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# Optimizing Electrical Wire Selection by Integrating Entropy, Merec, and Topsis Methods

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**Abstract:** Solving multi-objective optimization problems is a fundamental task across various fields, including economics, management, and engineering. Two critical components of addressing these problems are determining objective weights and selecting an appropriate mathematical method for optimization. This study integrates three methods—Entropy, MEREC, and TOPSIS—to solve a multi-objective optimization problem aimed at identifying the optimal copper-core electrical wire among 28 available alternatives. Specifically, the Entropy and MEREC methods were employed to calculate the criteria weights, while the TOPSIS method was utilized to rank the copper-core wire types.

The results indicate that although the rankings of the electrical wires were inconsistent when using weights derived from different methods (Entropy vs. MEREC), certain alternatives maintained a consistent rank regardless of the weighting approach. The wire type associated with product code 20255114 was identified as the optimal choice among the 28 types evaluated in this study.

**Keywords:** optimization, weight method, Entropy method, MEREC method, TOPSIS method.

## 1. Introduction

Determining objective weights (also referred to as criteria weights) and selecting a Multi-Criteria Decision-Making (MCDM) method are two crucial tasks in ranking alternatives to identify the optimal solution among numerous available options [1-3]. To calculate criteria weights, one can apply objective weighting methods, subjective weighting methods, or hybrid weighting methods—the latter of which integrates both subjective and objective factors [4, 5]. Within this context, several studies have indicated that the use of objective weighting methods provides users with more accurate and transparent decisions [6-8].

Numerous objective weighting methods have been widely adopted across various fields, such as the Entropy method [9], MEREC method [10], SPC method [11], LOPCOW method [12], CRITIC method [13], and ITARA method [14], etc. Among these, the Entropy and MEREC methods have been validated for their high accuracy and are highly recommended for use [15]. Consequently, these two methods were selected for the current study.

Currently, there are hundreds of different MCDM methods, each developed based on distinct underlying philosophies [16]. Many prominent methods have been extensively utilized over time, including TOPSIS [17], SAW [18], PIV [19], VIKOR [20], COCOSO [21], MOORA [22], COPRAS [23], CODAS [24], and EDAS [25], etc. Among them, TOPSIS is regarded as the most well-known and frequently applied method [26]. This rationale explains why the TOPSIS method was also incorporated into this research.

Section 2 of this paper outlines the procedural steps for applying the Entropy and MEREC methods to calculate criteria weights, as well as the implementation of the TOPSIS method for ranking alternatives. The integration of these three methods—Entropy, MEREC, and TOPSIS—to rank various types of copper-core electrical wires is presented in Section 3. Finally, the conclusion regarding the optimal copper-core wire type identified concludes this article.

## 2. Methodology

### 2.1. Entropy Method

To determine the criteria weights using the Entropy method, the following sequential steps are implemented [27]:

**Step 1:** Construct the decision matrix consisting of $m$ rows and $n$ columns, where $m$ represents the number of alternatives to be ranked (number of experiments) and $n$ denotes the number of evaluation criteria for each alternative. Let x_{ij} be the value of criterion j for alternative i, where j = 1, ..., n and i = 1, ..., m.

**Step 2:** Determine the normalized values for the criteria using formula (1):

$$n_{ij} = \frac{x_{ij}}{m + \sum_{i=1}^{m} x_{ij}^2} \quad (1)$$

**Step 3:** Calculate the Entropy measure for each criterion using formula (2):

$$e_j = \sum_{i=1}^{m}\left[n_{ij} \times \ln(n_{ij})\right] - \left(1 - \sum_{i=1}^{m} n_{ij}\right) \times \ln\left(1 - \sum_{i=1}^{m} n_{ij}\right) \quad (2)$$

**Step 4:** Calculate the weight for each criterion using formula (3):

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{n}(1 - e_j)} \quad (3)$$

### 2.2. MEREC Method

To calculate the criteria weights using the MEREC (MEthod based on the Removal Effects of Criteria) method, the following procedure is applied [28]:

**Step 1:** Construct the decision matrix (identical to Step 1 of the Entropy method).

**Step 2:** Calculate the normalized values using formulas (4) and (5):

+ For beneficial criteria (the larger, the better):

$$n_{ij} = \frac{min x_{ij}}{x_{ij}} \quad (4)$$

+ For non-beneficial criteria (the smaller, the better):

$$n_{ij} = \frac{x_{ij}}{max\ x_{ij}} \quad (5)$$

**Step 3:** Calculate the overall performance of the alternatives using formula (6):

$$S_i = Ln\left[1 + \left(\frac{1}{n}\sum_{j}^{n}\left|ln(n_{ij})\right|\right)\right] \quad (6)$$

**Step 4:** Calculate the performance of the alternatives by removing each criterion using formula (7):

$$S'_{ij} = Ln\left[1 + \left(\frac{1}{n}\sum_{k,k\neq j}^{n}\left|ln(n_{ij})\right|\right)\right] \quad (7)$$

**Step 5:** Calculate the absolute deviation values using formula (8):

$$E_j = \sum_{i}^{m}\left|S'_{ij} - S_i\right| \quad (8)$$

**Step 6:** Determine the criteria weights using formula (9):

$$w_j = \frac{E_j}{\sum_{k}^{n} E_k} \quad (9)$$

### 2.3. TOPSIS Method

To rank the alternatives using the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method, the following procedure is implemented [29]:

**Step 1:** Construct the decision matrix (identical to Step 1 of the Entropy method).

**Step 2:** Determine the normalized values using formula (10):

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{10}$$

**Step 3:** Calculate the weighted normalized values using formula (11):

**Step 4:** Identify the Positive Ideal Solution ($A^+$) and the Negative Ideal Solution ($A^-$) for the criteria using formulas (12) and (13):

$$A^+ = \{y_1^+, y_2^+, \dots, y_j^+, \dots, y_n^+\} \tag{12}$$

$$A^- = \{y_1^-, y_2^-, \dots, y_j^-, \dots, y_n^-\} \tag{13}$$

Where $yj+$ và $yj-$ are the best and worst values of the weighted normalized value $y_{ij}$ for criterion $j$, respectively.

**Step 5:** Determine the separation measures $S_i^+$ and $S_i^-$ using formulas (14) and (15):

$$S_i^+ = \sqrt{\sum_{j=1}^{n}\left(y_{ij} - y_j^+\right)^2} \qquad i = 1, 2, \dots, m \tag{14}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n}\left(y_{ij} - y_j^-\right)^2} \qquad i = 1, 2, \dots, m \tag{15}$$

**Step 6:** Calculate the closeness coefficient $C_i*$ using formula (16):

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-} \qquad \mathrm{i} = 1, 2, \dots, \mathrm{m};\ 0 \le C_i^* \le 1 \tag{16}$$

**Step 7:** Rank the alternatives according to the principle that the alternative with the highest *Ci* value is the optimal choice.

## 3. Results and Discussion

Table 1 summarizes the data for 28 types of copper-core electrical wires provided by a supplier, designated from A1 to A28, with their corresponding product codes as shown in column 2 [30]. Each alternative is described by nine criteria, denoted from C1 to C9. Among these, C9 is a non-beneficial criterion (the smaller, the better), while the remaining eight criteria are beneficial criteria (the larger, the better).

**C1:** Nominal cross-sectional area ($mm^2$)
**C2: Number of strands**
**C3: Diameter of copper strands (mm)**
**C4:** Insulation thickness (mm)
**C5: Sheath thickness (mm)**
**C6: Overall diameter (mm)**
**C7: Maximum DC resistance of conductor at** $20^0$C (Ohm/km)
**C8:** Mass (Weight) (kg/m)
**C9: Price (**VNDT/m, VNDT= Viet Nam dong thoursand)

Table 1: Specifications of copper-core electrical wires [30]

| Alt. | CODE | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **A1** | 20225103 | 1.00 | 20 | 0.18 | 0.6 | 0.8 | 5.4 | 39.00 | 0.0489 | 7.201 |
| **A2** | 20225106 | 1.50 | 30 | 0.18 | 0.6 | 0.8 | 6.3 | 26.00 | 0.0587 | 11.533 |
| **A3** | 20225107 | 2.00 | 40 | 0.18 | 0.6 | 0.8 | 6.6 | 19.50 | 0.0688 | 18.346 |
| **A4** | 20225108 | 2.00 | 32 | 0.20 | 0.6 | 0.8 | 6.6 | 19.50 | 0.0686 | 26.607 |
| **A5** | 20225110 | 3.00 | 48 | 0.20 | 0.7 | 0.8 | 7.6 | 13.20 | 0.0935 | 42.857 |
| **A6** | 20225111 | 3.00 | 30 | 0.25 | 0.7 | 0.8 | 7.6 | 13.30 | 0.0930 | 24.388 |
| **A7** | 20225114 | 5.00 | 50 | 0.25 | 0.8 | 1 | 9.3 | 7.98 | 0.1405 | 38.284 |
| **A8** | 20235103 | 1.50 | 20 | 0.18 | 0.6 | 0.8 | 6.2 | 39.00 | 0.0573 | 57.225 |
| **A9** | 20235106 | 2.25 | 30 | 0.18 | 0.6 | 0.8 | 6.7 | 26.00 | 0.0709 | 23.670 |
| **A10** | 20235107 | 3.00 | 40 | 0.18 | 0.6 | 0.8 | 7 | 19.50 | 0.0833 | 38.418 |
| **A11** | 20235108 | 3.00 | 32 | 0.20 | 0.6 | 0.8 | 7 | 19.50 | 0.0830 | 58.843 |
| **A12** | 20235110 | 4.50 | 48 | 0.20 | 0.7 | 0.9 | 8.3 | 13.30 | 0.1187 | 38.699 |
| **A13** | 20235111 | 4.50 | 30 | 0.25 | 0.7 | 0.9 | 8.3 | 13.30 | 0.1172 | 24.412 |
| **A14** | 20235114 | 7.50 | 50 | 0.25 | 0.8 | 1.1 | 10.1 | 7.98 | 0.1782 | 35.212 |
| **A15** | 20245103 | 2.00 | 20 | 0.18 | 0.6 | 0.8 | 6.7 | 39.00 | 0.0706 | 26.117 |
| **A16** | 20245106 | 3.00 | 30 | 0.18 | 0.6 | 0.8 | 7.2 | 26.00 | 0.0869 | 36.484 |
| **A17** | 20245107 | 4.00 | 40 | 0.18 | 0.6 | 0.9 | 7.9 | 19.50 | 0.1074 | 54.228 |
| **A18** | 20245108 | 4.00 | 32 | 0.20 | 0.6 | 0.9 | 7.9 | 19.50 | 0.1071 | 26.685 |
| **A19** | 20245110 | 6.00 | 48 | 0.20 | 0.7 | 1 | 9.3 | 13.30 | 0.1517 | 48.426 |
| **A20** | 20245111 | 6.00 | 30 | 0.25 | 0.7 | 1 | 9.3 | 13.30 | 0.1507 | 48.426 |
| **A21** | 20245114 | 10.00 | 50 | 0.25 | 0.8 | 1.1 | 10.9 | 7.98 | 0.2200 | 66.126 |
| **A22** | 20255103 | 2.50 | 20 | 0.18 | 0.6 | 0.9 | 7.7 | 39.00 | 0.0830 | 26.123 |
| **A23** | 20255106 | 3.75 | 30 | 0.18 | 0.6 | 0.9 | 8.2 | 26.00 | 0.1075 | 33.170 |
| **A24** | 20255107 | 5.00 | 40 | 0.18 | 0.6 | 0.9 | 8.9 | 19.50 | 0.1294 | 34.208 |
| **A25** | 20255108 | 5.00 | 32 | 0.20 | 0.6 | 0.9 | 8.9 | 19.50 | 0.1298 | 37.816 |
| **A26** | 20255110 | 7.50 | 48 | 0.20 | 0.7 | 1.1 | 9.7 | 13.30 | 0.1871 | 44.126 |
| **A27** | 20255111 | 7.50 | 30 | 0.25 | 0.7 | 1.1 | 9.7 | 13.30 | 0.1858 | 54.212 |
| **A28** | 20255114 | 12.50 | 50 | 0.25 | 0.8 | 1.2 | 11 | 13.30 | 0.2724 | 65.746 |

The objective is to identify the optimal electrical wire type from Table 1. However, an analysis of the data reveals that C1 is highest at A28; C2 reaches its maximum at A14, A21, and A28; C3 is highest at A13, A14, and A28; C4 is highest at A14 and A21; C5, C6, and C8 are all at their maximum at A28; C7 is highest at A22; while C9 is at its minimum at A1. This indicates that no single alternative excels across all criteria simultaneously. Instead, the goal is to identify an alternative where the collective set of criteria is considered "optimal." Consequently, solving a multi-objective optimization problem is essential. In this study, the TOPSIS method was employed to fulfill this task.

To implement the TOPSIS method for multi-objective optimization, determining the criteria weights is a critical prerequisite. By applying formulas (1) through (3), the weights for criteria C1 to C9 using the Entropy method were calculated as 0.1089, 0.0759, 0.1183, 0.1675, 0.1739, 0.1008, 0.0804, 0.0994, and 0.0749, respectively. Similarly, by applying formulas (4) through (9), the weights derived from the MEREC method were 0.2710, 0.1089, 0.0240, 0.0162, 0.0223, 0.0773, 0.1781, 0.1572, and 0.1450, respectively.

It is observed that the weight values for each criterion differ significantly between the two methods. This discrepancy is attributed to the fundamentally different underlying philosophies of the Entropy and MEREC approaches. Nevertheless, utilizing both methods provides an opportunity to identify the best electrical wire type through a more objective and robust selection process.

Using the criteria weights calculated by the Entropy and MEREC methods, formulas (10) through (16) were applied to determine the closeness coefficient $C_i$ for each alternative. Based on these scores, the ranking of the alternatives was established, as summarized in Figure 1.

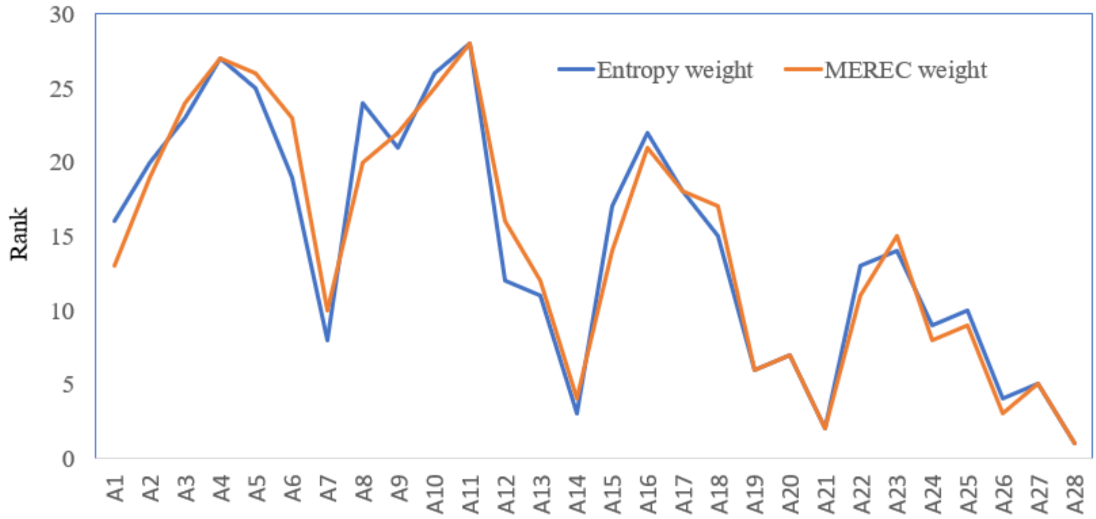

Figure 1: Rankings of electrical wire types

As observed in Figure 1, there are significant differences in the rankings of the alternatives when criteria weights are calculated using two different methods. This outcome is entirely expected, given the substantial disparities between the weight values derived from the Entropy and MEREC methods, as discussed previously. Nevertheless, certain alternatives demonstrate consistent rankings regardless of the weighting method applied. Specifically, A19 consistently ranks 6th, A20 ranks 7th, A21 ranks 2nd, A27 ranks 5th, and notably, A28 consistently holds the 1st position. Consequently, it can be concluded that A28 is the optimal alternative. In other words, the electrical wire with product code 20255114 is identified as the best performing type among the 28 evaluated options.

## Conclusion

This study successfully integrated three methods—Entropy, MEREC, and TOPSIS—to solve a multi-objective optimization problem, specifically to identify the optimal electrical wire among 28 alternatives available from a supplier. The electrical wire with product code 20255114 was determined to be the best-performing option. This optimal wire is characterized by the following technical specifications:

- Nominal cross-sectional area: 12.50 $mm^2$
- Number of strands: 50
- Strand diameter: 0.25 mm
- Insulation thickness: 0.8 mm
- Sheath thickness: 1.2 mm
- Overall diameter: 11 mm
- Maximum DC resistance at $20^0$C: 13.30 Ohm/km
- Mass per unit length: 0.2724 kg/m
- Unit price: 65.746 kVND/m

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