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Supplementary Material

A Hybrid Approach of Data Envelopment Analysis Based Grey Relational Analysis: A Study on Egg Yield

Hande Küçükönder[1], Pınar Çelebi Demirarslan[1,*], Aykut Burgut[2] and Mustafa Boğa[3]

[1]*Faculty of Economics and Administrative Sciences, Bartın University, Ağdacı Campus 74000, Bartın, Turkey*

[2]*Faculty of Agriculture, Çukurova University, Yüreğir 01230, Adana, Turkey*

[3]*Bor Vocational School, Niğde University, Bor 51700, Niğde, Turkey*

* Corresponding author: pdemirarslan@bartin.edu.tr

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The steps of the ARAS method

The steps of the Additive Ratio Assesment (ARAS) method presented as a new MCDM method by Turskis and Zavadskas are given below (Zavadskas and Turskis, 2010).

Step 1 - Creating the decision matrix

The X_0 optimal solution vector consisting of optimal values for each criterion was added as a line to the $D = [x_{ij}]_{.....}$ decision matrix with m alternatives and n criteria.

$$\begin{matrix} X_0 \\ A_1 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} x_{01} & x_{02} & \cdots & x_{0j} & \cdots & x_{0n} \\ x_{11} & x_{12} & \cdots & x_{1j} & \cdots & x_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{i1} & x_{i2} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix}_{(m+1)xn} \quad \ldots\ldots\ldots (24)$$

Where, $X_0 = (x_{0j})$ is the optimal value in the j^{th} criterion ($j = 1, \ldots, n$).

Step 2 - Normalized decision matrix

The normalization process depends on whether the criterion is a benefit or cost criterion. The values in the cost criterion were converted to the benefit criterion form by taking its inversion according to the multiplication. $\bar{X} = [\bar{x}_{ij}]_{(m+1)xn}$ normalized the decision matrix was calculated by means of the following equations.

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, when\ j^{th} criterion\ is\ benefit\ criterion \ldots\ldots (25)$$

$$\bar{x}_{ij} = \frac{\frac{1}{x_{ij}}}{\sum_{i=1}^{m} \frac{1}{x_{ij}}}, when\ j^{th} criterion\ is\ cost\ criterion \ldots\ldots (26)$$

Step 3 - Weighted normalized decision matrix

Normalized values were obtained by multiplying by the w_j criterion weights in the form of $\hat{X} = [\hat{x}_{ij}]_{(m+1)xn}$ weighted normalized decision matrix $\hat{x}_{ij} = \bar{x}_{ij}\, w_j$.

Step 4 - Calculation of optimality function values

In this step, the alternatives were evaluated by calculating the S_i optimality function value of each alternative. S_i value the K_i benefit ratios of each alternative were calculated by dividing to the S_0 optimal function value. Then, K_i benefit ratios were ranked from small to large, and their alternatives are evaluated.

$$S_i = \sum_{j=1}^{n} \hat{x}_{ij}, i = 0,1, \ldots, m \quad \ldots\ldots (27)$$

$$K_i = \frac{S_i}{S_0}, i = 0,1, \ldots, m \ldots\ldots (28)$$

MOORA method

Below are explanations of the MOORA-Reference Point (Multi-Objective Optimization on the basis of Ratio Analysis-Reference Point) method with significance coefficients (weighted) used in the study and the steps of the process (Şimşek *et al.*, 2015; Brauers and Zavadskas, 2006).

Step 1 – Normalization

$$x_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}} \ldots\ldots (29)$$

Step 2 – Weighted Tchebycheff min-max metric

$$\min_i \left\{ \max_j \left(\left| w_j r_j - w_j x_{ij}^{*} \right| \right) \right\} \ldots\ldots (30)$$

Where, r_j is reference point for the j^{th} criterion and when the j^{th} criterion is the benefit criterion, the maximum value is taken as the reference point, and when it is the cost criterion, then the minimum value is taken as the reference point.

Step 3 – Ranking

The alternative with the smallest value is the best alternate.