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Decision Making in Interior Designing Project Using an Innovative Fuzzy TOPSIS Approach

R. Radhika and S. Sreenivasan

Panimalar Institute of Technology, Varadarajapuram, Chennai – 600 123, India

Abstract: An attempt is made in this paper, to model the problem of selecting appropriate material for an interior designing project by a construction firm as a multi – criteria decision making problem and provide a scientific decision support framework for the same. Usage of suitable material for interior designing projects is essential to produce an aesthetic appeal. Impressing and satisfying clients by providing a unique façade is vital for the success of interior designers. The fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is a standard fuzzy MCDM technique that hinges on the concept that the chosen alternative should have the shortest distance from a pre-defined Positive Ideal Solution (PIS) and the farthest distance from a pre-defined Negative Ideal Solution (NIS). An innovative, enhanced fuzzy TOPSIS method is proposed to help an interior designer decide on which type of overlay product should be used to decorate wooden surfaces.

Key words Veneer · Laminate · Interior designing · Decision making · TOPSIS

INTRODUCTION

Decision making in the interior designing industry is a laborious task as the problems itself are often ill defined and are taken in a group decision making situation. Utilizing scientific decision making methods to arrive at correct assessment during times of decision making involving vagueness will improve decision making to a large extent. An interior designer is required to conceptualize the theme of his/her design, consider the natural and artificial lighting on the site, contemplate the colour of the flooring and walls to select the right shade and material needed to decorate wooden surfaces. Identifying the best overlay materials to use on [1] wooden surfaces will go a long way in adding an appealing look to a room which may otherwise seem dull and lackluster.

Multi – criteria decision making (MCDM) involves choosing the best alternative from a set of alternatives, based on the opinion of a team of decision makers. Various MCDM methods like AHP, TOPSIS and ELECTRE have been developed. In real life situations, it is difficult for decision makers to make crisp numerical comparisons to select the best overlay material. The usage of linguistic variables to convey the preferences of the decision makers helps us overcome the difficulty of expressing the character and significance of the criteria exactly through numerical assessments. The ratings of the alternatives against each criterion and the importance weight of each criterion are expressed as positive trapezoidal fuzzy numbers [2]. We use the fuzzy TOPSIS approach to analyze the above problem.

The traditional fuzzy TOPSIS introduced by Chen is enhanced to include the importance of decision makers [3]. The NSAM (New Similarity Aggregation Method) algorithm [4] is used to obtain the consensus opinion of the decision makers. Graded Mean Integer Representation (GMIR) is used to compute the fuzzy distance between each alternative and the ideal solutions. A ranking method based on rank and mode is used to order the fuzzy closeness coefficients obtained.

Definitions and Notations:

- A trapezoidal fuzzy number (TrFN) $A = (a, b, c, d)$ is defined by the membership function

$$\mu_A(x) = \begin{cases} 0 & if\ x < a \\ \dfrac{x-a}{b-a} & if\ a < x < b \\ 1 & if\ b < x < c \\ \dfrac{x-d}{c-d} & if\ c < x < d \\ 0 & if\ x > d \end{cases}$$

Corresponding Author: R. Radhika, Panimalar Institute of Technology, Varadarajapuram, Chennai – 600 123, India.

- The graded mean integer representation (GMIR) of a trapezoidal fuzzy number $A = (a, b, c, d)$ is given by

$$P(A) = \frac{c + 2a + 2b + d}{6}$$

- Let $A = (a_1,a_2,a_3,a_4)$, $B = (b_1,b_2,b_3,b_4)$ be two trapezoidal fuzzy numbers. Let $P(A)$ and $P(B)$ represent their GMIR respectively. Let $S_i = \left(\frac{a_i - P(A) + b_i - P(B)}{2}\right)$, I=1,2,3,4;, $C_i = |P(A)–P(B)| + S_i$ =1,2,3,4. Then the fuzzy distance between A and B is $C = (c_1,c_2,c_3,c_4)$, [5].
- Let $A = (a_1,a_2,a_3,a_4)$, $B = (b_1,b_2,b_3,b_4)$, be two trapezoidal fuzzy numbers. The fuzzy closeness coefficient between A and B is $CC = (c_1,c_2,c_3,c_4)$, where $C_1 = \frac{b_1}{b_1 + a_1}, C_2 = \frac{b_2}{b_2 + a_2}, C_3 = \frac{b_3}{b_3 + a_3}, C_4 = \frac{b_4}{b_4 + a_4}$

THE NASM (New Similarity Aggregation Method) Algorithm

Definitions Used:

- The centroid point $\overline{(x_i, y_i,)}$ of a trapezoidal fuzzy number (TrFN) $\overline{R_I} = (a_i, b_i, c_i, d_i$ is given by ;

$$\bar{x}_i = \frac{1}{3}\left[\frac{d_i^2 + c_i^2 - a_i^2 - b_i^2 + d_i c_i - a_i b_i}{d_i + c_i - a_i - b_i}\right]; \bar{y}_i = \frac{1}{3}\left[\frac{a_i + 2b_i + d_i 2c_i}{d_i + c_i + a_i - b_i}\right]$$

- Agreement degree between two experts E_i and E_j is defined as

$$S_{ij} = \frac{min(\bar{x}_i, \bar{x}_j) min(\bar{y}_i, \bar{y}_j)}{min(\bar{x}_i, \bar{x}_j) min(\bar{y}_i, \bar{y}_j)}$$

where $(\bar{x}_i, \bar{y}_i)$ and $(\bar{x}_j, \bar{y}_j)$ are the centroid points of R_i and R_j.

- The average agreement degree of expert E_i is defined as;

$$A(E_i) = \frac{1}{n-1}\sum_{j=1, j\neq i}^{n} S_{ij}$$

- The relative agreement degree RAD_i of expert E_i is given by

$$RAD_i = \frac{A(E_i)}{\sum_{j=1}^{n} A(E_j)}$$

- The consensus degree coefficient of each expert $E_i (i = 1,2,3, \ldots, T)$ is defined as $CDC_i = \beta \varepsilon_i + (1-\beta) RAD_i, \beta \in [0,1]$. ε_I is the weight of the expert $E_i (i = 1,2,3, \ldots, T)$ where ε_I satisfies $\varepsilon_i \geq 0 (i = 1,2,3, \ldots T), \sum_{i=1}^{n} \varepsilon_i = 1$
- The aggregated opinion $\tilde{R}$ is obtained as

$$\tilde{R} = \sum_{i=1}^{n} (CDC_i)$$

Methodology:

- For a given criterion and alternative in the group decision making [5], every expert $E_t(t = 1,2,3...T)$ constructs a trapezoidal fuzzy number (using linguistic variables) denoted by $\bar{R}_t = (a_t, b_t, c_t, d_t)$ to represent his personal estimate.
- The centroid point of $\bar{R}_t$ is calculated using (a).
- The agreement degree S_{ij} between two experts E_i and $E_j(i,j = 1,2,3, ..., T)$ is computed using (b).
- The relative agreement degree RAD_i of expert $E_j(i = 1,2,3, ..., T)$ is found out using (d).
- The consensus degree coefficient $CDC_i(i = 1,2, ..., T)$ is obtained using (e). We take into consideration the relative importance of each expert and obtain ε_i just as in [4].
- The aggregated opinion $\tilde{R}$ is obtained using (f).
- Steps a. to e are repeated for every pair of experts for each criterion and alternative and the $\tilde{R}$ value is calculated in each case.

THE RM Approach for Ranking of Trapezoidal Fuzzy Numbers: Let A = (a_1,b_1,c_1,d_1) and $B = (a_2,b_2,c_2,d_2)$, be two trapezoidal fuzzy numbers

Method to find RM(A ⊖ B): The following steps are used to find ***RM*(A ⊖ B)**

- Find $\Re(A \Theta B) = \frac{(a_1 - d_2 + b_1 - c_2 + c_1 - b_2 + d_1 - a_2)}{4}$
- If $\Re(A \Theta B) \neq 0, RM(A \Theta B) = \Re(A \Theta B)$
- If $\Re(A \Theta B) = 0, RM(A \Theta B) =$ mode $(A \Theta B) = \frac{(b_1 - c_2 + c_1 - b_2)}{2}$

Method of ranking A and B:

- $A > B$ if $RM(A \ominus B) > RM(B \ominus B)$
- $A < B$ if $RM(A \ominus B) < RM(B \ominus B)$
- $A \sim B$ if $RM(A \ominus B) \sim RM(B \ominus B)$

THE Innovative Fuzzy TOPSIS Methodology:

- Let $E = \{E_1, E_2, E_{3,} \ldots E_T\}$ be the set of n decision makers.
- Let $A = \{A_1, A_2, A_3, \ldots \ldots A_n\}$ to be the set of n alternatives.
- Let $C = \{C_1, C_2, C_3, \ldots \ldots C_m)$ to be the set of m criteria.
- Let $\tilde{W}_J^t = (w_{j1}^t, w_{j2}^t, w_{j3}^t, w_{j4}^t)$ to be the fuzzy importance weights of criterion $G_j(j = 1,2,...m)$ by decision maker E_t.
- Obtain x_{ij}, = $(a_{ij}, b_{ij}, c_{ij}, d_{ij})$, the fuzzy rating of each alternative under each criterion after using the NASM algorithm mentioned in III.
- Obtain $\tilde{N} = [nij]_{n \times m}$, the normalized fuzzy decision matrix, where

$$n_{ij} = (A_{ij}, B_{ij}, C_{ij}, D_{ij}) = \left(\frac{a_{ij}}{\max_i d_{ij}}, \frac{b_{ij}}{\max_i d_{ij}}, \frac{c_{ij}}{\max_i d_{ij}}, \frac{d_{ij}}{\max_i d_{ij}}\right) i = 1,2,$$

- Obtain the aggregated weights of each criterion $\tilde{W}_J^t = (w_{j1}^t, w_{j2}^t, w_{j3}^t, w_{j4}^t)$ where

$$w_{j1} = \min_t\left\{w_{j1}^t\right\}, w_{j2} = \sum_{t=1}^{T}\frac{w_{j2}^t}{T}, w_{j3} = \sum_{t=1}^{T}\frac{w_{j3}^t}{T}, w_{j4} = \max_t\left\{w_{j4}^t\right\}$$

- Obtain the weighted normalized fuzzy decision matrix $\tilde{A} = \begin{bmatrix} X_{11} & \cdots & X_{1m} \\ \vdots & \ddots & \vdots \\ X_{n1} & \cdots & X_{nm} \end{bmatrix}$, where

$$X_{ij} = (\alpha_{ij}, \beta_{ij}, \gamma_{ij}, \delta_{ij}) = (A_{ij} \times w_{j1}, B_{ij} \times w_{j2}, C_{ij} \times w_{j3}, D_{ij} \times w_{j4}), i = 1,2,3, \ldots n$$

- Determine the set of positive ideal and negative ideal solutions as:

$$Y_{MAX\,j} = \max(\delta_{ij}, i = 1,2,3, \ldots n)\,\forall j = 1,2,3 \ldots m$$

$$Y_{MIN\,j} = \min(\alpha_{ij}, i = 1,2,3, \ldots n)\,\forall j = 1,2,3 \ldots m$$

$$\tilde{A}_j^+ = (Y_{MAX\,j}, 1,1,1)\ \forall j = 1,2,3, \ldots m; \tilde{A}_j^- = (0,0,0, Y_{MIN\,j})\ \forall j = 1,2,3, \ldots m$$

$$FPIS = A^+ = (A_1^+, A_2^+, A_3^+, \ldots A_n^+);\ FNIS = A^- = (A_1^-, A_2^-, A_3^-, \ldots A_n^-)$$

- Calculate the fuzzy distance of each alternative from the fuzzy positive and negative ideal solutions using definition c from II.
- Obtain the aggregated fuzzy distance of each alternative from FPIS and FNIS.
- Obtain the fuzzy closeness coefficient of each alternative using definition i from 5.
- Rank the alternatives using the RM Approach.

Selection of the Bestoverlay Material for Decorating Wooden Surfaces in Interior Designing Project Using an Innovative Fuzzy Topsis Approach – an Illustrative Example: The case of an interior designing firm is discussed. Let us assume the firm has acquired a major project to design the interiors and wooden furniture of a chain of offices. The firm has an important decision to make [6]: Whether to use Veneers(V) or Laminates(L) as an overlay for the wooden surfaces.

Veneers are very thin slices of wood obtained from a tree log. Laminates, also known as decorative laminates are artificially produced materials made from paper and plastic resins. While veneers are difficult to maintain compared to laminates which are resistant to wear and tear, veneers offer an aesthetic look as they feel natural. Veneers are available in wood grain designs and have wooden appearance. Since laminates are artificially made, there are an abundant variety of designs and patterns, including natural wood grain patterns. Laminates, however, are brittle and prone to chipping. Veneers are costly as also are some branded laminates [7]. Veneers feel better to touch and have no visible seams. Veneer is a renewable resource and is timeless, in the sense that it would never become outdated. Laminates however look uniform throughout.

A team of decision makers is formed to arrive at the decision. There are three decision makers in the team:

DM1 – Senior Architect
DM2 – Customer
DM3 – Interior Designer
DM4 – Interior Designer
DM5 – Carpentry Head

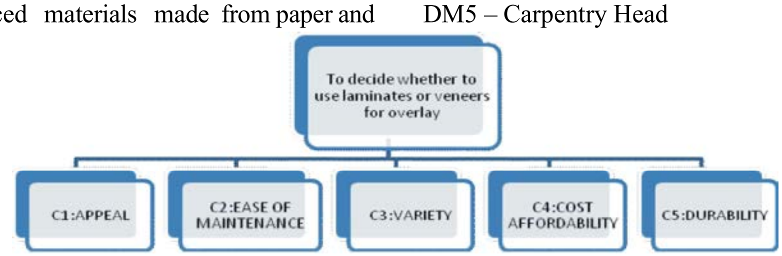

Fig. 1: Diagrammatic Representation of the Problem

Table 1: Linguistic Variables for the Importance Weight of Criteria

VERY LOW (VL)	(0,0,0.1,0.2)
LOW (L)	(0.1,0.2,0.2,0.3)
MEDIUM (M)	(0.3,0.4,0.5,0.5)
MEDIUM HIGH (MH)	(0.4,0.5,0.6,0.7)
HIGH (H)	(0.7,0.7,0.8,0.9)
VERY HIGH (VH)	(0.8,0.9,1,1)

Table 2: Linguistic Variables for the Ratings of Criteria

VERY POOR (VP)	(0,0,1,2)
POOR (P)	(1,2,3,3)
MEDIUM (M)	(3,4,4,5)
FAIR(F)	(5,6,7,8)
GOOD(G)	(7,8,8,9)
VERY GOOD(VG)	(9,9,10,10)

Table 3: Importance of Criteria by Decision Makers

CRITERIA	DM1	DM2	DM3	DM4	DM5
C1	VH	VH	VH	VH	H
C2	MH	H	M	M	H
C3	H	VH	H	H	L
C4	M	H	M	L	VL
C5	M	VH	M	M	MH

Table 4: Ratings of Alternatives by Decision Makers

	DM1		DM2		DM3		DM4		DM5	
	V	L	V	L	V	L	V	L	V	L
C1	VG	G	G	VG	VG	G	G	G	G	F
C2	F	G	F	F	F	G	M	F	F	G
C3	M	VG	G	VG	VG	VG	G	G	VG	G
C4	F	F	M	F	F	G	M	F	F	F
C5	VG	G	G	G	VG	G	VG	VG	F	G

Table 5: Calculation of ε_i Values

Decision Maker	Weight	ε_i
DM1	1	0.28
DM2	0.7	0.21
DM3	0.6	0.18
DM4	0.6	0.18
DM5	0.5	0.15

Table 6: Fuzzy Decision Matrix

Alternative	C1	C2	C3	C4	C5
V	(4.39,4.7,5.2,5.2)	(2.85,3.35,3.78,4.28)	(3.18,3.59,3.79,4.19)	(2.63,3.13,3.44,3.94)	(4.46,4.65,5.05,5.23)
L	(4.01,4.42,4.92,5)	(3.61,4.11,4.31,4.81)	(4.61,4.8,5.11,5.31)	(1.48,1.88,2.29,2.59)	(4.18,4.59,4.68,5.09)

Table 7: Calculation of Fuzzy Distance of Each Alternative from Fpis and Fnis

Alternative	Distance from Fpis	Distance from Fnis
V	(0.328,0.428,0.505,0.645)	(0.313,0.429,0.488,0.839)
L	(0.323,0.43,0.448,0.635)	(0.329,0.452,0.452,0.667)

Table 8: Calculation of Fuzzy Closeness Coefficient

Alternative	Closeness Coefficient
V	(0.28,0.47,0.54,0.67)
L	(0.33,0.49,0.5,0.66)

By applying the ranking order explained in 4, laminatesare found to bea better option to use for overlay than veneers in the current project.

CONCLUSION

The selection of the best overlay material for wooden surfaces is a common problem faced in interior designing. As the good will of the company and consequently its growth depends on its ability to satisfy customers and offer them an appealing result according to their taste, it is essential to use a scientific method to arrive at this decision. The proposed method will serve the purpose.

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