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METHODS

# A simple modification to the EDAS method for two exceptional cases

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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 an 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

## Introduction

In problems, we are usually confronted with some alternatives that need to be evaluated with respect to multiple criteria. Multi-criteria decision-making (MCDM) methods and techniques are very useful to handle such problems. 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 (ELimination Et Choix Traduisant la REalite), multi-objective optimization by ratio analysis (MOORA), preference ranking organization method for enrichment of evaluations (PROMETHEE), technique for order of preference by similarity to an ideal solution (TOPSIS), and VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje). Interested readers are referred to some recent review papers in this field (1).

The EDAS method is a relatively new and efficient method proposed by Keshavarz Ghorabaee et al. (2). The process of evaluation in this method is based on positive and negative distances from an average solution. According to this method, an alternative that has higher values of positive distances and lower values of negative distances than the average solution is a more desirable alternative. This method has been extended to deal with MCDM problems in the presence of uncertainty (3–8). Also, it has been applied to several real-world problems (9–19).

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 the section "The EDAS method," the steps of the EDAS method are presented. Then, two exceptional cases are explained in the section "Exceptional cases," A modification is proposed in the section "A simple modification to the EDAS method," and the results are analyzed in this section. Finally, conclusions are discussed in the section "A simple modification to the EDAS method."

## The EDAS method

Imagine that we have $n$ alternatives ($A_1$ to$A_n$) and $m$ criteria ($C_1$ to $C_m$), and the weight of each criterion ($w_j$, $j \in \{1, 2, .....m\}$)is known. The steps of the EDAS method for evaluation of the alternatives with respect to the criteria are as follows:

**Step 1.** Construction of decision matrix:

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

**Step 2.** Calculation of the elements of average solution ($g_j$):

$$g_j = \frac{\sum_{i=1}^{n} x_{ij}}{n}$$

**Step 3.** Determination of the positive ($P_{ij}^d$) and negative ($N_{ij}^d$) distances:

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

$$N_{ij}^d = \begin{cases} \dfrac{\max(0, g_j - x_{ij})}{g_j} & if\ j \in B \\ \dfrac{\max(0, x_{ij} - g_j)}{g_j} & if\ j \in C \end{cases}$$

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

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

$$P_i^w = \sum_{j=i}^{m} w_j \mathcal{P}_{ij}^d$$

$$N_i^w = \sum_{j=i}^{m} w_j N_{ij}^d$$

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

$$P_i^n = \frac{P_i^w}{\max_k P_k^w}$$

$$N_i^n = 1 - \frac{N_i^w}{\max_k N_k^w}$$

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

$$S_i = \frac{1}{2} \left(P_i^n + N_i^n\right)$$

**Step 7.** Rank the alternatives according to decreasing values of $S_i$.

# 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.

## Negative elements in the average solution

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

**Example A:**

Imagine that we have a problem with two alternatives ($A_1$ and $A_2$) and two criteria ($C_1 \in B$ and $C_2 \in C$) 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 is obvious that $A_1 \succ A_2$. However, if we use the EDAS method, the elements of the average solution is $g_1 = -2$ and $g_2 = -3$, and the positive and negative distances are as follows:

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

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

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

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

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

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

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

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

According to the decision matrix, $A_1$ has better values than $A_2$ on $C_1$, but as can be seen, the value of $P_{11}^d$ is lower than$P_{21}^d$. These values can result in a 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, $\max_k P_k^w$ and $\max_k N_k^w$ equals zero, and we cannot calculate the values of $P_i^n$, $N_i^n$ and$S_i$.

### 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:**

Imagine 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 is not possible to calculate the values of $\mathcal{P}^d_{11}$, $\mathcal{P}^d_{21}$, $\mathcal{P}^d_{31}$, $N^d_{11}$, $N^d_{21}$, and $N^d_{31}$ because the value of $g_1$ equals zero.

## 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.

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

where,

$$x'_{ij}, = x_{ij} - \min_{j} x_{ij}$$

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 $g_1 = 1$ and $g_2 = 1$. According to Eqs. 3, 4, we can obtain rational values for the positive and negative distances.

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

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

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

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

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

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

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

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

For instance, we can see that$P^d_{11}$, which was lower than $P^d_{21}$before this transformation, has a greater value than $P^d_{21}$. Also, the final appraisal scores after this transformation are $S_1 = 1$ and $S_2 = 0$, which confirm that $A_1 \succ A_2$.

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

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

According to Eq. 2, the average solutions are $g_1 = 5$ and$g_1 = 1$. As it can be seen, there is no element in the average solution that equals zero. Therefore, the other steps of the EDAS method can be made without any problem.

## Conclusion

In this study, two exceptional cases that caused some problems in 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.

## Author contributions

The author confirms sole responsibility for the study.

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