha_2^- = \left(0.112e^{i2\pi(0.075)}, 0.854e^{i2\pi(0.890)}\right) \\
\alpha_3^+ &= \left(0.685e^{i2\pi(0.601)}, 0.217e^{i2\pi(0.260)}\right) \quad ; \quad \alpha_3^- = \left(0.179e^{i2\pi(0.130)}, 0.771e^{i2\pi(0.799)}\right) \\
\alpha_4^+ &= \left(0.679e^{i2\pi(0.617)}, 0.251e^{i2\pi(0.296)}\right) \quad ; \quad \alpha_4^- = \left(0.230e^{i2\pi(0.173)}, 0.694e^{i2\pi(0.706)}\right)
\end{aligned}$$

Step 5: Using the values of α_i^+, α_i^-, we compute the priority values $\mathbb{Q}_i$'s for each x_i with Eq (15) and get

$$\mathbb{Q}_1 = 0.8796 \quad ; \quad \mathbb{Q}_2 = 0.8775 \quad ; \quad \mathbb{Q}_3 = 0.8787 \quad ; \quad \mathbb{Q}_4 = 0.8172$$

Step 6: The utility degree γ_i's for each alternative is computed by using Eq (16) and get

$$\gamma_1 = 100\% \quad ; \quad \gamma_2 = 99.76\% \quad ; \quad \gamma_3 = 99.89\% \quad ; \quad \gamma_4 = 92.91\%$$

From these values, the order preference of the given ERP software system is found as $x_1 \succ x_3 \succ x_2 \succ x_4$ and, thus x_1 is the best alternative.

4.2. *Comparative analysis and advantages*

In this section, the advantages of the proposed CIFS-SWARA-COPRAS method are underlined, which are listed as follows.

The criteria weights which are determined by SWARA approach include the exactness of experts' opinion in ERP software selection process. Also, COPRAS procedure contains the ratios of the benefit and the cost solutions, simultaneously. The automotive manufacturing company needs to select the suitable alternative of ERP system with its current version simultaneously. This two-dimensional problem can be solved by CIFSS atmosphere. In CIFSS, the amplitude term denoted an experts' decision regarding option of ERP system and the phase term denoted an experts' decision regarding current version of ERP system. This cannot be done by using traditional IFSs. To verify the strength of the proposed technique a comparative study is obtained in Table 7. From Table 7, we determined that x_3 is the best alternative by using [20, 21]. This result is based on overall rating about an alternative. Suppose the rating about current version of an ERP software is taken into account, the result may be affected. This findings certify that the proposed technique is more powerful than previously developed techniques [6, 20, 21].

Table 7. Ranking of alternatives as for the existing methods.

	x_1	x_2	x_3	x_4	Rank Order
IF-WASPAS [20]					
(i) Weight Sum Model (WSM)	0.9155	0.8175	0.9300	0.9025	$x_3 \succ x_1 \succ x_4 \succ x_2$
(ii) Weight Product Model (WPM)	0.6965	0.5305	0.7270	0.6250	$x_3 \succ x_1 \succ x_4 \succ x_2$
(iii) Weighted Aggregated Sum Product Assessment (WASPAS) with $\vartheta = 0.5$	0.8065	0.6745	0.8285	0.7640	$x_3 \succ x_1 \succ x_4 \succ x_2$
IF-SWARA-COPRAS [21]	0.8985	0.8660	0.9270	0.8580	$x_3 \succ x_1 \succ x_2 \succ x_4$
CIFWA operator with criteria weights w_j [6]	0.7595	0.6275	0.7545	0.6145	$x_1 \succ x_3 \succ x_2 \succ x_4$
Proposed CIFS - SWARA - COPRAS	0.8796	0.8775	0.8787	0.8172	$x_1 \succ x_3 \succ x_2 \succ x_4$

4.3. Sensitivity analysis

In this section, we investigate a sensitivity according to the strategy value of the decision expert (DE) in [0,1] by using Eq (17), which can be demonstrated by Eq (15).

$$\mathbb{Q}_i = \vartheta\, \mathbb{S}^*(\alpha_i^+) + (1-\vartheta)\frac{\sum_{i=1}^{n} \mathbb{S}^*(\alpha_i^-)}{\mathbb{S}^*(\alpha_i^-) \sum_{i=1}^{n} \left(\frac{1}{\mathbb{S}^*(\alpha_i^-)}\right)}, \tag{17}$$

where $\vartheta \in [0, 1]$. If $\vartheta < 0.5$, the DE indicates pessimistic type, (i.e.,) the least value is related as the weight to the benefit criteria. Consequently, if $\vartheta > 0.5$, the DE gives optimistic type and so, the least value is related as the weight to the cost criteria. Also, if $\vartheta = 0.5$, the DE indicates neutral and the same preference is associated with both benefit and cost criteria. From this, the various values of ϑ can able to evaluate the sensitivity of the proposed technique. The ranking values as to the parameters are given in Table 8 and Figure 2. From this Table, we can see that an alternative x_1 has the highest value, when $\vartheta = 0.5$ to 1 whereas x_2 has the highest value when ϑ= 0 to 0.4. On the other side, x_4 has the lowest value when $\vartheta = 0$ to 0.6 and x_2 has the lowest value when ϑ= 0.7 to 1. It is cleared that the proposed technique has good stability.

5. Conclusions

The main contribution of the work is listed in the following points.

Table 8. Diverse values with respect to $\vartheta \in [0, 1]$.

ϑ	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
x_1	0.1556	0.2125	0.2693	0.3262	0.3830	0.4398	0.4967	0.5534	0.6103	0.6672	0.7240
x_2	0.2945	0.3233	0.3522	0.3810	0.4099	0.4387	0.4676	0.4964	0.5253	0.5541	0.5830
x_3	0.1767	0.2292	0.2817	0.3343	0.3868	0.4393	0.4919	0.5444	0.5969	0.6495	0.7020
x_4	0.1172	0.1859	0.2416	0.2973	0.3529	0.4086	0.4643	0.5200	0.5756	0.6313	0.6870

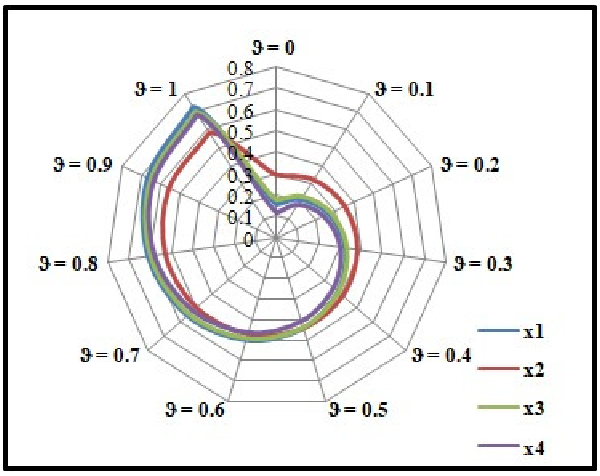

Figure 2. Utility degree over different ϑ value.

1) The present study proposed an integrated CIFS-SWARA-COPRAS method by utilizing the features of the CIFS information. CIFS is a poweful way to handle the imprecise information using the two-dimensional information including the phase term. In this stated framework, criteria weights are evaluated by the SWARA technique, and the ranking of alternatives is determined by the COPRAS method using CIFSs. The presented approach has been applied to handle the ERP software selection problem.

2) A multiple experts has been taken during the process to rate the information in terms of the CIFS features. A weighted average CIFWA operator has been used to aggregate such preferences. The criteria weight are computed by following the SWARA method which include the exactness of experts' opinion during the process.

3) A utility degree has been used to rank the different alternatives.

4) To verify the strength of the proposed technique a comparative study is conducted with the existing studies [6, 20, 21] and found that the proposed method has its superiority over these existing methods. Furthermore, the sensitivity analysis by varying the degree $\vartheta \in [0, 1]$. A decision maker may chose the the parameter according to their choices as pessimistic $\vartheta < 0.5$ or optimistic $\vartheta > 0.5$ or neutral $\vartheta = 0.5$ towards the benefit and cost criteria. The ranking order corresponding to each parameter is listed in Table 8 and Figure 2.

In future, the work will be developed, by considering a maximum number of alternatives and DEs as well as to solve real data. Moreover, we expand our work using different multi-criteria decision making platforms under the different environment [5, 8, 31, 33].

Conflict of interest

There is no conflict of interest.

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