



A New Approach for Solving Rough Interval MCDM Problems Based on BWM and WASPAS Methods

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ABSTRACT

The process of ranking alternatives in Multi-Criteria Decision Making (MCDM) problems with rough intervals is a situation really tough to handle. Despite, there are dozens of proposals to handle MCDM problems under different types of uncertainty but still there is limited number of articles to explore Rough MCDM specially, the rough interval ones with no weights for criteria. Mainly, this research is to propose a new approach combining two novel methods to treat such MCDM problems. First, Rough Interval Best-Worst Method (RIBWM), where RIBWM is applied for assigning weights to criteria based on the criteria preference given by the Decision Makers (DMs). This is done in a new manner to handle rough interval preference given. Second, a new Rough Interval Weighted Aggregated Sum-Product Assessment method (RIWASPAS) is presented to rank the alternatives. A merit of this new approach that it sustains rough interval representation of the problem till the end as well as it deals with it efficiently. Finally, an illustrative example is provided for validation.

Key words: Best Worst Method, Multi-criteria Decision Making (MCDM), Rough Interval, WASPAS.

1. INTRODUCTION

On daily basis most of people face situations involving criteria of judgment are not compatible. This type of decisions is so-called MCDM and it refers to undertaking decisions under the existence of conflicting criteria. For illustration if one criterion is fulfilled or satisfied by an option, there is other criterion is not satisfied or fulfilled with the same option. Both words multiple or multi which are coined to criteria refer to the conflict between not the meaning of many criteria. This philosophy makes this branch is widely applied [7]. A typical MCDM problem contains a number of competing alternatives measured via number of criteria [6]. Performance measurements should be

done and calculated for all alternatives under all criteria considered [10]. Some of the most widely used MCDM methods are SAW, MAUT, AHP, PROMETHEE, COPRAS, and ELECTRE methods [4].

In MCDM, the weights reflect the comparative importance and play the biggest role in determining the best alternatives to be selected. Two main categories exist for allocating weights, Subjective and Objective weights' allocation methods. Subjective weights' allocation methods are translating the preference of Decision Maker(s) into quantified values while the Objective weights' allocation methods are extracting weights from the alternatives' performance measurements [5].

One of the critical criticisms of the AHP refers to its inconsistency of decision makers' judgments in pairwise comparisons [20]. Recently, the Best-Worst Method (BWM) was introduced to tackle such drawbacks [16]. BWM has been applied broadly like in [2], and [18].

In many real-life problems, different types of uncertainty are found. Guo and Zhang tackled the supplier selection problem [9]; Aydogan tried to rank aviation firms [1]. Radovic et. al. introduced a rough ARAS approach [14]. Many other applications are done like in [3] [8], [12], [15], and [19].

The WASPAS method adds in some manner the Weighted Sum Model (WSM) to the Weighted Product Model (WPM) with certain ratio derived from a coefficient to reach the highest accuracy of multiple attribute estimation [15]. This article is to propose a new approach for solving rough interval MCDM problems using the merits of a novel incorporation between a new Weighted Aggregated Sum-Product Assessment Method with Rough Interval (RIWASPAS) and a novel Rough Interval Best-Worst Method (RIBWM). The rest of this paper is organized as following; section 2 is made for Rough Set Theory and it contains an illustration of Rough Interval operations. Section

3 is made for the proposed approach; it shows the rough interval Best-Worst Method (RIBWM) weights allocation proposed scheme as well as the steps of the proposed approach (RIWASPAS). Section 4 is devoted to a numerical example for illustration; and finally section 5 is for conclusion.

2. ROUGH SET THEORY

The main idea behind rough set theory initially proposed by Pawlak is an approximation of a conventional set in terms of two sets the *upper* and *lower* approximations of the original set [13]. Generally, a rough interval contains two parts: an upper approximation interval (UAI) and a lower approximation interval (LAI) [12]

Basic Operations of Rough Interval

Let $* \in \{+, -, \times, \div\}$ be a binary operation on rough intervals. For rough intervals x^R and y^R when $x^R \geq 0$ and $y^R \geq 0$, we have [11]:

$$x^R + y^R = [x^{(UAI)} + y^{(UAI)}; [x^{(LAI)} + y^{(LAI)}]] \tag{1}$$

$$x^R - y^R = [[x^{(UAI)} - y^{(UAI)}]; [x^{(LAI)} - y^{(LAI)}]] \tag{2}$$

$$x^R \times y^R = [[x^{(UAI)} \times y^{(UAI)}]; [x^{(LAI)} \times y^{(LAI)}]] \tag{3}$$

$$x^R \div y^R = [[x^{(UAI)} \div y^{(UAI)}]; [x^{(LAI)} \div y^{(LAI)}]] \tag{4}$$

As $x^{(UAI)}, x^{(LAI)}, y^{(UAI)}$ and $y^{(LAI)}$ are conventional intervals, $x^{UAI} = [x^{(-UAI)}, x^{(+UAI)}]$, $x^{LAI} = [x^{(-LAI)}, x^{(+LAI)}]$, $y^{UAI} = [y^{(-UAI)}, y^{(+UAI)}]$, and $y^{LAI} = [y^{(-LAI)}, y^{(+LAI)}]$, where $x^{(-LAI)}, x^{(+LAI)}, y^{(-UAI)}, y^{(+UAI)}, y^{(-LAI)}$, and $y^{(+LAI)}$ are deterministic numbers denoting bounds of intervals.

3. PROPOSED APPROACH

In this section, the new Approach is introduced to solve (MCDM) problems under rough interval environment via tow novel methods. First subsection will illustrates the novel proposed weights' allocation method (RIBWM) which works under rough interval environment to produce rough weights and second subsection will shows the new proposed (RIWASPAS) which deals with rough intervals' alternatives and criteria.

3.1 Rough Interval Best-Worst Method (RIBWM)

The original BWM found in [17] relies on two steps, first identifying the best criterion and the worst criterion by the DM. After, The DM expresses how better the best and how worse is the worst relative to other criteria using the scale (e.g. 1 to 9). As shown it eliminates a lot of pairwise comparisons made by other subjective methods. This

subsection extends the classical BWM method to the rough interval environment. The steps of the new Rough Interval Best-Worst Method (RIBWM) method to determine the rough interval weight of each criterion can be as shown below:

Step 1: Define the set of decision factors

DM introduces n decision factors, namely $\{c_1, c_2, \dots, c_n\}$ to make a decision.

Step 2: Specify the Best decision factor (B) and the Worst decision factor (W)

Step 3: Identify the preference of the rough interval best decision factor over the other decision factors

The rough interval best-to-others (BO) vector is:

$$A_B^{RI} = (a_{B1}^{RI}, a_{B2}^{RI}, \dots, a_{Bn}^{RI}) \tag{5}$$

$$a_{BB}^{RI} = [1, 1]; [1, 1]$$

a_{Bj}^{RI} represents the preference of the rough interval best factor B over selection factor j.

Step 4: Identify the preference the rough interval of all decision factors over worst decision factor

The rough interval others-to-worst (OW) vector is:

$$A_W^{RI} = (a_{1w}^{RI}, a_{2w}^{RI}, \dots, a_{nw}^{RI})^T \tag{6}$$

$$(a_{ww}^{RI}) = [1, 1]; [1, 1]$$

a_{jw}^{RI} represents the preference of selection factor j over the rough interval worst decision factor W.

Step 5: Compute the best possible rough interval weights

The rough weights' vector $(w_1^{RI}, w_2^{RI}, \dots, w_n^{RI})$ is calculated by the Model as shown in Eq. [7]:

$$\text{Min } \varepsilon \tag{7}$$

S.t

$$\left[\frac{[w_B^{-UAI}, w_B^{+UAI}]: [w_B^{-LAI}, w_B^{+LAI}]}{[w_j^{-UAI}, w_j^{+UAI}]: [w_j^{-LAI}, w_j^{+LAI}]} - [a_{Bj}^{-UAI}, a_{Bj}^{+UAI}]: [a_{Bj}^{-LAI}, a_{Bj}^{+LAI}] \right] \leq \varepsilon$$

for all j

$$\left[\frac{[w_j^{-UAI}, w_j^{+UAI}]: [w_j^{-LAI}, w_j^{+LAI}]}{[w_w^{-UAI}, w_w^{+UAI}]: [w_w^{-LAI}, w_w^{+LAI}]} - [a_{jw}^{-UAI}, a_{jw}^{+UAI}]: [a_{jw}^{-LAI}, a_{jw}^{+LAI}] \right] \leq \varepsilon$$

for all j

$$\sum_{j=1}^n [[w_j^{-UAI}, w_j^{+UAI}]: [w_j^{-LAI}, w_j^{+LAI}]] = 1$$

$$[w_j^{-UAI}, w_j^{+UAI}]: [w_j^{-LAI}, w_j^{+LAI}] \geq 0$$

for all j

where $[w_j^{-UAI}, w_j^{+UAI}]: [w_j^{-LAI}, w_j^{+LAI}]$ are the rough interval weights' values. $[w_B^{-UAI}, w_B^{+UAI}]: [w_B^{-LAI}, w_B^{+LAI}]$ represents

the rough interval weights of the best criterion and $[w_w^{-UAI}, w_w^{+UAI}]$: $[w_w^{-LAI}, w_w^{+LAI}]$ the rough interval weights of the worst criterion. While $[a_{Bj}^{-UAI}, a_{Bj}^{+UAI}]$: $[a_{Bj}^{-LAI}, a_{Bj}^{+LAI}]$ and $[a_{jw}^{-UAI}, a_{jw}^{+UAI}]$: $[a_{jw}^{-LAI}, a_{jw}^{+LAI}]$, respectively represent the values of the rough interval best-to-others (BO) and the rough interval others-to-worst (OW). By solving model (7) we obtain the values of the rough interval weights for the evaluation criteria.

3.2 Rough Interval Weighted Aggregated Sum-Product Assessment method (RIWASPAS)

Some modifications should be done to WASPAS method in order to explore the rough interval environment [21]. In this subsection these modifications are illustrated to extend WASPAS method to deal with problems when the data given are rough intervals. The proposed RIWASPAS method consists of the following steps:

Step 1: Construct the decision matrix with RI X^{RI}

$$X^{RI} = \begin{bmatrix} x_{11}^{RI} & \dots & x_{12}^{RI} & \dots & x_{1n}^{RI} \\ \vdots & & \vdots & & \vdots \\ x_{21}^{RI} & \dots & x_{22}^{RI} & \dots & x_{2n}^{RI} \\ \vdots & & \vdots & & \vdots \\ x_{m1}^{RI} & \dots & x_{m2}^{RI} & \dots & x_{mn}^{RI} \end{bmatrix} \tag{8}$$

$$i = 1, 2, \dots, m; \quad j = 1, 2, \dots, n$$

where $x_{ij}^{RI} = [x_{ij}^{LAI}, x_{ij}^{UAI}]$, $x_{ij}^{LAI} = [x_{ij}^{-LAI}, x_{ij}^{+LAI}]$, x_{ij}^{-LAI} = lower lower interval and x_{ij}^{+LAI} = lower upper interval. $x_{ij}^{UAI} = [x_{ij}^{-UAI}, x_{ij}^{+UAI}]$, x_{ij}^{-UAI} = upper lower interval and x_{ij}^{+UAI} = upper upper interval, m = number of alternatives, n = number of criteria, $i = 1, 2, \dots, m$; and $j = 1, 2, \dots, n$.

Step 2: Normalize the RI decision-making matrix

For rough interval beneficial criteria

$$\bar{x}_{ij}^{RI} = \frac{[[x_{ij}^{-UAI}, x_{ij}^{+UAI}]: [x_{ij}^{-LAI}, x_{ij}^{+LAI}]]}{\max[x_{ij}^{+UAI}, x_{ij}^{+LAI}]} \tag{9}$$

For rough interval non-beneficial criteria

$$\bar{x}_{ij}^{RI} = \frac{\min[x_{ij}^{-UAI}, x_{ij}^{-LAI}]}{[[x_{ij}^{-UAI}, x_{ij}^{+UAI}]: [x_{ij}^{-LAI}, x_{ij}^{+LAI}]]} \tag{10}$$

Where \bar{x}_{ij}^{RI} is the normalized value of x_{ij}^{RI} .

Step 3: Calculate the weighted normalized RI decision matrix \hat{X}^{RI}

a. The weighted normalized RI decision matrix \hat{X}_q^{RI} for WSM:

$$\hat{x}_{ij}^{RI} = [[\bar{x}_{ij}^{-UAI}, \bar{x}_{ij}^{+UAI}]: [\bar{x}_{ij}^{-LAI}, \bar{x}_{ij}^{+LAI}]] \times W_j^{RI} \tag{11}$$

$$i = 1, 2, \dots, m; \quad j = 0, 1, 2, \dots, n$$

where W_j^{RI} is the RI weight(importance) of the j criterion and \hat{x}_{ij}^{RI} is the rough interval normalized rating of the j criterion.

b. The weighted normalized RI decision matrix \hat{X}_p^{RI} for WPM:

$$\hat{x}_{ij}^{RI} = [[\bar{x}_{ij}^{-UAI}, \bar{x}_{ij}^{+UAI}]: [\bar{x}_{ij}^{-LAI}, \bar{x}_{ij}^{+LAI}]]^{W_j^{RI}} \tag{12}$$

$$i = 1, 2, \dots, m; \quad j = 0, 1, 2, \dots, n$$

Step 4: Calculate values of the optimality function

a. according to the RI WSM for each alternative:

$$\hat{x}_{ij}^{RI} = [[\bar{x}_{ij}^{-UAI}, \bar{x}_{ij}^{+UAI}]: [\bar{x}_{ij}^{-LAI}, \bar{x}_{ij}^{+LAI}]] \tag{13}$$

$$Q_i^{RI} = \sum_{j=1}^n \hat{x}_{ij}^{RI}, \quad i = 1, 2, \dots, m$$

b. according to the RI WPM for each alternative:

$$\hat{x}_{ij}^{RI} = [[\bar{x}_{ij}^{-UAI}, \bar{x}_{ij}^{+UAI}]: [\bar{x}_{ij}^{-LAI}, \bar{x}_{ij}^{+LAI}]]^{W_j^{RI}} \tag{14}$$

$$P_i^{RI} = \prod_{j=1}^n \hat{x}_{ij}^{RI}, \quad i = 1, 2, \dots, m$$

Step 5: Calculate the integrated utility function value of the RIWASPAS

For an alternative (i) the integrated utility function could be determined as follows:

$$K_i^{RI} = [K_i^{-UAI}, K_i^{+UAI}, K_i^{-LAI}, K_i^{+LAI}]$$

$$K_i^{RI} = \lambda \sum_{j=1}^n Q_i^{RI} + (1-\lambda) \prod_{j=1}^n P_i^{RI} \tag{15}$$

Coefficient (λ) can be crisp values in the range of [0,1] but it is recommended to apply Eq.(16) for its calculation

$$\lambda = \frac{\sum_{i=1}^m P_i^{RI}}{\sum_{i=1}^m Q_i^{RI} + \sum_{i=1}^m P_i^{RI}} \tag{16}$$

Step 6: Transform the RI values of K_i^{RI} into crisp values by the centroid method

$$K_i = \frac{1}{4} [K_i^{-UAI} + K_i^{+UAI} + K_i^{-LAI} + K_i^{+LAI}] \tag{17}$$

Step 7: Rank the alternatives, the best of them with maximum K_i value

4. NUMERICAL EXAMPLE

As shown below the numerical example is composed from five competing alternatives (A_1, A_2, A_3, A_4, A_5) and four criteria. C_2, C_3 and C_4 are the beneficial while C_1 is cost or non-beneficial type. The RI decision matrix presented in Table 1 is defined as in Eq. (8). Results and illustration are shown later in the rest of the section.

Table 1: Rough interval decision making matrix

Optimization	Criteria							
	Min		Max		Max		Max	
	C ₁		C ₂		C ₃		C ₄	
Alternatives	UAI	LAI	UAI	LAI	UAI	LAI	UAI	LAI
A ₁	[[200,250] : [220,240]]		[[585,620] : [600 ,610]]		[[690, 720] : [710 , 715]]		[[790,810] : [795 ,800]]	
A ₂	[[300,360]:[330,340]]		[[625 ,640] : [630,635]]		[[730, 760] : [740, 750]]		[[820, 850] : [830 ,840]]	
A ₃	[[400,450] : [430,445]]		[[300, 500] : [450,480]]		[[770, 785] : [775, 780]]		[[790 ,860] : [835 ,845]]	
A ₄	[[500 ,540]:[520,530]]		[[650 ,680] : [655, 670]]		[[600 ,700] : [650 ,680]]		[[865 ,885] : [870 ,880]]	
A ₅	[[550 ,580]:[560,570]]		[[500 ,690] : [590,680]]		[[775 ,790] : [780 , 785]]		[[785,895] : [850 ,890]]	

Results and Discussion

First, RIBWM method is applied to determine the weights of criteria. In this problem, C₂ and C₄ are selected as the best and the worst criteria, respectively. The rough interval Preferences of the best criterion over the less important

Criteria and other criteria over the worst criterion should be determined by integers as found in Tables 2 and 3, respectively. Weights are assigned to criteria by solving the Mathematical Model found in Eq. (7). Then, the final overall weights will be as shown in Table 4.

Table 2: Rough interval best-to-others (BO) vector

Criteria	C ₁	C ₂	C ₃	C ₄
	UAI : LAI	UAI : LAI	UAI : LAI	UAI : LAI
Best Criterion: C₂	[3,8]:[5,5]	[1,1]:[1,1]	[5,7]:[3,6]	[6,5]:[9,8]

Table 3: Rough interval others-to-worst (OW) vector

Criteria	C ₁	C ₂	C ₃	C ₄
	UAI : LAI	UAI : LAI	UAI : LAI	UAI : LAI
Worst criterion: C₄	[2,6]:[5,6]	[6,5]:[9,8]	[4,4]:[5,7]	[1,1]:[1,1]

Table 4: Weights allocated using RIBWM method

Criteria	W_j^{RI}
C ₁	[0.121926,0.232558]:[0.139024, 0.170984]
C ₂	[0.55814, 0.667009]:[0.578049, 0.634715]
C ₃	[0.139344,0.231707]:[0.139535,0.142487]
C ₄	[0.05122, 0.071721]:[0.051813, 0.069767]

Second, by applying the procedure of RIWASPAS method, we obtain the solution results for rough interval WSM and rough interval WPM for each alternative as in table 5 by applying Eqs. (9-14). Table 6 shows the Integrated utility function values of the RIWASPAS method by using Eqs. (15-16). After which, the Final rank of alternatives based on Eq. (17) as shown in Table 7.

Table 5: Solution results for rough interval WSM and rough interval WPM

Alternatives	Q_i^{RI}	P_i^{RI}
A ₁	[0.737663,1.107986]:[0.809968,0.932855]	[0.865372,0.914207]:[0.900948,0.904831]
A ₂	[0.748987, 1.064737]:[0.805359, 0.908684]	[0.854585,0.890012]:[0.867293,0.883982]
A ₃	[0.477886, 0.898776]:[0.637632, 0.743334]	[0.563427, 0.711633]:[0.683614,0.71058]
A ₄	[0.726275, 1.026596]:[0.780693, 0.890132]	[0.777509,0.842485]:[0.823233,0.837166]
A ₅	[0.628116, 1.055004]:[0.743332, 0.914142]	[0.726896,0.852355]:[0.790368,0.804373]

Table 6: Integrated utility function values of the RIWASPAS method

Alt.	$\lambda = [0.404514, 0.592495]:[0.476603, 0.528016]$		
	$\lambda \times Q_i^{RI}$	$(1 - \lambda) \times P_i^{RI}$	K_i^{RI}
A ₁	[0.298395,0.656476]:[0.386033,0.492562]	[0.352644,0.544397]:[0.425233,0.473587]	[0.651039,1.200873]:[0.811266,0.966148]
A ₂	[0.302976,0.630851]:[0.383836,0.479799]	[0.348248,0.529989]:[0.409349,0.462674]	[0.651224,1.16084]:[0.793185,0.942473]
A ₃	[0.193312,0.53252]:[0.303897,0.392492]	[0.229599,0.423767]:[0.322655,0.371916]	[0.422911,0.956288]:[0.626552,0.764408]
A ₄	[0.293789,0.608253]:[0.37208,0.470004]	[0.316839,0.501688]:[0.388553,0.438171]	[0.610628,1.109941]:[0.760633,0.908175]
A ₅	[0.254082,0.625085]:[0.354274,0.482681]	[0.296214,0.507565]:[0.373041,0.421007]	[0.550296,1.13265]:[0.727315,0.903688]

Table 7: Final rank of alternatives

	K_i	Rank
A ₁	0.907332	1
A ₂	0.88693	2
A ₃	0.69254	5
A ₄	0.847344	3
A ₅	0.828487	4

Then, the final rank of alternatives by applying the new RIWASPAS method is as follows: $A_1 > A_2 > A_4 > A_5 > A_3$. The highest value represents the best alternative, which in this case is alternative A₁, while the worst one is alternative A₃.

5. CONCLUSION

This paper proposed a novel combination rough interval MCDM approach for selecting a suitable alternative under rough interval. RIBWM and RIWASPAS are two novel methods employed together in the proposed method; the RIBWM was used to determine the weights of the attributes, while RIWASPAS was employed to rank the alternative. The proposed method is practical and efficient in rough interval domain. An illustrative example is given to show the results for testing the proposed approach.

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