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Multiple-Criteria Framework for Cloud Service Selection

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Abstract—**This paper proposes the Multiple-Criteria Decision-Making (MCDM) framework as an aid for the evaluation of the cloud services and selection of an appropriate one regarding the given conditions. The proposed framework is based on the recently proposed *MEthod based on the Removal Effects of Criteria – MEREC* and *The Simple Weighted Sum Product – WISP* method. The MEREC method is used for defining the criteria weights and it represents the objective type of weighting method. The WISP method is used for the final evaluation and ranking of the considered alternatives. The applicability of the proposed framework is demonstrated by using the numerical example borrowed from the literature. Four alternatives are assessed regarding the four evaluation criteria. The final results are adequate and confirm the applicability of the proposed framework.**

Keywords – MCDM, MEREC method, WISP method, cloud service selection.

I. INTRODUCTION

Existence of the cloud services, that can very easily replace the IT infrastructure within an organization, has influenced the understanding in which way the computing resources could be solicited. Cloud Service Providers (CSPs) gain an important role because the organizations leave it to them to handle their computer resources, while the organizations can freely perform their crucial business activities [1].

CSPs offer various types of services to their customers, to mention some of them: IaaS, PaaS, and SaaS. The number of different types of cloud services is constantly increasing which makes it more difficult to make a decision about the selection of the appropriate one [2]. The main task for an organization is to select the optimal service from the appropriate cloud provider at the right period [3]. The mentioned leads to the conclusion that the various criteria impact the final decision. Making the decision about cloud service regarding one or smaller number of criteria is not appropriate approach for an organization. In order to elicit the best possible solution, it is necessary to involve all of the influential criteria important for succeeding in the optimal decision. For that matter, the application of the Multiple-Criteria Decision-Making methods represents an appropriate way to incorporate all the evaluation criteria into the decision-making process.

MCDM is a scientific field which is developing very fast in recent years, and gained significant popularity among scientists. Until now, many different MCDM approaches are proposed for the resolving of different types of problems [4]–[10]. These techniques are used as a decision-making aid in the field of information and communication technologies as well [11]–[17].

In this paper, the MCDM framework based on the *MEthod based on the Removal Effects of Criteria – MEREC* [18] and *The Simple Weighted Sum Product – WISP* [19] is proposed. The MEREC method will be used for defining of the criteria weights, while the WISP method will be applied for the final ranking of the considered alternatives. These two methods are relatively novel and their potential is not completely tested yet. The applicability of this framework will be shown by using numerical example retrieved from the literature [2]. The main aim of this paper is to demonstrate the usefulness of the proposed framework for the application in the field of cloud service selection and not only that, but the all-necessary computer resources. With that goal the paper is organized as follows: in the second section the proposed framework is explained; the third section contains the numerical example which is followed by the conclusion.

II. THE PROPOSED FRAMEWORK

A. The MEREC Method

Defining the criteria weights represents a very important part of the application of any multiple-criteria decision-making method. In this case, the recently proposed MEREC method is used [18]. The MEREC method represents the objective weighting method which the computational procedure relies on the input data presented in a decision matrix. Opposite to the other methods, in the process of defining the criteria weights, this method applies the removal effect of each criterion on the aggregate performance of alternatives. If the removal of the criterion causes greater effects on alternatives` aggregate performances, than the criterion has greater importance, which leads to the conclusion that this method is based on the concept of causality. Also, the MEREC method is very flexible because, decision-makers could use different functions to calculate the performance. In this case, the simple logarithmic measure is used for the calculation of the alternatives` performances, while the absolute deviation measure is applied for defining the effects of removing each criterion. Because the MEREC method is relatively novel, until now it is mentioned in a few studies [20-22].

The computational procedure of the MEREC method could be presented by the following series of steps [18].

Step 1. Form a decision matrix. The decision matrix should contain the values of each alternative relative to each criterion. If we have n alternatives and m criteria, the form of the decision matrix will be as follows:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1j} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2j} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & x_{i2} & \dots & x_{ij} & \cdots & x_{im} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \dots & x_{nj} & \cdots & x_{nm} \end{bmatrix} \quad (1)$$

where x_{ij} denotes the elements of the decision matrix i.e. performance or rating of alternative i in relation to criterion j ($x_{ij} > 0$).

Step 2. Normalize the decision matrix. The normalized ratings are calculated in the following way:

$$n_{ij}^{x} = \begin{cases} \dfrac{\min_k x_{kj}}{x_{ij}} \, if \quad j \in B \\ \dfrac{x_{ij}}{\max_k x_{kj}} \, if \quad j \in C \end{cases}, \quad (2)$$

where n_{ij}^{x} represents elements of the normalized matrix N, B depicts the set of benefit criteria, and C shows the set of cost criteria.

Step 3. Calculate the overall performance of the alternatives. This is achieved by using (3):

$$S_i = \ln\left(1 + \left(\frac{1}{m}\sum{}_j \left|\ln(n_{ik}^{x})\right| ij\right)\right), \quad (3)$$

where S_i represents the overall performance of the alternatives.

Step 4. Calculate the alternatives` performances by removing each criterion. In this step, the performances of the alternatives are computed based on removing each criterion individually. The equation looks as follows:

$$S_{ij} = \ln\left(1 + \left(\frac{1}{m}\sum{}_j \left|\ln(n_{ik}^{x}\right| ij\right)\right), \quad (4)$$

where S'_{ij} denotes the overall performance of alternative i regarding the removal of criterion j.

Step 5. Calculate the summation of the absolute deviations. The removal effect of the criterion j is calculated by using (5):

$$E_j = \sum{}_i \left|S'_{ij} - S_i\right|, \quad (5)$$

where E_j represents the effect of removing criterion j.

Step 6. Define the overall criteria weights. The final value of the criteria weights is calculated as follows:

$$W_j = \frac{E_j}{\sum_k E_k}, \quad (6)$$

where w_j represents the weight of the criterion j.

B. The WISP Method

The WISP method is proposed by Stanujkic, Popovic, Karabasevic, Meidute-Kavaliauskiene, and Ulutaş [19]. To define a final utility of an alternative, the WISP method incorporates four relationships between benefit and cost criteria. Until now, there is no evidence of application of the WISP method because it has been proposed very recently.

The calculation procedure of this method could be represented by using the following series of steps.

Step 1. Form a normalized decision matrix. The normalized ratings are computed in the following way:

$$r_{ij} = \frac{x_{ij}}{\max_i x_{ij}}, \tag{7}$$

where r_{ij} denotes a dimensionless number that represents a normalized rating of alternative *i* regarding the criterion *j*.

Step 2. Compute the values of four utility measures, by using the following Eqs.:

$$u_i^{wsd} = \sum_{j\in\Omega_{\max}} r_{ij} w_j - \sum_{j\in\Omega_{\min}} r_{ij} w_j, \tag{8}$$

$$u_i^{wpd} = \prod_{j\Omega_{\max}} r_{ij} w_j - \prod_{j\Omega_{\min}} r_{ij} w_j, \tag{9}$$

$$u_i^{wsr} = \frac{\sum_{j\in\Omega_{\max}} r_{ij} w_j}{\sum_{j\in\Omega_{\min}} r_{ij} w_j}, \tag{10}$$

$$u_i^{wpr} = \frac{\prod_{j\in\Omega_{\max}} r_{ij} w_j}{\prod_{j\in\Omega_{\min}} r_{ij} w_j}, \tag{11}$$

where: u_i^{wsd} and u_i^{wpd} represent differences between the weighted sum and weighted product of normalized ratings of alternative *i*, respectively. Analogous to the previous one, u_i^{wsr} and u_i^{wpr} remarks ratios between weighted sum and weighted product of normalized ratings of alternative *i*, respectively.

Step 3. Recalculate values of four utility measures, in the following way:

$$\bar{u}_i^{wsd} = \frac{1+u_i^{wsd}}{\left(1+u_{\max_i}^{wsd}\right)}, \tag{12}$$

$$\bar{u}_i^{wsd} = \frac{1+u_i^{wpd}}{\left(1+u_{\max_i}^{wpd}\right)}, \tag{13}$$

$$\bar{u}_i^{wsd} = \frac{1+u_i^{wsr}}{\left(1+u_{\max_i}^{wsr}\right)}, \tag{14}$$

$$\bar{u}_i^{wpr} = \frac{1+u_i^{wpr}}{\left(1+u_{\max_i}^{wpr}\right)}, \tag{15}$$

where: $\bar{u}_i^{wsd}$, $\bar{u}_i^{wpd}$ $\bar{u}_i^{wsr}$ and $\bar{u}_i^{wpr}$ represents recalculated values of u_i^{sd}, u_i^{pd}, u_i^{sr} and u_i^{pr}.

Step 4. Define the overall utility u_i of each alternative by using (16):

$$u_i = \frac{1}{4}\left(\bar{u}_i^{wsd} + \bar{u}_i^{wpd} + \bar{u}_i^{wsr} + \bar{u}_i^{wpr}\right). \tag{16}$$

Step 5. Rank the alternatives and select the most appropriate one. The ranking of alternatives is performed in descending order. The alternative with the highest value of u_i is the best one.

III. NUMERICAL EXAMPLE

The applicability of the proposed model is demonstrated over a numerical example regarding the selection of a suitable cloud service. This example is retrieved from the paper of Nawaz, Asadabadi, Janjua, Hussain, Chang, and Saberi [2]. Four alternative cloud services are evaluated against four criteria. The used criteria are as follows:

- Central processing unit (CPU) represents the main part of any digital computer system, which is generally constituted of the main memory, control unit, and arithmetic-logic unit.
- Memory refers to a possibility to acquire, store, retain, and later restore information.
- Input/output (I/O) is the communication between an information processing system, such as a computer, and the environment, such as a human user or another information processing system.
- Cost means the price which the user or client pays to the CSPs for using the services that they provide.

TABLE I. INPUT DATA.

		C_1	C_2	C_3	C_4
unit		***CPU***	***Memory***	***I/O***	***Cost***
measure		***ms***	***ms***	***ms***	***$***
optimization		***max***	***max***	***max***	***min***
A_1	OP_1	2056.19	1455.72	1035.82	0.09
A_2	OP_2	80.77	81.94	260.42	0.02
A_3	OP_3	860.15	126.66	722.40	0.03
A_4	OP_4	2200.70	532.28	4187.19	0.07

Information about the considered alternatives and evaluation criteria are presented in Table I.

First, for defining the weights of criteria the MEREC method is applied. By using Eq. (2) decision-maker calculated normalized performance ratings which are presented in Table II.

Further, it is necessary to obtain the overall performances of alternatives. This is achieved by using (3). The calculated values are presented in Table III.

Table IV shows the overall performances of alternatives gained by removing each criterion (S'_{ij}).

Calculation of the removal effect of each criterion on the alternatives` overall performance is defined by using (5). The obtained results are presented in Table V.

Finally, the weights of criteria are obtained by applying (6) and they are as in Table VI.

TABLE II. THE NORMALIZED DECISION MATRIX.

	C_1	C_2	C_3	C_4
A_1	0.0393	0.0563	0.2514	1.0000
A_2	1.0000	1.0000	1.0000	0.2260
A_3	0.0939	0.6469	0.3605	0.3051
A_4	0.0367	0.1539	0.0622	0.7345

TABLE III. THE OVERALL PERFORMANCES OF ALTERNATIVES.

	S_i
A_1	1.06
A_2	0.32
A_3	0.81
A_4	1.12

TABLE IV. S'_{ij} VALUES.

	C_1	C_2	C_3	C_4
A_1	0.72	0.77	0.93	1.06
A_2	0.32	0.32	0.32	0.00
A_3	0.51	0.76	0.69	0.67
A_4	0.81	0.95	0.86	1.09

TABLE V. E_j VALUES.

	E_j
C_1	0.97
C_2	2.35
C_3	1.23
C_4	0.96

TABLE VI. THE CRITERIA WEIGHTS.

	w_j
C_1	0.18
C_2	0.43
C_3	0.22
C_4	0.17

As Table VI shows, the most significant criterion is C_2 – *Memory*, while the least important is criterion C_4 – *Price*. It should be remarked again that the obtain weights are objective because the computational procedure is based on the input data and not on the standpoint of a decision-maker.

After defining the criteria weights, the final ranking order of the considered alternatives will be determined by using the WISP method.

Recalculated values of four utility measures are computed by using (12) – (15), and they are shown in Table VII.

TABLE VII. RECALCULATED VALUES OF FOUR UTILITY MEASURES.

	$\bar{u}_i^{wsd}$	$\bar{u}_i^{wpd}$	$\bar{u}_i^{wsr}$	$\bar{u}_i^{wsd}$
A_1	0.33	-0.17	0.70	0.02
A_2	0.00	-0.04	0.21	0.00
A_3	0.06	-0.05	0.51	0.00
A_4	0.29	-0.12	0.82	0.05

TABLE VIII. FINAL RANKING ODRDER OF THE ALTERNATIVES.

	u_i	*Rank*
A_1	0.219	2
A_2	0.044	4
A_3	0.131	3
A_4	0.258	1

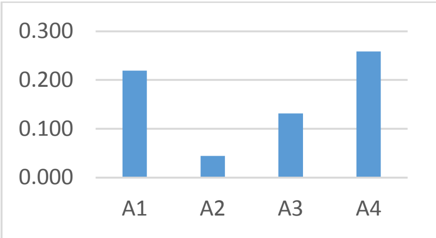

Figure 1. The ranking order of the alternative cloud services.

By using (16) the final ranking order of the alternative cloud services is calculated. The rank of the alternatives submitted under the evaluation is presented in Table VIII.

As can be seen, the most suitable alternative is $A_4 – OP_4$, while the worst-ranked is alternative $A_2 – OP_2$. The obtained results are presented graphically, as well (Fig. 1).

IV. CONCLUSION

The MCDM framework for the evaluation and selection of the optimal cloud service is proposed in this paper. The mentioned framework relies on the MEREC method, which is used for defining the criteria weights, and the WISP method, which is applied for the final ranking and selection of the optimal alternative cloud service. The numerical example is borrowed from the literature [2], because the main intention is to demonstrate the usefulness of this framework based on the two newly introduced MCDM methods. The final results confirm the adequacy of this novel approach which is supported by the fact that the obtained ranking order of the alternatives matches with that one gained by the other authors [2].

The main limitation of the paper is the involvement of only one decision-maker in the evaluation process. Also, the numerical example is based on the crisp numbers that lead to the neglecting of the vagueness and uncertainty of the environment. Additionally, the results would be more representative o the greater number of criteria is introduced into decision procedure.

The propositions for future research are directed to the introduction of the adequate extensions of these methods by involving the grey, fuzzy or neutrosophic numbers. Also, it is desirable to perform the decision-making process under the group decision environment. Besides, it would be very interesting to define objective-subjective weights of criteria by introducing some of the subjective weighting methods. But, after all, the proposed framework demonstrated its potential which should be verified in the other business fields, as well.

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