The Effect of CoCoSo Method on the Ranks of Alternatives: A Case Study of Copper Electrical Wire Selection

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ABSTRACT

When using MCDM (Multi-Criteria Decision-Making) methods to rank alternatives, decision makers' opinions have a huge influence on the ranking results. The decision makers' opinions can vary depending on the chosen MCDM method, data normalization method, and weighting method. For some MCDM methods, during the application process, users also need to choose the value of a certain coefficient (called the user coefficient). Obviously, the value of the user coefficient depends on users' opinions, and of course, these opinions can affect the ranking of the alternatives. In this article, the effects of users' opinions on the ranks of the alternatives when using the CoCoSo (Combined Compromise Solution) method are investigated. Users' opinions (including the weighting criteria method and the user coefficient) are considered the input of the investigation process. Organizing the investigation of the effects of these two parameters on the ranks of alternatives was applied to the case of copper electrical wire selection. The results show that the users' opinions have little effect on the ranks of alternatives. This result confirms CoCoSo's outstanding advantage.

Keywords-MCDM; CoCoSo; weighting method; user coefficient; copper electrical wire

I. INTRODUCTION

Choosing the best option among many available alternatives is a goal that can be achieved with Multi-Criteria Decision-Making (MCDM) methods [1, 2], with more than 200 been proposed [3]. MCDM methods have been widely applied in various fields [4-7]. Choosing an MCDM method and the way of applying it can lead to different ranking results. When selecting an MCDM method, the user still has to choose a weighting method for the criteria and a data normalization method. These choices have a great influence on the ranking results [8-10]. On the other hand, in some MCDM methods, the user has to choose the value of one or several coefficients, which can also lead to different results. CoCoSo is one such method [11]. Many studies from different fields have applied this method for ranking alternatives [12-20]. Some studies compared the effectiveness of CoCoSo method with other MCDM methods. When used to rank alternatives of EDM (Electrical Discharge Machining), the CoCoSo method showed the same results with MABAC (Multi-Attributive Border Approximation area Comparison) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) [21]. When it was used to rank 15 options against the Covid 19 pandemic, the best alternative determined by the CoCoSo method also matched MOORA (Multiobjective Optimization On the basis of Ratio Analysis), COPRAS (COmplex PRroportional Assessment), and MARCOS (Measurement Alternatives and Ranking according to COmpromise Solution) [22]. In [23], six methods including CoCoSo, WPM (Weighted Product Method), WSM (Weighted Sum Method), PIV (Proximity Indexed Value), TOPSIS, and MABAC showed the same best material when they were used to rank materials to create automobile brake pads [23]. The CoCoSo method was also confirmed to be as effective as MABAC, MAIRCA (Multi Atributive Ideal-Real Com parative Analysis), EAMR (Evaluation by an Area-based Method of Ranking), and

TOPSIS in selecting the best alternative of hole turning process [24]. In [25], the CoCoSo method was also determined to be as effective as MABAC, MAIRCA, VIKOR (Vlsekriterijumska optimizacijaI KOmpromisno Resenje), and ROV (Range Of Value) in selecting the best milling plan and selecting the best environment in office [25].

Concluding, the CoCoSo method has been extensively used to rank alternatives in many different fields. The best alternatives determined when using the CoCoSo method is similar to the ones defined by other MCDM methods. This creates confidence in the CoCoSo method. However, when using the CoCoSo method, the user needs to choose the value of a coefficient (called the user coefficient). The meaning of this coefficient will be presented in detail below. As recommended by the inventors of this method, the value of that coefficient ranges from 0 to 1 [11]. But all the studies that have applied this method chose that coefficient to be 0.5. What will happen if that coefficient is chosen with a value other than 0.5 is a question that has not been answered before. Exploiting this gap to discover new arguments is the driving force behind this study.

As mentioned above, the results of ranking alternatives depend on the utilized data normalization and criteria weighting methods. For the CoCoSo method, the Weitendorf normalization has been determined to be suitable for use [26]. This data normalization method will also be used in this study. Investigating the effects of the criteria weighting method on the ranks of the alternatives is the second questions this study aims to answer.

II. THE COCOSO METHOD

The six steps to rank alternatives according to the CoCoSo method include [11]:

Step 1. Construct a matrix of *n* columns and *m* rows, where *n* is the number of criteria to evaluate an alternative and *m* is the number of alternatives to be ranked. The value of criterion *j* of alternative *i* is denoted by y_{ij} (Table I).

TABLE I. DECISION MATRIX

No.	C_1	C_2	C_j	C_n
A_1	y_{11}	y_{12}	y_{1j}	y_{1n}
A_2	y_{21}	y_{22}	y_{2j}	y_{2n}
A_i	y_{i1}	y_{i2}	y_{ij}	y_{in}
A_m	y_{m1}	y_{m2}	y_{mj}	y_{mn}

Step 2. If *j* is the larger the better criterion, (1) is used to normalize data and (2) will be used to normalize data if *j* is a the smaller the better criterion.

$$n_{ij} = \frac{y_{ij} - \min y_{ij}}{\max y_{ij} - \min y_{ij}} \quad (1)$$

$$n_{ij} = \frac{\max y_{ij} - y_{ij}}{\max y_{ij} - \min y_{ij}} \quad (2)$$

Step 3. Call w_j the weight of criterion *j*. Equations (3) and (4) are used to calculated the quantities S_i and P_i, that represent the sum and the product of the normalized values, respectively, considering the weights of the criteria.

$$S_i = \sum_{j=1}^{n} w_j . n_{ij} \quad (3)$$

$$P_i = \sum_{j=1}^{n} \left(n_{ij}\right)^{w_j} \quad (4)$$

Step 4. Equations (5), (6), and (7) are used respectively to calculate the quantities k_{ia}, k_{ib}, and k_{ic}:

$$k_{ia} = \frac{P_i + S_i}{\sum_{i=1}^{m}(P_i + S_i)} \quad (5)$$

$$k_{ib} = \frac{S_i}{\min S_i} + \frac{P_i}{\min P_i} \quad (6)$$

$$k_{ic} = \frac{\lambda . S_i + (1-\lambda) P_i}{\lambda . \max S_i + (1-\lambda) \max P_i}, 0 \le \lambda \le 1 \quad (7)$$

The difference of CoCoSo with other MCDM methods is that it integrates three different strategies for evaluating alternatives. The first strategy used in the CoCoSo is shown in (5). This formula calculates the average of the total scores of *WSM* and *WPM*. The second strategy is shown in (6). This formula calculates the relative total scores of WSM and WPM against the best score. The third strategy is presented in (7). This strategy shows the balance of WSM and WPM scores through the coefficient λ, called the user coefficient. This coefficient can be chosen according to the opinion of the decision maker, it has a value ranging from 0 to 1, and is usually chosen as 0.5 [11]. As mentioned above, all the studies that have applied this method chose the user coefficient to be 0.5. In this study, the change of the ranking of the alternatives when the user coefficient has different values will be investigated.

Step 5. The quantity k_i is calculated according to (8):

$$k_i = (k_{ia} . k_{ib} . k_{ic})^{1/3} + \frac{1}{3}(k_{iaa} + k_{ib} + k_{ic}) \quad (8)$$

Step 6. The ranks of the alternatives are arranged according to the descending order of quantity k_i.

III. WEIGHTING METHODS USED

Five methods were used to determine the weights of the criteria, namely the MEAN weight method, the ROC (Rank Order Centroid) weight method, the RS (Rank Sum) weight method, the MEREC (Method based on the Removal Effects of Criteria) weight method, and the ENTROPY weight method. The first three methods are used due to their simplicity [27, 28]. The other two methods were used because they are recommended [29]. Equations (9), (10) and (11) were used to calculate the criteria weights according to the MEAN, the ROC, and the RS weighting methods [27, 28]:

$$w_j = \frac{1}{n} \quad (9)$$

$$w_j = \frac{1}{n} \sum_{k}^{n} \frac{1}{k} \quad (10)$$

$$w_j = \frac{2\,(n+1-k)}{n(n+1)} \quad (11)$$

In (10) and (11), *k* represents the priority ranking of criterion *j*. Assuming there are *n*=9 criteria and criterion *j* has a priority ranking of *k*=3, then the weights of criterion *j* calculated by the ROC and RS methods are, respectively: (1/9)(1/3+1/4+1/5+1/6+1/7+1/8+1/9) = 0.1477 and 2(9+1-3)/(9(9+1)) = 0.1556.

Equations (12)-(17) were used to calculate the criteria weights according to the MEREC method [29]. The letter B in (12) represents the criteria that are the larger the better and the letter C in (13) represents the criteria that are the smaller the better.

$$n_{ij} = \frac{y_{ij}}{max\, y_{ij}} \text{ for criterion B} \quad (12)$$

$$n_{ij} = \frac{min\, y_{ij}}{y_{ij}} \text{ for criterion C} \quad (13)$$

$$S_i = Ln\left[1 + \left(\frac{1}{n}\sum_j^n \left|ln(n_{ij})\right|\right)\right] \quad (14)$$

$$S_i = Ln\left[1 + \left(\frac{1}{n}\sum_j^n \left|ln(n_{ij})\right|\right)\right] \quad (15)$$

$$E_j = \sum_i^m \left|S'_{ij} - S_i\right| \quad (16)$$

$$w_j = \frac{E_j}{\sum_{j=1}^n E_j} \quad (17)$$

Equations (18), (19), and (20) are used to calculate the criteria weights according to the ENTROPY method [25]:

$$n_{ij} = \frac{y_{ij}}{m + \sum_{i=1}^m y_{ij}^2} \quad (18)$$

$$e_j = \sum_{i=1}^m \left[n_{ij} \times \ln(n_{ij})\right] - \left(1 - \sum_{i=1}^m n_{ij}\right) \times \ln\left(1 - \sum_{i=1}^m n_{ij}\right) \quad (19)$$

$$w_j = \frac{1 - e_j}{\sum_{j=1}^n (1 - e_j)} \quad (20)$$

IV. SELECTION OF COPPER ELECTRICAL WIRE

Twenty-eight types of copper electrical wire recommended by a supplier on its website were used as alternatives that need ranking [30]. Each alternative is specified by nine criteria namely nominal cross-section, number of conductors, diameter of copper conductor, insulation thickness between copper conductors, sheath thickness, overall diameter, maximum direct current resistance of the conductor at 20 ^{0}C, weight, and price, which are denoted from *C1* to *C9*, respectively. Table II summarizes the data of 28 types of copper electrical wire. Note that the unit of *C9* is TVD/m, where TVD stands for Thousand Vietnamese Dong. The best values of the criteria are shown in Table II. Thus, it is clear that there is no alternative with best values in all the criteria. That shows the need for MCDM to select the best alternative among the 28 available. The weight values of the criteria calculated according to the considered methods are summarized in Table III. These values are obtained by applying the equations presented above.

The equations of Section II were applied to rank the alternatives according to each method, for different weights and for different values of the coefficient λ according to the CoCoSo method. Firstly, the weight set of the criteria is calculated using the MEAN method and the value of λ is set to 0.1. The results of the normalized data according to (1) and (2) are summarized in Table IV.

TABLE II. COPPER ELECTRICAL WIRE TYPES [26]

Alt.	CODE	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*
A1	20225103	1.00	20	0.18	0.6	0.8	5.4	39.00	0.0489	**7.201**
A2	20225106	1.50	30	0.18	0.6	0.8	6.3	26.00	0.0587	11.533
A3	20225107	2.00	40	0.18	0.6	0.8	6.6	19.50	0.0688	18.346
A4	20225108	2.00	32	0.20	0.6	0.8	6.6	19.50	0.0686	26.607
A5	20225110	3.00	48	0.20	0.7	0.8	7.6	13.20	0.0935	42.857
A6	20225111	3.00	30	0.25	0.7	0.8	7.6	13.30	0.0930	24.388
A7	20225114	5.00	50	0.25	0.8	1	9.3	**7.98**	0.1405	38.284
A8	20235103	1.50	20	0.18	0.6	0.8	6.2	39.00	0.0573	57.225
A9	20235106	2.25	30	0.18	0.6	0.8	6.7	26.00	0.0709	23.670
A10	20235107	3.00	40	0.18	0.6	0.8	7	19.50	0.0833	38.418
A11	20235108	3.00	32	0.20	0.6	0.8	7	19.50	0.0830	58.843
A12	20235110	4.50	48	0.20	0.7	0.9	8.3	13.30	0.1187	38.699
A13	20235111	4.50	30	**0.25**	0.7	0.9	8.3	13.30	0.1172	24.412
A14	20235114	7.50	**50**	**0.25**	**0.8**	1.1	10.1	**7.98**	0.1782	35.212
A15	20245103	2.00	20	0.18	0.6	0.8	6.7	39.00	0.0706	26.117
A16	20245106	3.00	30	0.18	0.6	0.8	7.2	26.00	0.0869	36.484
A17	20245107	4.00	40	0.18	0.6	0.9	7.9	19.50	0.1074	54.228
A18	20245108	4.00	32	0.20	0.6	0.9	7.9	19.50	0.1071	26.685
A19	20245110	6.00	48	0.20	0.7	1	9.3	13.30	0.1517	48.426
A20	20245111	6.00	30	0.25	0.7	1	9.3	13.30	0.1507	48.426
A21	20245114	10.00	**50**	0.25	**0.8**	1.1	10.9	**7.98**	0.2200	66.126
A22	20255103	2.50	20	0.18	0.6	0.9	7.7	39.00	0.0830	26.123
A23	20255106	3.75	30	0.18	0.6	0.9	8.2	26.00	0.1075	33.170
A24	20255107	5.00	40	0.18	0.6	0.9	8.9	19.50	0.1294	34.208
A25	20255108	5.00	32	0.20	0.6	0.9	8.9	19.50	0.1298	37.816
A26	20255110	7.50	48	0.20	0.7	1.1	9.7	13.30	0.1871	44.126
A27	20255111	7.50	30	0.25	0.7	1.1	9.7	13.30	0.1858	54.212
A28	20255114	**12.50**	**50**	**0.25**	**0.8**	**1.2**	**11**	13.30	**0.2724**	65.746
Unit		mm^2	-	mm	mm	mm	mm	Ohm/km	kg/m	TVD/m
Type		B	B	B	B	B	B	C	B	C

TABLE III. CRITERIA WEIGHTS

Weighting method	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*
MEAN	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111	0.1111
ROC	0.3143	0.2032	0.1477	0.1106	0.0828	0.0606	0.0421	0.0262	0.0123
RS	0.2000	0.1778	0.1556	0.1333	0.1111	0.0889	0.0667	0.0444	0.0222
MEREC	0.2746	0.1099	0.0243	0.0162	0.0229	0.0788	0.1587	0.1593	0.1553
ENTROPY	0.1089	0.0759	0.1183	0.1675	0.1739	0.1008	0.0804	0.0994	0.0749

TABLE IV. NORMALIZED VALUES

Alt.	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*
A1	0.09	0.40	0.29	0.00	0.00	0.21	0.63	0.09	0.67
A2	0.04	0.33	0.00	0.00	0.00	0.16	0.42	0.04	0.93
A3	0.09	0.67	0.00	0.00	0.00	0.21	0.63	0.09	0.81
A4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
A5	0.24	0.33	0.00	0.00	0.25	0.50	0.42	0.26	0.56
A6	0.17	0.33	1.00	0.50	0.00	0.39	0.83	0.20	0.71
A7	0.35	1.00	1.00	1.00	0.50	0.70	1.00	0.41	0.47
A8	0.04	0.00	0.00	0.00	0.00	0.14	0.00	0.04	0.15
A9	0.11	0.33	0.00	0.00	0.00	0.23	0.42	0.10	0.72
A10	0.57	0.33	1.00	0.50	0.75	0.77	0.83	0.61	0.20
A11	0.17	0.40	0.29	0.00	0.00	0.29	0.63	0.15	0.12
A12	0.30	0.93	0.29	0.50	0.25	0.52	0.83	0.31	0.47
A13	0.30	0.33	1.00	0.50	0.25	0.52	0.83	0.31	0.71
A14	0.57	1.00	1.00	1.00	0.75	0.84	1.00	0.58	0.52
A15	0.09	0.00	0.00	0.00	0.00	0.23	0.00	0.10	0.68
A16	1.00	1.00	1.00	1.00	1.00	1.00	0.83	1.00	0.01
A17	0.26	0.67	0.00	0.00	0.25	0.45	0.63	0.26	0.20
A18	0.26	0.40	0.29	0.00	0.25	0.45	0.63	0.26	0.67
A19	0.43	0.93	0.29	0.50	0.50	0.70	0.83	0.46	0.30
A20	0.43	0.33	1.00	0.50	0.50	0.70	0.83	0.46	0.30
A21	0.78	1.00	1.00	1.00	0.75	0.98	1.00	0.77	0.00
A22	0.13	0.00	0.00	0.00	0.25	0.41	0.00	0.15	0.68
A23	0.17	0.93	0.29	0.50	0.00	0.39	0.83	0.20	0.39
A24	0.35	0.67	0.00	0.00	0.25	0.63	0.63	0.36	0.54
A25	0.35	0.40	0.29	0.00	0.25	0.63	0.63	0.36	0.48
A26	0.57	0.93	0.29	0.50	0.75	0.77	0.83	0.62	0.37
A27	0.17	0.67	0.00	0.00	0.00	0.29	0.63	0.15	0.47
A28	0.17	0.33	0.00	0.00	0.00	0.32	0.42	0.17	0.50

The values of S_i, P_i, k_{ia}, k_{ib}, k_{ic}, and k_i for each alternative were calculated according to the (3), (4), (5), (6), (7), and (8) and the data are summarized in Table V. The last column of this table summarizes the ranking of the alternatives based on their k_i values. When the weights of the criteria were calculated according to the MEAN method, the ranking of the alternatives when λ equals 0.1 was completed. Similar calculations were performed for other values of λ and the results are summarized in Table VI.

According to the data in Table VI, when using the MEAN method to calculate the criteria weights, the ranks of the alternatives are very similar when changing the value of the λ. In particular, with the λ changing 9 times (from 0.1 to 0.9), 27 out of 28 alternatives have the same rank. Only alternative *A11* changes from rank 20 to rank 21. When λ is equal to 0.1, 0.2, 0.3, 0.4, and 0.5, *A11* ranks 20th, and when λ is equal to 0.6, 0.7, 0.8, and 0.9 *A11* ranks 21st. This indicates that the coefficient λ has very little influence on the ranks of the alternatives. Especially, λ does not have any effects on the best alternative (*A16*).

When the weights of the criteria were calculated according to the ROC, RS, MEREC, and ENTROPY methods, the ranking of the alternatives was similar to when they were calculated with the MEAN method, and the results are summarized in Tables VII, VIII, IX, and X.

From the data in Table VII, it can be seen that although the value of the coefficient λ changed nine times (from 0.1 to 0.9), the ranks of the alternatives are completely the same. This shows that the coefficient λ does not have any effect on the ranks of the alternatives. *A16* is again determined as the best alternative.

In Table VIII, we can see that the ranks of the alternatives are exactly the same for all the values of λ. Again, we can come to the conclusion that the user coefficient does not affect the ranking. *A16* is again determined to be the best alternative.

Observing the data in Table IX, we can see that the ranks of the alternatives change a little when the value of λ changes. Out of total of 28 alternatives, there are two rank swaps between *A4* and *A8*, and between *A18* and *A24*, which means that in this case the user coefficient has a little effect on the ranks of the alternatives, and *A16* is always determined to be the best alternative.

In Table X, there is no rank reversal, confirming that in this case the user coefficient does not affect the ranks. *A16* is again determined to be the best alternative.

TABLE V. PARAMETERS OF THE COCOSO METHOD AND RANKING OF THE ALTERNATIVES

Alt.	S_i	*Pi*	k_{ia}	k_{ib}	k_{ic}	k_i	rank
A1	0.264	6.048	0.033	12.380	0.686	5.019	18
A2	0.214	5.013	0.027	10.152	0.569	4.121	24
A3	0.277	5.252	0.029	11.910	0.596	4.767	19
A4	0.111	1.000	0.006	3.667	0.1143	1.3965	28
A5	0.285	6.228	0.034	13.064	0.7068	5.2795	17
A6	0.459	7.312	0.040	18.338	0.8314	7.2533	11
A7	0.714	8.601	0.048	25.740	0.9802	9.9910	4
A8	0.042	3.016	0.016	4.016	0.3411	1.7368	27
A9	0.212	5.162	0.028	10.261	0.5855	4.1760	23
A10	0.618	8.453	0.047	23.279	0.9622	9.1136	6
A11	0.228	6.021	0.032	11.488	0.6827	4.7010	20
A12	0.489	8.228	0.045	19.955	0.9351	7.9233	10
A13	0.528	8.292	0.046	20.953	0.9429	8.2806	9
A14	0.806	8.760	0.050	28.115	0.9992	10.8380	2
A15	0.122	3.342	0.018	6.263	0.3789	2.5692	26
A16	0.871	8.550	0.049	29.445	0.9764	11.2764	1
A17	0.302	6.237	0.034	13.481	0.7081	5.4276	16
A18	0.356	7.173	0.039	15.711	0.8144	6.3149	14
A19	0.549	8.358	0.046	21.530	0.9506	8.4901	8
A20	0.561	8.380	0.046	21.844	0.9532	8.6028	7
A21	0.809	7.910	0.045	27.326	0.9033	10.4620	3
A22	0.180	4.330	0.023	8.657	0.4912	3.5205	25
A23	0.412	7.231	0.040	17.130	0.8216	6.8202	12
A24	0.380	6.428	0.035	15.549	0.7306	6.1756	15
A25	0.376	7.234	0.039	16.246	0.8215	6.5099	13
A26	0.625	8.490	0.047	23.484	0.9665	9.1895	5
A27	0.264	5.331	0.029	11.676	0.6052	4.6929	21
A28	0.213	5.246	0.028	10.368	0.5950	4.2227	22

TABLE VI. ALTERNATIVE RANKING RESULT WHEN THE WEIGHTS ARE DETERMINED BY THE MEAN METHOD

Alt.	λ								
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
A1	18	18	18	18	18	18	18	18	18
A2	24	24	24	24	24	24	24	24	24
A3	19	19	19	19	19	19	19	19	19
A4	28	28	28	28	28	28	28	28	28
A5	17	17	17	17	17	17	17	17	17
A6	11	11	11	11	11	11	11	11	11
A7	4	4	4	4	4	4	4	4	4
A8	27	27	27	27	27	27	27	27	27
A9	23	23	23	23	23	23	23	23	23
A10	6	6	6	6	6	6	6	6	6
A11	20	20	20	20	20	21	21	21	21
A12	10	10	10	10	10	10	10	10	10
A13	9	9	9	9	9	9	9	9	9
A14	2	2	2	2	2	2	2	2	2
A15	26	26	26	26	26	26	26	26	26
A16	1	1	1	1	1	1	1	1	1
A17	16	16	16	16	16	16	16	16	16
A18	14	14	14	14	14	14	14	14	14
A19	8	8	8	8	8	8	8	9	8
A20	7	7	7	7	7	7	7	7	7
A21	3	3	3	3	3	3	3	3	3
A22	25	25	25	25	25	25	25	25	25
A23	12	12	12	12	12	12	12	12	12
A24	15	15	15	15	15	15	15	15	15
A25	13	13	13	13	13	13	13	13	13
A26	5	5	5	5	5	5	5	5	5
A27	21	21	21	21	21	20	20	20	20
A28	22	22	22	22	22	22	22	22	22

TABLE VII. ALTERNATIVE RANKING RESULT WHEN THE WEIGHTS ARE DETERMINED BY THE ROC METHOD

Alt.	λ								
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
A1	21	21	21	21	21	21	21	21	21
A2	24	24	24	24	24	24	24	24	24
A3	20	20	20	20	20	20	20	20	20
A4	28	28	28	28	28	28	28	28	28
A5	18	18	18	18	18	18	18	18	18
A6	12	12	12	12	12	12	12	12	12
A7	4	4	4	4	4	4	4	4	4
A8	27	27	27	27	27	27	27	27	27
A9	23	23	23	23	23	23	23	23	23
A10	6	6	6	6	6	6	6	6	6
A11	19	19	19	19	19	19	19	19	19
A12	9	9	9	9	9	9	9	9	9
A13	10	10	10	10	10	10	10	10	10
A14	3	3	3	3	3	3	3	3	3
A15	26	26	26	26	26	26	26	26	26
A16	1	1	1	1	1	1	1	1	1
A17	16	16	16	16	16	16	16	16	16
A18	15	15	15	15	15	15	15	15	15
A19	7	7	7	7	7	7	7	7	7
A20	8	8	8	8	8	8	8	8	8
A21	2	2	2	2	2	2	2	2	2
A22	25	25	25	25	25	25	25	25	25
A23	11	11	11	11	11	11	11	11	11
A24	13	13	13	13	13	13	13	13	13
A25	14	14	14	14	14	14	14	14	14
A26	5	5	5	5	5	5	5	5	5
A27	17	17	17	17	17	17	17	17	17
A28	22	22	22	22	22	22	22	22	22

TABLE VIII. ALTERNATIVE RANKING RESULT WHEN THE WEIGHTS ARE DETERMINED BY THE RS METHOD

Alt.	λ								
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
A1	20	20	20	20	20	20	20	20	20
A2	24	24	24	24	24	24	24	24	24
A3	21	21	21	21	21	21	21	21	21
A4	28	28	28	28	28	28	28	28	28
A5	17	17	17	17	17	17	17	17	17
A6	11	11	11	11	11	11	11	11	11
A7	4	4	4	4	4	4	4	4	4
A8	27	27	27	27	27	27	27	27	27
A9	23	23	23	23	23	23	23	23	23
A10	5	5	5	5	5	5	5	5	5
A11	18	18	18	18	18	18	18	18	18
A12	10	10	10	10	10	10	10	10	10
A13	9	9	9	9	9	9	9	9	9
A14	3	3	3	3	3	3	3	3	3
A15	26	26	26	26	26	26	26	26	26
A16	1	1	1	1	1	1	1	1	1
A17	16	16	16	16	16	16	16	16	16
A18	15	15	15	15	15	15	15	15	15
A19	8	8	8	8	8	8	8	8	8
A20	7	7	7	7	7	7	7	7	7
A21	2	2	2	2	2	2	2	2	2
A22	25	25	25	25	25	25	25	25	25
A23	12	12	12	12	12	12	12	12	12
A24	14	14	14	14	14	14	14	14	14
A25	13	13	13	13	13	13	13	13	13
A26	6	6	6	6	6	6	6	6	6
A27	19	19	19	19	19	19	19	19	19
A28	22	22	22	22	22	22	22	22	22

TABLE I. ALTERNATIVE RANKING RESULT WHEN THE WEIGHTS ARE DETERMINED BY THE MEREC METHOD

Alt.	λ								
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
A1	18	18	18	18	18	18	18	18	18
A2	24	24	24	24	24	24	24	24	24
A3	19	19	19	19	19	19	19	19	19
A4	28	28	28	28	28	28	28	28	27
A5	17	17	17	17	17	17	17	17	17
A6	13	13	13	13	13	13	13	13	13
A7	5	5	5	5	5	5	5	5	5
A8	27	27	27	27	27	27	27	27	28
A9	23	23	23	23	23	23	23	23	23
A10	6	6	6	6	6	6	6	6	6
A11	21	21	21	21	21	21	21	21	21
A12	9	9	9	9	9	9	9	9	9
A13	10	10	10	10	10	10	10	10	10
A14	2	2	2	2	2	2	2	2	2
A15	26	26	26	26	26	26	26	26	26
A16	1	1	1	1	1	1	1	1	1
A17	16	16	16	16	16	16	16	16	16
A18	14	14	14	15	15	15	15	15	15
A19	7	7	7	7	7	7	7	7	7
A20	8	8	8	8	8	8	8	8	8
A21	3	3	3	3	3	3	3	3	3
A22	25	25	25	25	25	25	25	25	25
A23	12	12	12	12	12	12	12	12	12
A24	15	15	15	14	14	14	14	14	14
A25	11	11	11	11	11	11	11	11	11
A26	4	4	4	4	4	4	4	4	4
A27	20	20	20	20	20	20	20	20	20
A28	22	22	22	22	22	22	22	22	22

TABLE I. ALTERNATIVE RANKING RESULT WHEN THE WEIGHTS ARE DETERMINED BY THE ENTROPY METHOD

Alt.	λ								
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
A1	18	18	18	18	18	18	18	18	18
A2	24	24	24	24	24	24	24	24	24
A3	21	21	21	21	21	21	21	21	21
A4	28	28	28	28	28	28	28	28	28
A5	17	17	17	17	17	17	17	17	17
A6	11	11	11	11	11	11	11	11	11
A7	4	4	4	4	4	4	4	4	4
A8	27	27	27	27	27	27	27	27	27
A9	23	23	23	23	23	23	23	23	23
A10	5	5	5	5	5	5	5	5	5
A11	19	19	19	19	19	19	19	19	19
A12	10	10	10	10	10	10	10	10	10
A13	9	9	9	9	9	9	9	9	9
A14	2	2	2	2	2	2	2	2	2
A15	26	26	26	26	26	26	26	26	26
A16	1	1	1	1	1	1	1	1	1
A17	16	16	16	16	16	16	16	16	16
A18	14	14	14	14	14	14	14	14	14
A19	8	8	8	8	8	8	8	8	8
A20	7	7	7	7	7	7	7	7	7
A21	3	3	3	3	3	3	3	3	3
A22	25	25	25	25	25	25	25	25	25
A23	12	12	12	12	12	12	12	12	12
A24	15	15	15	15	15	15	15	15	15
A25	13	13	13	13	13	13	13	13	13
A26	6	6	6	6	6	6	6	6	6
A27	20	20	20	20	20	20	20	20	20
A28	22	22	22	22	22	22	22	22	22

The results of ranking copper electrical wires with changing user coefficient and changing the weighting method are summarized in Figure 1. In this Figure, symbols Mean0.1, Mean0.2, Mean0.3, etc. represent the results of alternative ranking when the user coefficient is equal to 0.1, 0.2, 0.3, etc. and the weighting method is the MEAN. Similarly, symbols ROC0.1, ROC0.2, ROC0.3, etc. represent the results of ranking the alternatives when the user coefficient is 0.1, 0.2, 0.3, etc. for the ROC weighting method. The symbols are made in the same form for the other weighting methods (RS, MEREC, ENTROPY).

Observing the chart in Figure 1, it can again be seen that the ranks of the alternatives barely change when the weights of the criteria change. The ranks of the alternatives also change just a little when changing the value of user coefficient, while in all the investigated cases, A16 is always determined to be the best alternative. This shows that the weighting method and the user coefficient have very little effect on the ranking results. This is considered an outstanding advantage of the CoCoSo method compared to other MCDM methods.

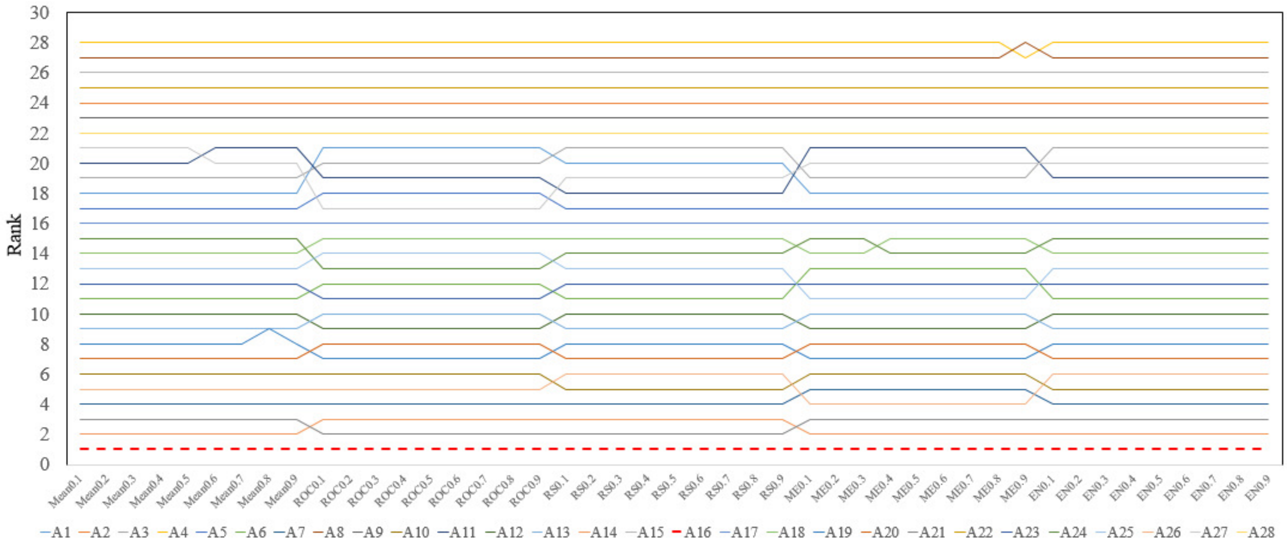

Fig. 1. Ranking results for all the investigated cases.

V. CONCLUSIONS

In this study, the impact of decision-maker's perspective on the ranking of alternatives when using the CoCoSo method was investigated. Two aspects related to the decision-maker's perspective were considered: the decision-maker's coefficient (λ) and the method for determining criteria weights. A survey was conducted to rank 28 types of copper electrical wires. The main conclusions drawn from this study are:

- The decision-maker's coefficient and the method for determining criteria weights had very little impact on the ranking of the alternatives. In particular, the best alternative was independent of the value of the decision-maker's coefficient and the method for determining criteria weights. This result further reinforces the advantage of the CoCoSo method, which evaluates alternatives based on three different strategies [11]. This finding is significant in alleviating user concerns regarding the method for calculating criteria weights or specifying the value of the coefficient λ when using the CoCoSo method to rank alternatives.
- Among the 28 types of electrical wire considered, the wire corresponding to alternative *A16* was the best (corresponding to product code 20245106) in each considered case.
- In the future, it is necessary to investigate the impact of the coefficient λ on the ranking of alternatives when the decision matrix contains fuzzy numbers to gain a deeper understanding of this aspect, which was not considered in the current study.

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