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The Selection of Beverage Cafes Using Fuzzy TOPSIS

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Abstract: Beverage Cafe business is growing too fast nowadays. Therefore, customers have many choices to choose the best cafe that suits their taste. The objectives of this study were to identify the most preferred beverage cafes by FSKM students and to evaluate the factors that influence their preferences using Fuzzy TOPSIS. This study also highlights five criteria for a cafe, namely price, taste, variety of menu, location, and service. The Fuzzy Technique for Order Performance by Similarity to Ideal Solution (FTOPSIS) was applied to solve a multicriteria decision-making (MCDM) problem. To rank all the alternatives, a similarity coefficient is calculated by calculating the distance to the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS) simultaneously. The higher the value of the closeness coefficient, the higher the ranking order of a particular beverage cafe that can satisfy consumer preferences.

Keywords: Beverage cafe, Decision making, Fuzzy TOPSIS

1 Introduction

Cafes come in a variety of styles including hipster cafes, luxury cafes, peaceful cafes, and others. Customers of the beverage cafe enjoy a variety of privileges. Some of the famous beverage cafes that are available in Kelantan are Xi Fu Tang, Starbuck, Cool blog, Kaori Cha and Tealive. These beverage cafes are located not far away from UiTM Cawangan Kelantan.

Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a method for objective and methodical evaluation of alternatives based on various criteria. TOPSIS is based on the idea that the alternative has the smallest geometric distance from the positive ideal solution (PIS) and the largest geometric distance from the negative ideal solution (NIS). TOPSIS [4] is a method for solving multicriteria decision making (MCDM) problems [13, 14].

Considering the fuzziness in the decision information and group decision-making process, linguistic variables are utilized to evaluate the weights of all criteria considered and the ratings of each alternative with respect to each criterion. We can change over the decision matrix into a fuzzy decision matrix and develop a weighted-normalized fuzzy decision matrix once the decision-makers' fuzzy ratings have been pooled. As indicated by the idea of TOPSIS, we characterize the fuzzy positive ideal arrangement (FPIS) and the fuzzy negative ideal arrangement (FNIS). Afterward, a vertex technique is applied in this paper to compute the distance between two fuzzy numbers.

By utilizing the vertex technique, we can compute the distance of each criterion from FPIS and FNIS, separately. At last, a closeness coefficient of each alternative is characterized to decide the ranking order of all alternatives. The higher value of closeness coefficient indicates that an alternative is nearer to FPIS and farther from FNIS at the same time [5].

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Many researchers were interested in determining users' decision making in fuzzy environments since fuzzy sets were introduced into MCDM [3]. To deal with fuzziness in a decision-making process, the use of MCDM approaches with fuzzy sets is recommended [9]. MCDM is also a decision-making process in which a clear agreement can be found by evaluating the different opinions of a group of specialists [1,2,6,7,10,11,12,15].

In this study, fuzzy TOPSIS is used to solve MCDM problems. As young people spend their time in restaurants to eat, socialize and study, beverage cafes have succeeded in meeting their needs and expectations. Our objectives were to identify the preferred beverage cafes of Universiti Teknologi MARA (UiTM) Machang students by using Fuzzy TOPSIS.

2 Definitions

Definition 2.1 [16]. Fuzzy Subset

Let F be a set with finite or infinite. Let $\bar{A}$ be a set contained in F. Then the set of ordered pairs $\left(x, \mu_{\bar{A}}(x)\right)$ gives the fuzzy subset $\bar{A}$ of F, where x is a component in F and $\mu_{\bar{A}}(x)$ is the degree of membership of x in F.

Definition 2.2 [16]. Fuzzy Number

A Fuzzy number is a generalization of a regular, real number. It alludes to an associated set of possible values, where every possible value has its own weight in the range of 0 and 1. A fuzzy number is thus a special case of a convex, normalized fuzzy set of the real line.

Definition 2.3 [17]. Triangular Fuzzy Number

Let r, s and u be real numbers with $r < s < u$. then Triangular Fuzzy Number (TFN), $A = (r, s, u)$ is a fuzzy number with membership function:

$$f(x) = \begin{cases} \dfrac{x-r}{s-r}, & u \le x \le s \\ \dfrac{u-x}{u-s}, & s \le x \le r \\ 0, & x < r, x > u \end{cases}$$

3 Methodology

In this paper, fuzzy TOPSIS method was applied in the decision-making process. This technique is entirely appropriate for taking care of the decision-making issue under fuzzy environment. There are nine steps involved in this study as cited in [5].

Step 1: Form a decision-making committee, then establish the evaluation criteria.
A group of decision-makers is established consist of five decision-makers such as DR_1, DR_2, DR_3, DR_4 and DR_5. Five alternatives are identified as B_1, B_2, B_3, B_4 and B_5 with five criteria such as C_1, C_2, C_3, C_4 and C_5.

Step 2: Assign a fuzzy number to each of the criteria and alternatives

The importance weights of the criteria and the ratings for the alternatives are considered as linguistic variables. These linguistic variables can be expressed in positive triangular fuzzy numbers as Tables 1 and 2 [18].

Table 1: Linguistics variables for importance weight of each criterion

Scale	**Triangular fuzzy number**
Very Low (VL)	(0, 0, 0.1)
Low (L)	(0, 0.1,0.3)
Medium Low (ML)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
Medium High (MH)	(0.5, 0.7, 0.9)
High (H)	(0.7, 0.9, 1.0)
Very High (VH)	(0.9, 1.0, 1.0)

Table 2: Linguistic variables for the ratings

Scale	**Triangular fuzzy number**
Very Poor (VP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Medium Poor (MP)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Medium Good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very Good (VG)	(9, 10, 10)

Step 3: Aggregate the weights of the criteria to get the aggregate fuzzy weight $\bar{w}_j$ of the criterion C_j and summarize the opinion of the decision maker to get the aggregate fuzzy rating $\bar{x}_{ij}$ of the alternative B_i under the criterion C_j.

Then the aggregate fuzzy numbers for the alternatives and aggregate fuzzy weights [15] for the criteria are given as follows:

$$\bar{x}_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right); i = 1, 2, ..., m, \ \ j = 1, 2, ..., n \tag{1}$$

where $a_{ij} = \min_k \left\{a^k{}_{ij}\right\}, b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b^k{}_{ij}, c_{ij} = \max_k \left\{c^k{}_{ij}\right\}$.

$$\bar{w}_j = \left(w_{j1}, w_{j2}, w_{j3}\right), j = 1, 2, ..., n \tag{2}$$

where $w_{j1} = \min_k \left\{w^k{}_{j1}\right\}, w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w^k{}_{j2}, w_{j3} = \max_k \left\{w^k{}_{j3}\right\}$.

where $\bar{w}_j$ and $\bar{x}_{ij}$ are characterized as linguistic values that can be expressed by triangular fuzzy numbers.

Step 4: Construct the fuzzy decision matrix and the fuzzy weight.

The fuzzy rating $\bar{x}_{ij}$ of the alternative B_i under the criterion C_j can be expressed in the form of matrix format as follows:

$$\bar{D} = \begin{pmatrix} \bar{x}_{11} & \bar{x}_{12} & \cdots & \bar{x}_{1n} \\ \bar{x}_{21} & \bar{x}_{22} & \cdots & \bar{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \bar{x}_{m1} & \bar{x}_{m2} & \cdots & \bar{x}_{mn} \end{pmatrix} \quad (3)$$

$$\bar{W} = \left(\bar{w}_{j1} \quad \bar{w}_{j2} \quad \bar{w}_{j3} \quad \bar{w}_{j4} \quad \bar{w}_{j5} \right) \quad (4)$$

where $\bar{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ and $\bar{w}_j = \left(w_{j1}, w_{j2}, w_{j3}\right)$; $i = 1, 2, ..., m, \quad j = 1, 2, ..., n$ can be approximated by the positive triangular fuzzy numbers.

Step 5: Compute the weighted normalized fuzzy decision matrix and normalized fuzzy decision matrix:

Normalizing:

$$\bar{R} = [\bar{r}_{ij}]_{m \times n}, i = 1, 2, ..., m; j = 1, 2, ..., n \quad (5)$$

$$\bar{r}_{ij} = \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+}\right), j \in B; \quad (6)$$

$$\bar{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), j \in C; \quad (7)$$

where B and C are the set of benefit criteria and cost criteria respectively

$c_j^+ = \max_i c_{ij}, j \in B;$

$a_j^- = \min_i a_{ij}, j \in C;$

Weighted Normalized Fuzzy Decision Matrix:

$$\bar{V} = [\bar{v}_{ij}]_{m \times n}, \quad i = 1, 2, 3, ..., m, \quad j = 1, 2, 3, ..., n \quad (8)$$

where $\bar{v}_{ij} = \bar{r}_{ij} \times \bar{w}_j$

Then the elements of $\bar{v}_{ij}$ are normalized positive triangular fuzzy numbers and their ranges belong to the closed interval [0,1].

Step 6: Define the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS) such that:

Based on the weighted normalized fuzzy decision matrix, normalized positive triangular fuzzy number can also approximate the elements $\bar{v}_{ij}, \forall i, j$. Define that FPIS is B^{+} and FNIS is B^{-}.

$$B^{+} = \left(\bar{v}_1^{+}, \bar{v}_2^{+}, \ldots, \bar{v}_n^{+}\right), \tag{9}$$

$$B^{-} = \left(\bar{v}_1^{-}, \bar{v}_2^{-}, \ldots, \bar{v}_n^{-}\right), \tag{10}$$

Where $\bar{v}_j^{+} = \max_i \{v_{ij3}\}$ and $\bar{v}_j^{-} = \min_i \{v_{ij1}\}$, $i = 1, 2, \ldots, m, \quad j = 1, 2, 3, \ldots, n$

Step 7: Determine the distance of each alternative of FPIS and FNIS, which can be calculated respectively using Fuzzy TOPSIS.

Let $\bar{m} = \left(m_1, m_2, m_3, m_4\right)$, and $\bar{n} = \left(n_1, n_2, n_3, n_4\right)$ be two triangular fuzzy numbers, then the vertex method is defined to calculate the distance between them as:

$$e(\bar{m}, \bar{n}) = \sqrt{\frac{1}{3}\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right]} \tag{11}$$

The distance of each weighted alternative:

$$e_i^{+} = \sum_{j=1}^{n} e\left(\bar{v}_{ij}, \bar{v}_j^{+}\right), \; i = 1, 2, \ldots, m, \tag{12}$$

$$e_i^{-} = \sum_{j=1}^{n} e\left(\bar{v}_{ij}, \bar{v}_j^{-}\right), \; i = 1, 2, \ldots, m \tag{13}$$

Step 8: Calculate the closeness coefficient of each alternative and defuzzification of each criterion.

Once the e_i^{+}, e_i^{-} of each alternative $B_i = \left(i = 1, 2, \ldots, m\right)$ is determined, a closeness coefficient is created to determine the ranking of all alternatives. The closeness coefficient (CC_i) of each alternative (cafe) is calculated as follows:

$$CC_i = \frac{e_i^{-}}{e_i^{-} + e_i^{+}} \text{ where } i = 1, 2, \ldots, m. \tag{13}$$

Step 9: Rank the alternatives and criteria.

According to the CC_i, the higher the value of closeness coefficient, the higher the ranking order of the beverage cafes that can satisfy consumer preferences.

4 Implementation

There were five students from the Faculty of Computer and Mathematical Sciences (FSKM) at UiTM Cawangan Kelantan became the decision-makers namely DR_1, DR_2, DR_3, DR_4, and DR_5. There were five beverage cafes as $B_1 =$ Starbucks, $B_2 =$ Tealive, $B_3 =$ Coolblog, $B_4 =$ Kaori Cha, and $B_5 =$ Xi Fu Tang. The criteria involved were $C_1 =$ price, $C_2 =$ taste, $C_3 =$ menu variety, $C_4 =$ location, and $C_5 =$ service.

The decision-makers were used the linguistic rating variables (shown in Table 2) to evaluate the rating of alternatives with respect to each criterion and present it in Table 3. The decision-makers were used the linguistic weighting variables (shown in Table 2) to assess the importance of the criteria as shown in Table 4.

Table 3: Alternative ratings by decision makers under all criteria.

		DR_1	DR_2	DR_3	DR_4	DR_5
C_1	B_1	P	M	M	P	M
	B_2	P	G	G	M	G
	B_3	M	G	G	G	VG
	B_4	P	G	M	M	P
	B_5	P	G	M	M	VP
C_2	B_1	G	VG	G	VG	P
	B_2	VG	M	VG	VG	M
	B_3	VG	M	VG	G	VG
	B_4	G	G	G	M	VP
	B_5	VG	G	VG	M	VP
C_3	B_1	VG	M	G	M	M
	B_2	VG	M	G	M	G
	B_3	VG	G	G	M	VG
	B_4	G	G	G	M	P
	B_5	VG	G	G	M	VP
C_4	B_1	VP	P	M	M	M
	B_2	VP	G	G	VG	G
	B_3	M	G	G	VG	VG
	B_4	P	M	G	M	P
	B_5	M	M	M	M	VP
C_5	B_1	G	G	G	G	G
	B_2	G	M	G	G	M
	B_3	G	VG	VG	G	VG
	B_4	G	G	M	M	M
	B_5	G	G	VG	M	P

Table 4: The importance weight of the criteria.

Criteria	DR_1	DR_2	DR_3	DR_4	DR_5
C_1	H	M	H	VH	VH
C_2	H	M	H	VH	VH
C_3	H	M	VH	H	VH
C_4	H	VL	VH	M	VH
C_5	H	M	VH	H	VH

In this study, the linguistic term for alternative rating and criteria weightage needs to be converted into fuzzy numbers using the scale shown in Table 1 and Table 2. Table 5 and Table 6 shows the criteria weightage and alternative ratings in fuzzy number respectively.

Table 5: Criteria weightage in fuzzy number.

Criteria	DR_1	DR_2	DR_3	DR_4	DR_5
C_1	H (0.7,0.9,1.0)	M (0.3,0.5,0.7)	H (0.7,0.9,1.0)	VH (0.9,1.0,1.0)	VH (0.9,1.0,1.0)
C_2	H (0.7,0.9,1.0)	M (0.3,0.5,0.7)	H (0.7,0.9,1.0)	VH (0.9,1.0,1.0)	VH (0.9,1.0,1.0)
C_3	H (0.7,0.9,1.0)	M (0.3,0.5,0.7)	VH (0.9,1.0,1.0)	H (0.7,0.9,1.0)	VH (0.9,1.0,1.0)
C_4	H (0.7,0.9,1.0)	VL (0,0,0.1)	VH (0.9,1.0,1.0)	M (0.3,0.5,0.7)	VH (0.9,1.0,1.0)
C_5	H (0.7,0.9,1.0)	M (0.3,0.5,0.7)	VH (0.9,1.0,1.0)	H (0.7,0.9,1.0)	VH (0.9,1.0,1.0)

Table 6: Alternative ratings in fuzzy number

		DR_1	DR_2	DR_3	DR_4	DR_5
C_1	B_1	P (0,1,3)	M (3,5,7)	M (3,5,7)	P (0,1,3)	M (3,5,7)
	B_2	P (0,1,3)	G (7,9,10)	G (7,9,10)	M (3,5,7)	G (7,9,10)
	B_3	M (3,5,7)	G (7,9,10)	G (7,9,10)	G (7,9,10)	VG (9,10,10)
	B_4	P (0,1,3)	G (7,9,10)	M (3,5,7)	M (3,5,7)	P (0,1,3)
	B_5	P (0,1,3)	G (7,9,10)	M (3,5,7)	M (3,5,7)	VP (0,0,1)
C_2	B_1	G (7,9,10)	VG (9,10,10)	G (7,9,10)	VG (9,10,10)	P (0,1,3)
	B_2	VG (9,10,10)	M (3,5,7)	VG (9,10,10)	VG (9,10,10)	M (3,5,7)
	B_3	VG (9,10,10)	M (3,5,7)	VG (9,10,10)	G (7,9,10)	VG (9,10,10)
	B_4	G (7,9,10)	G (7,9,10)	G (7,9,10)	M (3,5,7)	VP (0,0,1)
	B_5	VG (9,10,10)	G (7,9,10)	VG (9,10,10)	M (3,5,7)	VP (0,0,1)
C_3	B_1	VG (9,10,10)	M (3,5,7)	G (7,9,10)	M (3,5,7)	M (3,5,7)
	B_2	VG (9,10,10)	M (3,5,7)	G (7,9,10)	M (3,5,7)	G (7,9,10)
	B_3	VG (9,10,10)	G (7,9,10)	G (7,9,10)	M (3,5,7)	VG (9,10,10)
	B_4	G (7,9,10)	G (7,9,10)	G (7,9,10)	M (3,5,7)	P (0,1,3)
	B_5	VG (9,10,10)	G (7,9,10)	G (7,9,10)	M (3,5,7)	VP (0,0,1)
C_4	B_1	VP (0,0,1)	P (0,1,3)	M (3,5,7)	M (3,5,7)	M (3,5,7)
	B_2	VP (0,0,1)	G (7,9,10)	G (7,9,10)	VG (9,10,10)	G (7,9,10)
	B_3	M (3,5,7)	G (7,9,10)	G (7,9,10)	VG (9,10,10)	VG (9,10,10)
	B_4	P (0,1,3)	M (3,5,7)	G (7,9,10)	M (3,5,7)	P (0,1,3)
	B_5	M (3,5,7)	M (3,5,7)	M (3,5,7)	M (3,5,7)	VP (0,0,1)
C_5	B_1	G (7,9,10)	G (7,9,10)	G (7,9,10)	G (7,9,10)	G (7,9,10)
	B_2	G (7,9,10)	M (3,5,7)	G (7,9,10)	G (7,9,10)	M (3,5,7)
	B_3	G (7,9,10)	VG (9,10,10)	VG (9,10,10)	G (7,9,10)	VG (9,10,10)
	B_4	G (7,9,10)	G (7,9,10)	M (3,5,7)	M (3,5,7)	M (3,5,7)
	B_5	G (7,9,10)	G (7,9,10)	VG (9,10,10)	M (3,5,7)	P (0,1,3)

The aggregate fuzzy numbers for the alternatives and aggregate fuzzy weights for each criterion can be computed using equations (1) and (2). Then, expressed them in the form of a matrix in the format as follows:

$$\bar{D}=\begin{pmatrix}(0,3.4,7) & (0,7.8,10) & (3,6.8,10) & (0,3.2,7) & (7,9,10)\\ (0,6.6,10) & (3,8.8,10) & (3,7.6,10) & (0,7.4,10) & (3,7.4,10)\\ (3,8.4,10) & (3,8.8,10) & (3,8.6,10) & (3,8.6,10) & (7,9.6,10)\\ (0,4.2,10) & (0,6.4,10) & (0,6.6,10) & (0,4.2,10) & (3,6.6,10)\\ (0,4,10) & (0,6.8,10) & (0,6.6,10) & (0,4,7) & (0,6.8,10)\end{pmatrix}$$

$$\bar{W}=\big((0.3,0.86,1.0)\quad(0.3,0.86,1.0)\quad(0.3,0.86,1.0)\quad(0,0.68,1.0)\quad(0.3,0.86,1.0)\big)$$

Table 7 shows the normalized fuzzy decision matrix. The goal of the normalization approach is to maintain the property that the ranges of the normalized triangular fuzzy numbers are between 0 and 1. As a result, the value of alternatives B_1 in terms of criteria C_1 is (0,0.34,0.7), as determined by equations (6) and (7). Since all criteria are benefit criteria, each B_1 in C_1 is divided by the highest value in C_1 for all alternatives. The same method was used for the rest of the alternatives.

Table 7: Normalized fuzzy decision matrix

Criteria	C_1	C_2	C_3	C_4	C_5
B_1	$\left(\frac{0}{10},\frac{3.4}{10},\frac{7}{10}\right)$	$\left(\frac{0}{10},\frac{7.8}{10},\frac{10}{10}\right)$	$\left(\frac{3}{10},\frac{6.8}{10},\frac{10}{10}\right)$	$\left(\frac{0}{10},\frac{3.2}{10},\frac{7}{10}\right)$	$\left(\frac{7}{10},\frac{9}{10},\frac{10}{10}\right)$
B_2	$\left(\frac{0}{10},\frac{6.6}{10},\frac{10}{10}\right)$	$\left(\frac{3}{10},\frac{8.8}{10},\frac{10}{10}\right)$	$\left(\frac{3}{10},\frac{7.6}{10},\frac{10}{10}\right)$	$\left(\frac{0}{10},\frac{7.4}{10},\frac{10}{10}\right)$	$\left(\frac{3}{10},\frac{7.4}{10},\frac{10}{10}\right)$
B_3	$\left(\frac{3}{10},\frac{8.4}{10},\frac{10}{10}\right)$	$\left(\frac{3}{10},\frac{8.8}{10},\frac{10}{10}\right)$	$\left(\frac{3}{10},\frac{8.6}{10},\frac{10}{10}\right)$	$\left(\frac{3}{10},\frac{8.6}{10},\frac{10}{10}\right)$	$\left(\frac{7}{10},\frac{9.6}{10},\frac{10}{10}\right)$
B_4	$\left(\frac{0}{10},\frac{4.2}{10},\frac{10}{10}\right)$	$\left(\frac{0}{10},\frac{6.4}{10},\frac{10}{10}\right)$	$\left(\frac{0}{10},\frac{6.6}{10},\frac{10}{10}\right)$	$\left(\frac{0}{10},\frac{4.2}{10},\frac{10}{10}\right)$	$\left(\frac{3}{10},\frac{6.6}{10},\frac{10}{10}\right)$
B_5	$\left(\frac{0}{10},\frac{4}{10},\frac{10}{10}\right)$	$\left(\frac{0}{10},\frac{6.8}{10},\frac{10}{10}\right)$	$\left(\frac{0}{10},\frac{6.6}{10},\frac{10}{10}\right)$	$\left(\frac{0}{10},\frac{4}{10},\frac{7}{10}\right)$	$\left(\frac{0}{10},\frac{6.8}{10},\frac{10}{10}\right)$

The normalized fuzzy decision matrix is given by

$$\bar{R}=\begin{pmatrix}(0,0.34,0.7) & (0,0.78,1) & (0.3,0.68,1) & (0,0.32,0.7) & (0.7,0.9,1)\\ (0,0.66,1) & (0.3,0.88,1) & (0.3,0.76,1) & (0,0.74,1) & (0.3,0.74,1)\\ (0.3,0.84,1) & (0.3,0.88,1) & (0.3,0.86,1) & (0.3,0.86,1) & (0.7,0.96,1)\\ (0,0.42,1) & (0,0.64,1) & (0,0.66,1) & (0,0.42,1) & (0.3,0.66,1)\\ (0,0.4,1) & (0,0.68,1) & (0,0.66,1) & (0,0.4,0.7) & (0,0.68,1)\end{pmatrix}$$

The weighted normalized fuzzy decision matrix was calculated using equation (8). The matrix is formed as

$$\bar{V}=\begin{pmatrix}(0,0.292,0.7) & (0,0.671,1) & (0.09,0.585,1) & (0,0.218,0.7) & (0.21,0.774,1)\\ (0,0.568,1) & (0.09,0.757,1) & (0.09,0.654,1) & (0,0.503,1) & (0.09,0.636,1)\\ (0.09,0.722,1) & (0.09,0.757,1) & (0.09,0.74,1) & (0,0.585,1) & (0.21,0.826,1)\\ (0,0.361,1) & (0,0.55,1) & (0,0.568,1) & (0,0.286,1) & (0.09,0.568,1)\\ (0,0.344,1) & (0,0.585,1) & (0,0.568,1) & (0,0.272,0.7) & (0,0.585,1)\end{pmatrix}$$

Then, choose the maximum value from each column, B^{+} and the minimum value from each column, B^{-} as shown in Table 8.

Table 8: Minimum value, B^{-} and maximum value B^{+}

Criteria	C_1	C_2	C_3	C_4	C_5
B_1	(0,0.292,0.7)	(0,0.671,1)	(0.09,0.5851,1)	(0,0.218,0.7)	(0.21,0.774,1)
B_2	(0,0.568,1)	(0.09,0.757,1)	(0.09,0.654,1)	(0,0.503,1)	(0.09,0.636,1)
B_3	(0.09,0.722,1)	(0.09,0.757,1)	(0.09,0.74,1)	(0,0.585,1)	(0.21,0.826,1)
B_4	(0,0.361,1)	(0,0.55,1)	(0,0.568,1)	(0,0.286,1)	(0.09,0.568,1)
B_5	(0.0344,1)	(0,0.585,1)	(0,0.568,1)	(0,0.272,0.7)	(0,0.585,1)
B^{+}	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
B^{-}	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)

From equation (10), the distance of each criterion from FPIS and FNIS for alternative, B_1 was calculated as follows

$$e\left(B_1^{+}C_1\right)=\sqrt{\frac{1}{3}\left[(0-1)^2+(0.292-1)^2+(0.7-1)^2\right]}=0.728$$

$$e\left(B_1^{+}C_2\right)=\sqrt{\frac{1}{3}\left[(0-1)^2+(0.671-1)^2+(1-1)^2\right]}=0.608$$

$$e\left(B_1^{+}C_3\right)=\sqrt{\frac{1}{3}\left[(0.09-1)^2+(0.585-1)^2+(1-1)^2\right]}=0.577$$

$$e\left(B_1^{+}C_4\right)=\sqrt{\frac{1}{3}\left[(0-1)^2+(0.218-1)^2+(0.7-1)^2\right]}=0.753$$

$$e\left(B_1^{+}C_5\right)=\sqrt{\frac{1}{3}\left[(0.21-1)^2+(0.774-1)^2+(1-1)^2\right]}=0.474$$

$$e\left(B_1^{-}C_1\right)=\sqrt{\frac{1}{3}\left[(0-0)^2+(0.292-0)^2+(0.7-0)^2\right]}=0.438$$

$$e\left(B_1^{-}C_2\right)=\sqrt{\frac{1}{3}\left[(0-0)^2+(0.671-0)^2+(1-0)^2\right]}=0.695$$

$$e\left(B_1^{-}C_3\right)=\sqrt{\frac{1}{3}\left[(0.09-0)^2+(0.585-0)^2+(1-0)^2\right]}=0.671$$

$$e\left(B_1^{-}C_4\right)=\sqrt{\frac{1}{3}\left[(0-0)^2+(0.218-0)^2+(0.7-0)^2\right]}=0.423$$

$$e\left(B_1^{-}C_5\right)=\sqrt{\frac{1}{3}\left[(0.21-0)^2+(0.774-0)^2+(1-0)^2\right]}=0.740$$

The same calculations were used to find the other values in Table 9 and Table 10.

Table 9: Distance of criteria of each alternative from FPIS

Criteria	C_1	C_2	C_3	C_4	C_5
B_1	0.728	0.608	0.577	0.753	0.474
B_2	0.629	0.544	0.562	0.645	0.566
B_3	0.549	0.544	0.546	0.625	0.467
B_4	0.685	0.633	0.629	0.709	0.582
B_5	0.690	0.625	0.629	0.735	0.625

Table 10: Distance of criteria of each alternative from FNIS

Criteria	C_1	C_2	C_3	C_4	C_5
B_1	0.438	0.695	0.671	0.423	0.740
B_2	0.664	0.726	0.692	0.646	0.686
B_3	0.714	0.726	0.720	0.669	0.759
B_4	0.614	0.659	0.664	0.600	0.666
B_5	0.611	0.669	0.664	0.434	0.669

The closeness coefficient for each alternative was calculated using equation (13) and the values from Table 9 and Table 10.

$$CC_1 = \frac{2.967}{2.967 + 3.14} = 0.486, \quad CC_2 = \frac{3.414}{3.414 + 2.945} = 0.537, \quad CC_3 = \frac{3.588}{3.588 + 2.732} = 0.568,$$

$$CC_4 = \frac{3.203}{3.203 + 3.238} = 0.497, \quad CC_5 = \frac{3.046}{3.046 + 3.304} = 0.480,$$

Table 11: Closeness coefficients of all alternatives

	e_i^+	e_i^-	CC_i
B_1	3.14	2.967	0.486
B_2	2.945	3.414	0.537
B_3	2.732	3.588	0.568
B_4	3.238	3.203	0.497
B_5	3.304	3.046	0.480

5 Results

According to the values of CC_i in Table 11, the ranking order of the beverage cafes can be decided as shown in Table 12.

Table 12: Ranking of alternatives

	Cafe	CC_i	Ranking order
B_3	Cool blog	0.568	1
B_2	Tealive	0.537	2
B_4	Kaori Cha	0.497	3
B_1	Starbucks	0.486	4
B_5	Xi Fu Tang	0.480	5

The beverage cafe with highest value of CC_i was Cool blog with a score of 0.568. Cool blog seems to be the most preferred among FSKM students at UiTM Cawangan Kelantan, followed by Tealive with a score of 0.537. Kaori Cha was in the third place with a score of 0.497. Starbucks was fourth in this survey with a score of 0.486. The cafe with the lowest score was Xi Fu Tang, with a score of 0.4173.

6 Conclusions

The aim of this study was to rank the beverage cafes preferred by FSKM students at UiTM Cawangan Kelantan (UiTMCK). The alternatives included in this research were Starbucks, Tealive, Cool blog, Kaori Cha and Xi Fu Tang. Cool blog has dominated the beverage market among the students of UiTMCK as it is the most popular among the students. Five important criteria were considered, namely price, taste, menu variety, location, and service.

The research findings can help existing beverage cafes to understand the needs of UiTMCK students and improve their service. Since this study focuses only on students' views, the study will be more reliable if the respondents are expanded to include people from different levels.

Apart from this, it is suggested that this study is evaluated by the beverage industry. Future researchers could conduct a study on beverage cafe selection using other fuzzy MCDM such as fuzzy AHP.

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