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Determination of Preferences in Auto Glass Selection Process

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ABSTRACT

Glass is a solid material with an inorganic amorphous structure, prone to fracture, defined as transparent or translucent, and usually observed in a complicated form. In auto glasses, on the other hand, transparency, that is, light transmittance is directly proportional to the colour of the glass. In auto windows, the colour of the glass is of great importance because the driver's vision is crucial due to specific light transmission rules. However, the thickness of the auto glass characterized as durable also causes different preferences in terms of customer requests. In this study, we carried out to rank the customer preferences based on customer expectations using the sales data for three years in terms of the colour and thickness of auto glass. Within the scope of the study, we proposed a trapezoidal fuzzy number integrated fuzzy entropy and fuzzy TOPSIS model to rank the alternative auto glass. A case study is also presented for illustrative purposes.

Keywords: Auto glass, MCDM, Trapezoidal fuzzy entropy, Trapezoidal fuzzy TOPSIS

INTRODUCTION

Due to their excellent temperature resistance, high strength, abrasion resistance, and good photo stability, auto glasses are widely employed in the automotive industry. Typically, auto glasses are produced utilizing high-temperature equipment that causes high-temperature creep in the glass.

Chen et al. (2010) offer a nonlinear constitutive equation to describe the creep of glasses based on the experiments. The nonlinear uniaxial constitutive equation better represents the creep process of auto glasses at high temperatures when compared to theoretical prediction and experimental evidence. Due to their strong heat and mass transfer capabilities, impinging air jets are frequently used for heating, cooling, and drying applications. The purpose of their study is to research the car glass tempering project. Experimental research presented on the heat transfer properties of heated glass plates during cooling with cooperatively positioned circular air jets (Gölcü et al., 2012). During the manufacturing process of tempered car glass, heating, and abrupt cooling are two of the most crucial procedures impacting the tempering quality. Yazıcı et al., (2015) analysed cooling times and heat transfer properties during the production of tempered glass rapid cooling process. Akcay et al. (2016) changed the cooling time and the number of broken glass particles in the tempered glass plates. This was done by conducting an auto glass tempering process at various cooling unit configurations and cooling temperatures. The well-known glass maker and finisher Glas Trosch provides premium glass products for the whole building sector as well as the auto industry. The usage of an all-glass staircase demonstrates how Glas Trosch, a forward-thinking glass manufacturer, has embraced the trend toward massive facade components. The illustration clearly shows that provided the solutions selected are adequate for dealing with glass as the principal material, big, complicated structural all-glass components can have surprisingly simple yet aesthetically pleasing features (Wälchli et al., 2012).

TRAPOZEDIAL FUZZY NUMBER AND DEFUZZIFICATION PROCESS

Different fields, including linguistics, statistics, engineering, physics, biology, and experimental sciences, utilize fuzzy theory. The fuzzy sets theory was established by Zadeh (1965). The underlying theory and the theory of multiple criteria decision-making mesh well together. It improves it and broadens its application to include uncertain data. As a result, the option to employ fuzzy rather than crisp data expressed in terms of a single number becomes available. In this section, some basic definitions of fuzzy sets, fuzzy numbers, and the defuzzification process are given.

Definition 1: The membership function $\mu_{\widetilde{A}}(x)$ of a fuzzy set $\widetilde{A}$ in the discourse universe X assigns a real integer in the range $[0,1]$ to each element x in the universe. The grade of membership of x in A is represented by the value of the function $\mu_{\widetilde{A}}(x)$ for A and x.

Definition 2: $\widetilde{A}$ positive trapezoidal fuzzy number can be defined as $\widetilde{A} = (a_1, a_2, a_3, a_4)$ and the membership function $\mu_{\widetilde{A}}(x)$ is given in Eq. (1)

$$\mu_{\widetilde{A}}(x) = \begin{cases} 0, & x < a_1 \\ \frac{x-a_1}{a_2-a_1}, & a_1 < x < a_2 \\ 1, & a_2 < x < a_3 \\ \frac{x-a_1}{a_2-a_1}, & a_3 < x < a_4 \\ 0, & x > a_4 \end{cases} \tag{1}$$

Definition 3: The process of generating a quantifiable outcome in fuzzy logic is called defuzzification. When fuzzy logic is used in industrial processes, defuzzification issues arise (Lavasani et al., 2015). The center of the area is one of the defuzzification techniques which was developed by Sugeno (1999), given in Eq. (2).

$$def(\widetilde{A}) = \frac{\int_{a_1}^{a_2} \frac{x-a_1}{a_2-a_1} x dx + \int_{a_2}^{a_3} x dx + \int_{a_3}^{a_4} \frac{a_4-x}{a_4-a_3} x dx}{\int_{a_1}^{a_2} \frac{x-a_1}{a_2-a_1} dx + \int_{a_2}^{a_3} dx + \int_{a_3}^{a_4} \frac{a_4-x}{a_4-a_3} dx} \tag{2}$$

Definition 4: Let be two positive trapezoidal fuzzy number $\widetilde{A} = (a_1, a_2, a_3, a_4)$ and $\widetilde{B} = (b_1, b_2, b_3, b_4)$ and λ is a positive real number. Some main arithmetical operations are given below

$$\widetilde{A} \oplus \widetilde{B} = [a_1 + b_1, a_2 + b_2,\ a_3 + b_3,\ \ a_4 + b_4\ ] \tag{3}$$

$$\widetilde{A} \ominus \widetilde{B} = [a_1 - b_4, a_2 - b_3,\ a_3 - b_2,\ \ a_4 - b_1\ ] \tag{4}$$

$$\widetilde{A} \otimes \lambda = [a_1\lambda,\ a_2\lambda,\ a_3\lambda,\ a_4\lambda\ ] \tag{5}$$

$$\widetilde{A} \otimes \widetilde{B} = [a_1b_1, a_2b_2,\ a_3b_3,\ \ a_4b_4\ ] \tag{6}$$

Definition 5: The distance between two positive trapezoidal fuzzy number $\widetilde{A} = (a_1, a_2, a_3, a_4)$ and $\widetilde{B} = (b_1, b_2, b_3, b_4)$ can be calculated by vertex method given in Eq. (7)

$$d\left(\widetilde{A}, \widetilde{B}\right) = \sqrt{\frac{1}{4}\left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2 + (a_4 - b_4)^2\right]}. \tag{7}$$

FUZZY ENTROPY AND FUZZY TOPSIS WITH TRAPOZEDIAL FUZZY NUMBER

The uncertainty metric is used as the information measure. Consequently, the fuzziness measurements are often known as fuzzy information measures. Fuzzy entropy is a measurement of the amount of fuzzy information obtained from a fuzzy set or fuzzy system. It is important to emphasize how fuzzy entropy differs from traditional Shannon entropy in that no probabilistic idea is required to characterize it (Al-Sharhan, 2001).

One of the well-known traditional MCDM methods, the Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), may serve as the foundation for creating alternative selection models that can successfully handle these qualities. Its foundation is the idea that the option of choice should be closest to the Positive Ideal Solution (PIS) and farthest from the Negative Ideal Solution (NIS).

Entropy With Trapezoidal Fuzzy Number

- Determine the trapezoidal fuzzy decision matrix:

$$\widetilde{X} = \begin{bmatrix} \widetilde{x}_{11} & \widetilde{x}_{12} & \cdots & \widetilde{x}_{1n} \\ \widetilde{x}_{21} & \widetilde{x}_{22} & \cdots & \widetilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{x}_{m1} & \widetilde{x}_{m2} & \cdots & \widetilde{x}_{mn} \end{bmatrix} \tag{8}$$

  where $\widetilde{x}_{ij}$ are trapezoidal fuzzy number for i^{th} alternatives j^{th} criteria, $(i = 1, 2, \ldots, m; j = 1, 2, \ldots, n)$.

- Construct the normalized fuzzy decision matrix

  Normalized trapezoidal fuzzy decision value is calculated by Eq. (9). The benefit and cost criteria in this step change the normalization process.

$$\widetilde{p}_{ij} = \frac{\widetilde{x}_{ij}}{\sum_{j=1}^{n} \widetilde{x}_{ij}} \qquad i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n \tag{9}$$

- Obtain the entropy measure of each attribute
  Trapezoidal fuzzy entropy measure of each criteria denoted by Eq. (10)
  $\widetilde{e}_j = \left(-\frac{1}{\ln(n)}\right) \sum_{i=1}^{n} \widetilde{p}_{ij} \ln \widetilde{p}_{ij} \quad i = 1,2,\ldots,m;\ j = 1,2,\ldots,n$ (10)

- Defuzzify fuzzy entropy measure of each criteria
  Defuzzification trapezoidal fuzzy entropy measure is calculated by using Eq. (2)

- Calculate entropy weight for each criteria
  Entropy weight for each criterion is calculated by using Eq. (11)

$$w_j = \frac{1 - def(\widetilde{e}_j)}{\sum_{j=1}^{n} (1 - def(\widetilde{e}_j))} \qquad j = 1,2,\ldots,n. \tag{11}$$

TOPSIS With Trapezoidal Fuzzy Number

- Construct the weighted normalized fuzzy decision matrix:
  Weighted normalized fuzzy decision matrix is $\widetilde{R} = [\widetilde{r}_{ij}]_{mn}$ where $\widetilde{r}_{ij} = w_j \widetilde{\otimes p}_{ij}$.

- Determine fuzzy positive (FPIS, A^*) and negative (FNIS, A^-) ideal solutions:
  FNIS and FPIS can be defined as $A^* = (\widetilde{r}_1^*, r_2^*, \ldots, r_n^*)$, $A^- = (\widetilde{r}_1^-, \widetilde{r}_2^-, \ldots, \widetilde{r}_n^-)$ respectively, where $\widetilde{r}_j^* = \{r_{ij4}\}$ and $\widetilde{r}_j^- = \{r_{ij1}\}$.

- Obtain the distance from FPIS and FNIS:

$$d_i^* = \sum_{j=1}^{n} d\left(\widetilde{r}_{ij}, \widetilde{r}_j^*\right) \sum_{i=1}^{n} \widetilde{p}_{ij} \ln \widetilde{p}_{ij} \qquad i = 1,2,\ldots,m \tag{12}$$

$$d_i^- = \sum_{j=1}^{n} d\left(\widetilde{r}_{ij}, \widetilde{r}_j^-\right) \sum_{i=1}^{n} \widetilde{p}_{ij} \ln \widetilde{p}_{ij} \qquad i = 1,2,\ldots,m. \tag{13}$$

- Calculate the closeness coefficient of each alternative
  The closeness coefficient of each alternative is calculated by Eq. (14)

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \tag{14}$$

The evaluation status of each provider and the ranking of all alternatives can be understood in accordance with the closeness coefficient in Eq. (14).

NUMERICAL RESULTS

We apply the proposed methodology in this section. Firstly we determine the trapozedial fuzzy scale (Table 1). Then a trapezoidal fuzzy decision matrix is determine for the alternatives (Table 2).

Table 1. Trapozedial fuzzy scale (Aliabadi, 2020).

Trapezoidal fuzzy number	Linguistic term
(0.0,0.1,0.2)	Very Low (VL)
(0.1,0.2,0.2,0.3)	Low (L)
(0.2,0.3,0.4,0.5)	Midly Low (ML)
(0.4,0.5,0.5,0.6)	Medium (M)
(0.5,0.6,0.7,0.8)	Midly High (MH)
(0.7,0.8,0.8,0.9)	High (H)
(0.8,0.9,1.0,1.0)	Very High (VH)

Table 2. Trapezoidal fuzzy decision matrix.

Alternatives	Sales (number)	Quality	Reliability
I	(26752,29789,32177,35356)	VH	H
II	(31464,37487,43267,47493)	H	ML
III	(7688,9932,12191,16343)	H	MH
IV	(575,804,1256,1987)	M	M
V	(1,7,113,329)	ML	M
VI	(5376,6622,7599,8578)	MH	M
VII	(359,707,907,2175)	M	ML
VIII	(88,195,450,816)	ML	ML
IX	(1,91,161,1332)	L	L
X	(2448,5417,6507,12666)	M	ML

Table 3. Closeness coefficient.

	d_i^*	d_i^-	$d_i^* + d_i^-$	CC_i
II	0.2317	0.3939	0.6256	0.6297
I	0.2790	0.3143	0.5933	0.5297
III	0.4449	0.1374	0.5823	0.2360
X	0.4848	0.1011	0.5860	0.1726
VI	0.4893	0.0831	0.5724	0.1451
IV	0.5368	0.0339	0.5707	0.0594
VII	0.5463	0.0247	0.5710	0.0433
VIII	0.5544	0.0150	0.5694	0.0263
V	0.5546	0.0139	0.5685	0.0244
IX	0.5583	0.0125	0.5708	0.0218

Then we calculate entrophy weights for all criteria. Entropy weight for each criterion is $w_1 = 0.8367$, $w_2 = 0.0695$, $w_3 = 0.0938$. Finally, we transferred these weights to the TOPSIS method to rank the alternatives. According to the TOPSIS ranking results, Alternative II is the best choice for the case study. However, Alternative I is the competitive alternative with the second-best ranking score. Another alternative that is not suitable for the selection process is an auto glass (Table 3).

CONCLUSION

In this paper, we developed a trapezoidal fuzzy number integrated fuzzy entropy and fuzzy TOPSIS model to rank the auto glass alternatives. Our case problem has some linguistic criteria values. Also, our problem has sales values for the sales criteria. So, we developed a trapezoidal fuzzy number integrated fuzzy entropy and fuzzy TOPSIS model to rank the auto glass alternatives in this study. The fuzzy entropy method is used to determine data-based criteria weights to reflect the problem-based specification on the criteria weigh assignment process which is the most critical stage for the TOPSIS model. As a result of these new ranking models, we easily diversification the ranking scores of the alternatives and provide useful results for the auto glass selection problem.

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