Furniture material selection for hotel and airlines lounges using interval TOPSIS

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Abstract. The interior design of hotel inevitably includes the furniture installation. The design of furniture needs to select suitable material. Modern material production provides numerous alternatives but at the same time create another problem of selection the suitable one. The properties of materials in different aspects, e.g. strength, style, durability, etc., form a set of criteria in the selection. The criteria are normally conflicting and pose difficulty in the selection process. This paper proposes an MCDM methodology, namely interval TOPSIS, to facilitate the selection process by ranking the prospect materials according to a set of criteria. The interval TOPSIS is suitable for the real-world application where there is uncertainty in terms of interval numbers. The methodology is illustrated through an illustrative example. The methodology is readily extended to the material selection in other domain of application.

1. Introduction

The tourism industry is considered a main source of revenue of Thailand. Various classes of hotels are constructed to serve the visitors. The interior design of hotel inevitably includes the furniture installation. The design of furniture needs to select suitable material. Modern material production provides numerous alternatives but at the same time create another problem of selection the suitable one. The properties of materials in different aspects, e.g. strength, style, durability, etc., form a set of criteria in the selection. The criteria are normally conflicting and pose difficulty in the selection process.

There have been applications of Multi-criteria Decision Making (MCDM) to various domains, e.g. failure risk-based ranking of IT projects [1], evaluating museum websites [2], etc. For the material selection, the MCDM methods like gray relations (COPRAS-G), operational competitiveness rating analysis (OCRA), a new additive ratio assessment (ARAS) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods are used for design a multi-tubular packed-bed Fischer-Tropsch reactor (MPBR) [3]. The criteria weighting was performed by compromised weighting method composed of AHP (analytic hierarchy process) and Entropy methods. The ranking results showed that ASME SA-106 and ASME SA-106 would be the best materials for the pipes and the vessel of a MPBR. Four Multi Criteria Decision Making methods for solving pipes material selection problem in sugar industry are proposed [4]. FAHP-TOPSIS, FAHP-VIKOR, FAHP-ELECTRE, FAHP-PROMTHEE are the four methods used to choose the best alternative among the various materials. The ranking performance of various MCDM method is also compared with each other and exploring the effectiveness and flexibility of VIKOR method.
Five stainless steel grades such as J4, JS-LaUS, J204Cu, 409 M, 304 and seven evaluation criteria such as yield strength, ultimate tensile strength, percentage of elongation, hardness, cost, corrosion rate and wear rate are focussed in this study to choose the suitable material. A compromise ranking method in the perspective of regret theory as a multiple-criteria decision-making (MCDM) tool is applied to solve a material selection problem in a given manufacturing environment [5]. Entropy criteria weights and TOPSIS method are used for selection seven number of alternative martials and six criteria. The result shows that nitried steel material is best for the engineering design [6].

This paper proposes an MCDM methodology for furniture material selection for use in hotel. Specifically, the TOPSIS-based method is employed for the purpose. TOPSIS is used for a number of advantageous reasons [7]:

1. TOPSIS logic is rational and understandable.
2. The computation processes are straightforward.
3. The concept permits the pursuit of the best alternatives for each criterion depicted in a simple mathematical form.
4. The importance weights are incorporated into the comparison procedures. It should be emphasized that there has no work addressing this issue.

The key issues are the introduction of criteria to be considered in the selection. Since there can be uncertainty in the properties involved in the selection criteria, the interval number representing such uncertainty is taken into account, thus leading to the use of interval TOPSIS [8].

After this introduction, the criteria used in furniture material selection are described. The fundamentals of interval TOPSIS are later explained. To clarify the proposed methodology, an illustrative example is employed. Finally, the conclusion is made.

2. Furniture material selection criteria

Hotel furniture positioning involves many aspects. The first few criteria are service life and production time [9]. Matching to environment, strength, durability, maintenance difficulty are also important [10]. In terms of cost, the life-cycle costing should be considered [11]. These criteria will be considered in the illustrative example.

3. Interval TOPSIS

The interval TOPSIS simply extends the concept of the original TOPSIS to the cases where the quantitative elements in the decision matrix become interval numbers. The decision matrix in the context of the interval TOPSIS, \( \tilde{D} \), is

\[
\tilde{D} = \begin{bmatrix}
\tilde{w}_1 & \tilde{w}_2 & \tilde{w}_3 & \cdots & \tilde{w}_n \\
\tilde{z}_{11} & \tilde{z}_{12} & \tilde{z}_{13} & \cdots & \tilde{z}_{1n} \\
\tilde{z}_{21} & \tilde{z}_{22} & \tilde{z}_{23} & \cdots & \tilde{z}_{2n} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
\tilde{z}_{m1} & \tilde{z}_{m2} & \tilde{z}_{m3} & \cdots & \tilde{z}_{mn}
\end{bmatrix}
\]

(1)

in which

\[
\tilde{z}_{ij} = [z_{ij}, \bar{z}_{ij}]
\]

(2)

and

\[
\tilde{w}_j = [w_j, \bar{w}_j]
\]

(3)

2
The interval TOPSIS consists of the following steps:

1. Construction of normalized decision matrix.

\[
    r_{ij} = \frac{z_{ij}}{\left( \sum_{i=1}^{m} z_{ij}^2 + z_{ij}^2 \right)^{1/2}}; \quad i = 1, \ldots, m \text{ and } j = 1, \ldots, n
\]  

where \( m \) and \( n \) are the number of alternatives and attributes, respectively. 

\[
    \bar{r}_{ij} = \frac{-z_{ij}}{\left( \sum_{i=1}^{m} z_{ij}^2 + z_{ij}^2 \right)^{1/2}}; \quad i = 1, \ldots, m \text{ and } j = 1, \ldots, n
\]

2. Construction of weighted normalized decision matrix.

\[
    v_{ij} = w_{j} r_{ij}; \quad i = 1, \ldots, m \text{ and } j = 1, \ldots, n
\]

\[
    \bar{v}_{ij} = w_{j} \bar{r}_{ij}; \quad i = 1, \ldots, m \text{ and } j = 1, \ldots, n
\]

3. Determination of positive ideal solution \( V_{Di}^+ \) and negative ideal solution \( V_{Di}^- \). Both solutions are defined as:

\[
    V_{Di}^+ = \left\{ \max_{i} [v_{ij}, \bar{v}_{ij}] \mid j \in C^+ \right\} \left\{ \min_{i} [v_{ij}, \bar{v}_{ij}] \mid j \in C^- \right\} \quad i = 1, \ldots, m
\]

\[
    \equiv \left\{ v_{1}^+, \bar{v}_{1}^+ \right\} \left\{ \bar{v}_{2}^+, \bar{v}_{2}^- \right\} \ldots \left\{ v_{n}^+, \bar{v}_{n}^- \right\}
\]

\[
    V_{Di}^- = \left\{ \min_{i} [v_{ij}, \bar{v}_{ij}] \mid j \in C^+ \right\} \left\{ \max_{i} [v_{ij}, \bar{v}_{ij}] \mid j \in C^- \right\} \quad i = 1, \ldots, m
\]

\[
    \equiv \left\{ v_{1}^-, \bar{v}_{1}^- \right\} \left\{ \bar{v}_{2}^-, \bar{v}_{2}^- \right\} \ldots \left\{ v_{n}^-, \bar{v}_{n}^- \right\}
\]

where \( C^+ = \{ j = 1, \ldots, n \mid j \text{ is associated with benefit/profit/positive criteria} \} \)

\( C^- = \{ j = 1, \ldots, n \mid j \text{ is associated with cost/loss/negative criteria} \} \)

It is noted that the determination of \( V_{Di}^+ \) and \( V_{Di}^- \) involves the comparison of interval-valued numbers. Therefore, an ordinal comparison measure \( \Delta_{\tilde{a}, \tilde{b}} \) between \( \tilde{a} \) and \( \tilde{b} \) is necessary. The following formula is introduced for such a purpose [12]:

\[
    \Delta_{\tilde{a}, \tilde{b}} = \frac{1}{2} (\tilde{a} + \bar{\tilde{a}}) - \frac{1}{2} (\tilde{b} + \bar{\tilde{b}})
\]
which is the subtraction of the midpoint of $\tilde{b}$ from that of $\tilde{a}$. The value of $\Delta_{a-b}$ is negative when $\tilde{a} < \tilde{b}$ and becomes positive for $\tilde{a} > \tilde{b}$. The distance is based on the mid-point of interval number and therefore is referred to as the mid-point-based distance.

4. Calculation of separation measure. The separation between an alternative and the positive ideal solution $V_{DI}^+$, $S_{i}^{+DI}$, is

$$S_{i}^{+DI} = \frac{1}{2} \sum_{j \in C^+} \left( v_j^+ + v_j^- \right) - \left( \bar{v}_j^+ + \bar{v}_j^- \right) + \frac{1}{2} \sum_{j \in C^-} \left( v_j^+ + v_j^- \right) - \left( \bar{v}_j^+ + \bar{v}_j^- \right); \quad i = 1, \ldots, m$$  \hspace{1cm} (11)

The separation between an alternative and the negative ideal solution $V_{DI}^-$, $S_{i}^{-DI}$, is

$$S_{i}^{-DI} = \frac{1}{2} \sum_{j \in C^+} \left( v_j^+ + v_j^- \right) - \left( \bar{v}_j^+ + \bar{v}_j^- \right) + \frac{1}{2} \sum_{j \in C^-} \left( v_j^+ + v_j^- \right) - \left( \bar{v}_j^+ + \bar{v}_j^- \right); \quad i = 1, \ldots, m$$  \hspace{1cm} (12)

5. Calculation of the relative closeness to the positive ideal solution. The relative closeness of the alternative $A_i$ with respect to $V_{DI}^+$, $\kappa_{i}^{+DI}$, is defined as

$$\kappa_{i}^{+DI} = \frac{S_{i}^{-DI}}{S_{i}^{+DI} + S_{i}^{-DI}}; \quad i = 1, \ldots, m$$  \hspace{1cm} (13)

6. Ranking of the preference order. The alternatives are preferred in accordance with the descending order of $\kappa_{i}^{+DI}$, i.e. the alternatives with higher $\kappa_{i}^{+DI}$'s are preferred to the ones with lower $\kappa_{i}^{+DI}$'s.

4. Illustrative Example
Consider 3 candidate materials. The criteria considered herein include service life and production time, matching to environment, strength, durability, maintenance difficulty, and life-cycle cost. The positive criteria are $C_1$-service life, $C_2$-matching to environment, $C_3$-strength, $C_4$-durability, whereas the negative criteria are $C_5$-production time, $C_6$-maintenance difficulty, and $C_7$-life-cycle cost [13]. The performances of some criteria are given in the form of scores from 1 to 10. These encompass matching to environment and maintenance difficulty. For positive criteria, the higher the score is, the higher the advantage is. On contrary, for negative criteria, the higher the score is, the higher the disadvantage is.

Suppose each criterion is considered equally important. The final weight vector is then:

$$w = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 7 & 7 & 7 & 7 & 7 & 7 & 7 \end{bmatrix}$$  \hspace{1cm} (14)

The performance of each criterion is as follows:
C1-service life

Table 1. Service life.

| Material | Service life (year) |
|----------|---------------------|
| 1        | 20-25               |
| 2        | 10-15               |
| 3        | 15-20               |

C2-matching to environment

Table 2. Matching to environment.

| Material | Match |
|----------|-------|
| 1        | 4-5   |
| 2        | 8-9   |
| 3        | 3-6   |

C3-Strength

Table 3. Strength.

| Material | Strength \(10^6\) N/m² |
|----------|------------------------|
| 1        | 150-200                |
| 2        | 120-190                |
| 3        | 250-300                |

C4-durability

Table 4. Durability.

| Material | Durability |
|----------|------------|
| 1        | 4-7        |
| 2        | 5-8        |
| 3        | 6-9        |
C5-production time

Table 5. Production time.

| Material | Production time (months) |
|----------|--------------------------|
| 1        | 10-12                    |
| 2        | 8-12                     |
| 3        | 12-14                    |

C6-maintenance difficulty

Table 6. Maintenance difficulty.

| Material | Maintenance difficulty |
|----------|------------------------|
| 1        | 1-2                    |
| 2        | 3-5                    |
| 3        | 6-9                    |

C7-life-cycle cost

Table 7. Life-cycle cost.

| Material | Life-cycle cost (THB) |
|----------|-----------------------|
| 1        | 1000000-1500000       |
| 2        | 800000-1200000        |
| 3        | 900000-1300000        |

The positive ideal solution $V_{Di}^+$ and negative ideal solution $V_{Di}^-$ is, respectively,

$$V_{Di}^+ = \{0.0723, 0.0799, 0.0762, 0.0651, 0.0508, 0.0172, 0.05110\}$$  \hspace{1cm} (15)

, and

$$V_{Di}^- = \{0.0402, 0.0423, 0.0430, 0.0477, 0.0660, 0.0858, 0.0638\}$$  \hspace{1cm} (16)

The resulting relative closeness is
\[
\kappa^{DI} = \begin{bmatrix}
0.5368 \\
0.5268 \\
0.3427
\end{bmatrix}
\] (17)

The resulting preference for material in the descending order is the first, second, and third, respectively. Consequently, the first material is recommended for the furniture material.

5. Conclusions
The interior design of hotel inevitably includes the furniture installation [14,15]. The design of furniture needs to select suitable material. Modern material production provides numerous alternatives but at the same time create another problem of selection the suitable one. The properties of materials in different aspects, e.g. strength, style, durability, etc., form a set of criteria in the selection. The criteria are normally conflicting and pose difficulty in the selection process. This paper proposes an MCDM methodology for furniture material selection for use in hotel. Since there can be uncertainty in the properties involved in the selection criteria, the interval number representing such uncertainty is taken into account, thus leading to the use of interval TOPSIS. An illustrative example is shown, in which seven criteria of service life and production time, matching to environment, strength, durability, maintenance difficulty, and life-cycle cost are considered. The methodology is readily extended to the application to other domains.

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