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Short Note

A simple modification to the EDAS method for two exceptional cases

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Abstract: Multi-criteria decision-making (MCDM) methods and techniques have been applied to many real-world problems in different fields of engineering science and technology. The evaluation based on distance from average solution (EDAS) method is a new and efficient MCDM method. The aim of this study is to propose a modification to address two exceptional cases in which the EDAS method fails to solve an MCDM problem.

Keywords: multi-criteria decision-making; MCDM; MADM; EDAS method

1. Introduction

In decision-making problems, we are usually confronted with some alternatives which need to be evaluated with respect to multiple criteria. Multi-criteria decision-making (MCDM) methods and techniques are very useful to handle such problems [1,2]. Many MCDM methods and techniques have been proposed by researchers during the past decades such as analytic hierarchy process (AHP), analytic network process (ANP), complex proportional assessment (COPRAS), data envelopment analysis (DEA), ELECTRE (stands for: ELimination Et Choix Traduisant la REalité), multi-objective optimization by ratio analysis (MOORA), preference ranking organization method for enrichment of evaluations (PROMETHEE), technique for order of preference by similarity to ideal solution (TOPSIS) and VIKOR (stands for: VlseKriterijumska Optimizacija I Kompromisno Resenje). Interested readers are referred to some recent review paper in this field [3-8].

The EDAS method is a new and efficient method proposed by Keshavarz Ghorabaee, *et al.* [9]. The process of evaluation in this method is based on positive and negative distances from an average solution. An alternative which has higher values of positive distances and lower values of negative distances from the average solution is a more desirable alternative according this method. This method has been extended to deal with MCDM problems under uncertainty [10-15]. Also it has been applied to some real-world problems [16-25].

In this study, a modification is made to the EDAS method to improve its efficiency for handling MCDM problems. First, two exceptional cases in which the EDAS method fails to give a correct solution are considered, and then it is shown that the modification enables the EDAS method to give a correct solution. In Section 2, the steps of the EDAS method are presented. Then two exceptional cases are explained in Section 3. A modification is proposed in Section 4, and the results are analyzed in this section. Finally conclusions are discussed in Section 4.

2. The EDAS method

Suppose that we have n alternatives ($\mathcal{A}_1$ to $\mathcal{A}_n$) and m criteria ($\mathcal{C}_1$ to $\mathcal{C}_m$), and the weight of each criterion ($w_j,\ j \in \{1,2,\dots,m\}$) is known. The steps of the EDAS method for evaluation of the alternatives with respect to the criteria are as follows:

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Step 1. Construction of decision-matrix:

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

Step 2. Calculation of the elements of average solution ($\mathcal{g}_j$):

$$\mathcal{g}_j = \frac{\sum_{i=1}^{n} x_{ij}}{n} \tag{2}$$

Step 3. Determination of the positive ($\mathcal{P}_{ij}^d$) and negative ($\mathcal{N}_{ij}^d$) distances:

$$\mathcal{P}_{ij}^d = \begin{cases} \dfrac{max\left(0, x_{ij} - \mathcal{g}_j\right)}{\mathcal{g}_j} & if\ j \in B \\ \dfrac{max\left(0, \mathcal{g}_j - x_{ij}\right)}{\mathcal{g}_j} & if\ j \in C \end{cases} \tag{3}$$

$$\mathcal{N}_{ij}^d = \begin{cases} \dfrac{max\left(0, \mathcal{g}_j - x_{ij}\right)}{\mathcal{g}_j} & if\ j \in B \\ \dfrac{max\left(0, x_{ij} - \mathcal{g}_j\right)}{\mathcal{g}_j} & if\ j \in C \end{cases} \tag{4}$$

where B and C are the sets of benefit and cost criteria, respectively.

Step 4. Computation of the weighted summation of the distances:

$$\mathcal{P}_i^w = \sum_{j=1}^{m} w_j \mathcal{P}_{ij}^d \tag{5}$$

$$\mathcal{N}_i^w = \sum_{j=1}^{m} w_j \mathcal{N}_{ij}^d \tag{6}$$

Step 5. Normalization of the values of the weighted summations:

$$\mathcal{P}_i^n = \frac{\mathcal{P}_i^w}{\max\limits_k \mathcal{P}_k^w} \tag{7}$$

$$\mathcal{N}_i^n = 1 - \frac{\mathcal{N}_i^w}{\max\limits_k \mathcal{N}_k^w} \tag{8}$$

Step 6. Calculation of the appraisal score of each alternative:

$$\mathcal{S}_i = \frac{1}{2}\left(\mathcal{P}_i^n + \mathcal{N}_i^n\right) \tag{9}$$

Step 7. Rank the alternatives according to decreasing values of $\mathcal{S}_i$.

3. Exceptional cases

In this section, two exceptional cases are described using two examples. In these cases the EDAS method is not capable of giving a correct solution.

3.1. Negative elements in the average solution

If the elements of the average solution have negative values, the EDAS method can result in incorrect solution or no solution.

- Example A:

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Suppose that we have a problem with two alternatives ($\mathcal{A}_1$ and $\mathcal{A}_2$) and two criteria ($\mathcal{C}_1 \in B$ and $\mathcal{C}_2 \in C$) with the following decision matrix.

$$X = \begin{bmatrix} -1 & -4 \\ -3 & -2 \end{bmatrix}$$

According to this decision matrix and the type of the criteria, it's obvious that $\mathcal{A}_1 \succ \mathcal{A}_2$. However, if we use the EDAS method, the elements of the average solution is $\mathcal{g}_1 = -2$ and $\mathcal{g}_2 = -3$, and the positive and negative distances are as follows:

$$\mathcal{P}_{11}^d = \frac{max(0, -1 - (-2))}{-2} = -\frac{1}{2}$$

$$\mathcal{P}_{12}^d = \frac{max(0, -3 - (-4))}{-3} = -\frac{1}{3}$$

$$\mathcal{P}_{21}^d = \frac{max(0, -3 - (-2))}{-2} = 0$$

$$\mathcal{P}_{22}^d = \frac{max(0, -3 - (-2))}{-3} = 0$$

$$\mathcal{N}_{11}^d = \frac{max(0, -2 - (-1))}{-2} = 0$$

$$\mathcal{N}_{12}^d = \frac{max(0, -4 - (-3))}{-3} = 0$$

$$\mathcal{N}_{21}^d = \frac{max(0, -2 - (-3))}{-2} = -\frac{1}{2}$$

$$\mathcal{N}_{22}^d = \frac{max(0, -2 - (-3))}{-3} = -\frac{1}{3}$$

According to the decision matrix, $\mathcal{A}_1$ has better values than $\mathcal{A}_2$ on $\mathcal{C}_1$, but as can be seen, the value of $\mathcal{P}_{11}^d$ is lower than $\mathcal{P}_{21}^d$. These values can result in wrong evaluation of alternatives. We can see the same problem in the other values of positive and negative distances. Moreover, if all of the elements of the average solution have negative values, $\max_k \mathcal{P}_k^w$ and $\max_k \mathcal{N}_k^w$ equals zero, and we cannot calculate the values of $\mathcal{P}_i^n$, $\mathcal{N}_i^n$ and $\mathcal{S}_i$.

3.2. Zero elements in the average solution

If some elements of the average solution are equal to zero, we cannot calculate some positive and negative distances. Therefore, the EDAS method cannot give a solution.

- Example B:

Suppose that we have three alternatives and two criteria with the following decision-matrix.

$$X = \begin{bmatrix} 4 & 2 \\ 1 & 5 \\ -5 & 2 \end{bmatrix}$$

In this example, it's not possible to calculate the values of $\mathcal{P}_{11}^d$, $\mathcal{P}_{21}^d$, $\mathcal{P}_{31}^d$, $\mathcal{N}_{11}^d$, $\mathcal{N}_{21}^d$ and $\mathcal{N}_{31}^d$ because the value of $\mathcal{g}_1$ equals zero.

4. A simple modification to the EDAS method

We can see that the problems in the considered exceptional cases are definitely due to existing negative values in the decision matrix. For this reason, a modification is made to the EDAS method to eliminate this flaw from the evaluation process. A new step is added after the first step of the method as follows:

Step 1B. Transformation of the decision matrix.

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$$X' = \begin{bmatrix} x'_{11} & x'_{12} & \cdots & x'_{1j} & \cdots & x'_{1m} \\ x'_{21} & x'_{22} & \cdots & x'_{2j} & \cdots & x'_{2m} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ x'_{i1} & x'_{i2} & \cdots & x'_{ij} & \cdots & x'_{im} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ x'_{n1} & x'_{n2} & \cdots & x'_{nj} & \cdots & x'_{nm} \end{bmatrix} \tag{10}$$

where,

$$x'_{ij} = x_{ij} - \min_j x_{ij} \tag{11}$$

Then the values of x'_{ij} are used in the next steps.

In *Example A*, if we use this step, the transformed decision matrix will be:

$$X' = \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix}$$

Therefore, the elements of the average solution will be changed to $\mathcal{g}_1 = 1$ and $\mathcal{g}_2 = 1$. According to Eqs. (3) and (4) we can obtain rational values for the positive and negative distances.

$$\mathcal{P}^d_{11} = \frac{max(0,2-1)}{1} = 1$$

$$\mathcal{P}^d_{12} = \frac{max(0,1-0)}{1} = 1$$

$$\mathcal{P}^d_{21} = \frac{max(0,0-1)}{1} = 0$$

$$\mathcal{P}^d_{22} = \frac{max(0,1-2)}{1} = 0$$

$$\mathcal{N}^d_{11} = \frac{max(0,1-2)}{1} = 0$$

$$\mathcal{N}^d_{12} = \frac{max(0,0-1)}{1} = 0$$

$$\mathcal{N}^d_{21} = \frac{max(0,1-0)}{1} = 1$$

$$\mathcal{N}^d_{22} = \frac{max(0,2-1)}{1} = 1$$

For instance, we can see that $\mathcal{P}^d_{11}$, which was lower than $\mathcal{P}^d_{21}$ before this transformation, has a greater value than $\mathcal{P}^d_{21}$. Also the final appraisal scores after this transformation are $\mathcal{S}_1 = 1$ and $\mathcal{S}_2 = 0$ which confirm that $\mathcal{A}_1 \succ \mathcal{A}_2$.

Moreover, in *Example B*, using this modification leads to following transformed decision matrix:

$$X' = \begin{bmatrix} 9 & 0 \\ 6 & 3 \\ 0 & 0 \end{bmatrix}$$

According to Eq. (2), the average solutions are $\mathcal{g}_1 = 5$ and $\mathcal{g}_2 = 1$. As it can be seen, there is no element in the average solution which equals zero. Therefore, the other steps of the EDAS method can be made without any problem.

5. Conclusions

In this study, two exceptional cases which cause some problems in the process of the EDAS method have been addressed. The main issue was related to existing negative values in the decision matrix which could lead to negative or zero elements in the average solution. A modification by adding a new step has been made to the EDAS method. In this modification, the values of the decision matrix are transformed into positive values. It has been shown that the EDAS method is improved by this modification in the considered exceptional cases.

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