Supplementary Material

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

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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.

$$X_0 = (x_{0j})$$

**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.

$$\bar{X} = \left[ \bar{x}_{ij} \right]_{(m+1) \times n}$$

**Step 3 - Weighted normalized decision matrix**

Normalized values were obtained by multiplying by the $w_j$ criterion weights in the form of $\hat{x}_{ij} = \bar{x}_{ij} \cdot w_j$.

**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.

$$S_i = \sum_{j=1}^{n} \frac{\hat{x}_{ij}}{S_0}, i = 0, 1, ..., m \ldots \ldots (24)$$

$$K_i = \frac{S_i}{S_0}, i = 0, 1, ..., m \ldots \ldots (27)$$

**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**

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

**Step 2 – Weighted Tchebycheff min-max metric**

$$\min \left\{ \max_i \left( \frac{w_j r_j - w_j x_{ij}^*}{\alpha} \right) \right\} \ldots \ldots (30)$$

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.