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# Supplier Ranking in Dental Sector Using Integrated Fuzzy (AHP-TOPSIS)

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## HIGHLIGHTS

- The study identified the evaluation criteria that govern an accurate assessment of dental composite fillings suppliers.
- The F-AHP and F-TOPSIS methods are used to rank the suppliers.
- The result of the criteria evaluation indicated that quality is the most important criterion, followed by esthetic and durability criteria

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## ABSTRACT

Choosing a suitable supplier of materials and equipment in the healthcare sector is essential because it directly affects the patient's health and the organization's effectiveness and quality of services. Moreover, studies on supplier ranking are few in the field of health, particularly in the dental sector. For this purpose, an integrated fuzzy (AHP-TOPSIS) model has been developed for supplier ranking in the dental sector. The F-AHP is used to evaluate the importance of criteria, and then the F-TOPSIS method is applied to the supplier ranking process. A real case study is conducted on dental composite filling suppliers. Six evaluation criteria are identified, and five potential suppliers are selected through a direct interview with a group of experts. Then a questionnaire is applied to 12 experts (dentists) to rate the importance of evaluation criteria and to evaluate suppliers based on evaluation criteria. Evaluating the importance of criteria using F-AHP indicated that quality is the most important criterion. It has a weight of 0.22, followed by esthetic and durability with a weight of 0.21 for both. Moreover, the result of ranking using F-TOPSIS indicated that supplier A5 is the top supplier with a value of $(CC_i)$ (0.532).

## 1. Introduction

The dental unit is considered one of the main parts of the healthcare sector, as they fall within the concept of service organizations, in which the service (treatment) is provided to the patient by the dentist through using dental materials and equipment (fillings materials, impression materials, diagnosis tools, dental chair and so on). Therefore, selecting the right materials or equipment for a dental clinic is important. It directly affects patient satisfaction and the dentist's comfort while providing the service and suitable treatment. The process of supplier selection for dental materials is a multi-criteria decision-making (MCDM) problem, which involves various criteria that need to be evaluated by experts (dentists). On the other hand, criteria evaluation is carried out by obtaining the importance of criteria through decision-makers or expert judgments. The criteria evaluated by the experts' subjective decisions are subject to ambiguity, uncertainty, and subjectivity; thus, to overcome this problem, the fuzzy set theory is used.

According to previous studies, there are some articles about supplier ranking in the health field. Erdebilli et al. [1] developed supplier ranking in the dental sector for orthodontic brackets supplier selection, which used an intuitionistic fuzzy set with the TOPSIS method. Khumpang et al. [2] used the Rank Order Centroid method and Fuzzy TOPSIS method for medical equipment supplier selection for a hospital in Thailand. Rezahoseini et al. [3] used the Data Envelopment Analysis (DEA) model to find the initial ranking for sustainable suppliers. Then, the multi-attributed utility theory (MAUT) was used to introduce the most important criteria for selecting sustainable medical equipment suppliers. On the other side, various articles used MCDM techniques in different fields; Huseyinozder [4] used (AHP) and Preference Ranking Organization METHods for Enrichment Evaluations (PROMETHEE) method to find a suitable supplier for buying equipment which is used to produce a gas mask. Kumar et al. [5] used an integrated fuzzy-TOPSIS model for raw materials supplier selection in a small-scale steel manufacturing unit in India. Wang et al. [6] proposed an MCDM model using a hybrid of SCOR metrics, AHP, and TOPSIS approaches for supplier selection in the gas and oil industry. Gündüz et al. [7] considered the fuzziness in the group decision-making process to



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deal with supplier selection of textile manufacturing firm, which used the fuzzy-TOPSIS method for obtaining supplier performance rankings Torkayesh et al. [8] Used an MCDM based on Best Worst method and WASPAS model to determine the weights of criteria to supplier selection in the digital supply chain for an online retail shop in Iran. On the other side, some articles applied single methods where the articles [9,10], and [11] used a single F-AHP method, and the articles [12,13], and [14] applied a single F-TOPSIS method for supplier ranking. Therefore, this study performed the integrated F-AHP and F-TOPSIS models to rank the suppliers in the dental sector.

The study's objective is to identify the evaluation criteria that govern an accurate assessment of suppliers in the dental sector due to the scarcity of studies in this field. Therefore, this study is structured after the introduction, which includes a literature review as follows: The study's methodology in the second part. The application (case study) is in the third part, and the conclusion is in the fourth part.

## 2. Methodology

The supplier ranking model is developed using integrated fuzzy (AHP-TOPSIS) to rank the effective suppliers in the dental field. Figure 1 shows the flowchart of the methodology adopted in this study. It consists of five main steps: (1) defining the problem, (2) collecting data from an expert through a questionnaire, (3) evaluating the importance of criteria using F-AHP, (4) Ranking the alternatives using F-TOPSIS, (5) decision making by the decision maker. As shown in Figure 1, the model of the supplier ranking process includes two MCDM methods integrated with fuzzy set theory. Therefore, the adopted F-MCDM methods are detailed in the following subsections.

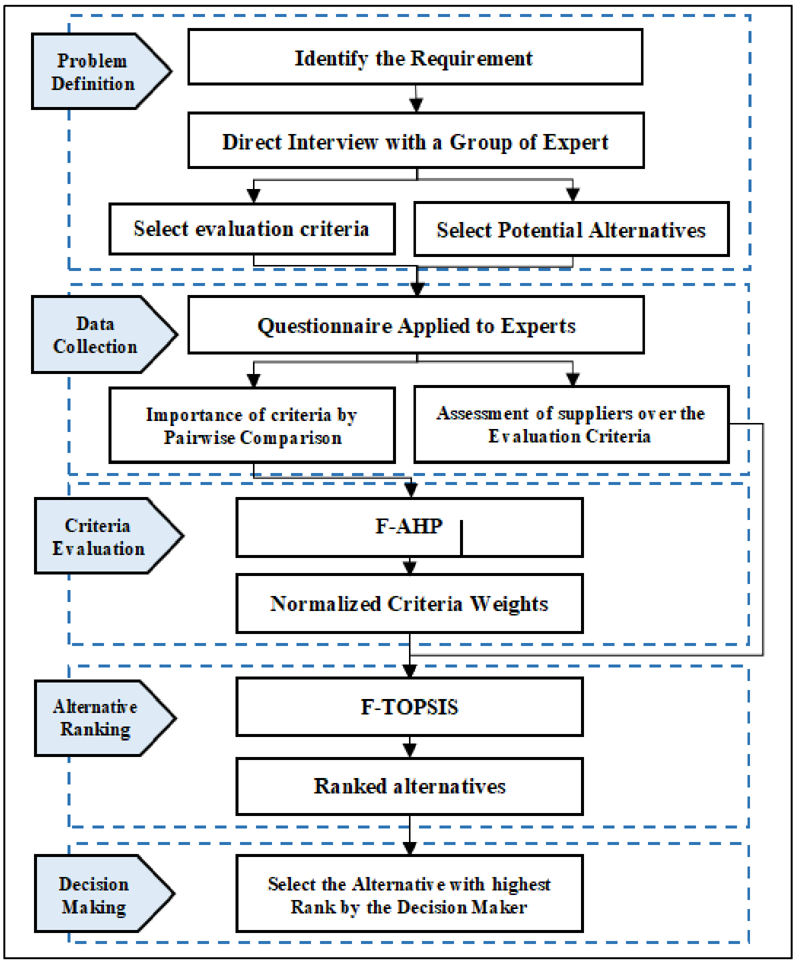


**Figure 1:** Integrated fuzzy (AHP-TOPSIS) supplier ranking model

### 2.1 Fuzzy AHP

AHP is a broadly used MCDM technique for criteria evaluation and alternatives ranking introduced by Saaty [15]. Therefore, the fuzzy-AHP approach of Buckley's method [16] will be detailed for the criteria evaluation process:

1) Establish fuzzy linguistic scales; in this study, fuzzy triangular numbers (TFN) are used to deal with the related ambiguity of linguistic scales. The expert's linguistic scales used for criteria evaluation are (equal importance, slightly important, important, fairly important, and very important), determining each criterion's degree of importance. The numerical values of TFN are listed in Table 1.

**Table 1:** Preference linguistic scale

| Symbol | Linguistic Scale | Fuzzy Scale (l, m, u) | Reciprocal Fuzzy Scale $(\frac{1}{u}, \frac{1}{m}, \frac{1}{l})$ |
|---|---|---|---|
| EI | Equal Importance | (1, 1, 3) | (1/3, 1, 1) |
| SI | Slightly Important | (1, 3, 5) | (1/5, 1/3, 1) |
| I | Important | (3, 5, 7) | (1/7, 1/5, 1/3) |
| FI | Fairly Important | (5, 7, 9) | (1/9, 1/7, 1/5) |
| VI | Very Important | (7, 9, 9) | (1/9, 1/9, 1/7) |

2) Establish fuzzy pairwise comparison matrices for evaluating the criteria. Suppose $i = \{1, 2, \ldots, n\}$ is the number of rows, and $j = \{1, 2, \ldots, m\}$ is the number of columns, where (n=m). Thus, the extent analysis values (M) for each cell will be as follows:

$$M_{gi}^1, M_{gi}^2, \ldots, M_{gi}^m, i = 1,2, \ldots, n$$

Where, $M_{gi}^j$ are $(g^{th})$ expert or decision maker's ratings of row criterion $(i^{th})$ over column criterion $(j^{th})$, and all are (TFN).

3) Aggregation of expert evaluations, using the geometric mean through the aggregation of individual judgment (AIJ) technique, if the evaluation is made by more than one expert, as in Equation (1). Where g = (1, 2… G) is the number of experts.

$$M_i^j = \left(\prod_{g=1}^{G} M_{gi}^j\right)^{\frac{1}{G}} \quad (1)$$

4) Criteria evaluation using the Fuzzy AHP (Buckley's method [16]), which calculates the geometric mean of the fuzzy values of each criterion, by the following steps:

a) Calculation of the fuzzy geometric mean value $(R_i)$ of $i^{th}$ criterion, as in Equation 2, where $R_i$ are (TFN):

$$R_i = \left[\prod_{j=1}^{m} M_i^j\right]^{1/m} \quad (2)$$

b) Calculation of the fuzzy weights of $i^{th}$ criterion

$$\widetilde{w}_i = R_i \times (R_1 + R_2 + \cdots + R_n)^{-1} \quad (3)$$

Where:
$R_1 + R_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$ and,
$R^{-1} = (l, m, u)^{-1} = (\frac{1}{u}, \frac{1}{m}, \frac{1}{l})$
$\widetilde{w}_i = (l, m, u)$, are (TFN)
$n$ is the number of criteria

c) Calculation of the non-fuzzy weights of $i^{th}$ the criterion by using the center of area (COA) method:

$$w_i = \frac{\widetilde{w}_{i(l+m+u)}}{3} \quad (4)$$

d) Calculation of normalized criteria weights through normalizing the non-fuzzy weights using the Equation:

$$w_i' = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (5)$$

The normalized criteria weights are obtained through the normalization process using Equation 5, which is then used in supplier ranking.

## 2.2 Fuzzy TOPSIS

The Fuzzy-TOPSIS method is one of the popular methods used for alternative ranking, which was introduced by [17]. The following steps are carried out for the alternative ranking process using the Fuzzy TOPSIS method:

1) Establish the decision matrix; the decision-makers give a comparative score for the alternatives over each criterion based on the facts and/or subjective data, using the fuzzy linguistic scales. The numerical values of TFN are listed in Table 2.

**Table 2:** Alternative ranking fuzzy linguistic scales using TOPSIS

| Symbol | Linguistic Scale | Fuzzy Scale (l, m, u) |
|---|---|---|
| VP | Very poor | (0, 0, 2.5) |
| P | poor | (0, 2.5, 5) |
| M | medium | (2.5, 5, 7.5) |
| G | good | (5, 7.5, 10) |
| VG | Very good | (7.5, 10, 10) |

2) The decision matrix of the decision-maker (g) to assess the alternatives (i) over criteria (e) is as follows:

$$\tilde{X}_{ie} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1E} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2E} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \cdots & \tilde{x}_{nE} \end{bmatrix} \quad (6)$$

3) Evaluate the aggregated value of decision makers' assessment if the assessment is made by more than one decision-maker. For example, assume there are (G) number of decision-makers, then the aggregated value of the decision matrix is evaluated by:

$$\tilde{X}_{ie} = \frac{\sum_{g=1}^{G} \tilde{x}_{ie}}{G} \quad (7)$$

4) Normalize the fuzzy decision matrix; in the F-TOPSIS, linear normalization is applied [17]. Thus, Equations 9 (a & b) give the normalized fuzzy decision matrix:

$$\tilde{F} = [\tilde{f}_{ie}]_{n \times E} \quad (8)$$

The normalized fuzzy value for (benefit criteria) is as follows:

$$\tilde{f}_{ie} = \left(\frac{l_{ie}}{u_e^*}, \frac{m_{ie}}{u_e^*}, \frac{u_{ie}}{u_e^*}\right), where\ u_e^* = \max_i u_{ie} \quad (9a)$$

The normalized fuzzy value for (cost criteria) is as follows:

$$\tilde{f}_{ie} = \left(\frac{l_e^-}{u_{ie}}, \frac{l_e^-}{m_{ie}}, \frac{l_e^-}{l_{ie}}\right), where\ l_e^- = \min_i l_{ie} \quad (9b)$$

5) Evaluate the weighted normalized decision matrix $\tilde{V}$, evaluated by multiplying the weight vector of the criteria by the normalized decision matrix, as given in the Equation below:

$$\tilde{V} = [\tilde{v}_{ie}]_{n \times E} \quad , \quad \tilde{v}_{ie} = [w_{criteria} \times \tilde{f}_{ie}] \quad (10)$$

Where i = (1, 2…n) No. of alternative, and e = (1, 2…E) No. of criteria, $w_{criteia}$ is the normalized weight vector of criteria in Equation (5).

6) Calculate the fuzzy positive ($H^*$) and fuzzy negative ($H^-$) ideal solution:

$$H^* = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_E^*), where\ \tilde{v}_e^* = \max_i(\tilde{v}_{ie}) \quad (11a)$$

$$H^- = (v_1^-, v_2^-, \ldots, v_E^-), where\ v_e^- = \min_i(\tilde{v}_{ie}) \quad (11b)$$

7) Determine the distance of $i^{th}$ alternative to the fuzzy positive ($H^*$) and fuzzy negative ($H^-$) ideal solution, as follows:

$$D_i^* = \sum_{e=1}^{E} d(\tilde{v}_{ie}, \tilde{v}_e^*) \ , i = (1,2, \ldots, n) \quad (12a)$$

$$D_i^- = \sum_{e=1}^{E} d(\tilde{v}_{ie}, \tilde{v}_e^-) \ , i = (1,2, \ldots, n) \quad (12b)$$

Where $d(\tilde{v}_{ie}, \tilde{v}_e^*)$ and $d(\tilde{v}_{ie}, \tilde{v}_e^-)$ are the distance between $i^{th}$ alternative and ($H^*$) and ($H^-$) respectively.

8) Determine the closeness coefficient using Equation (13), where the alternative with the highest value of ($CC_i$) is the highest-ranked.

$$CC_i = \frac{D_i^-}{D_i^* + D_i^-} \quad where\ i = 1,2, \dots, n \tag{13}$$

## 3. Case Study

This study uses the supplier ranking process model to rank the dental composite fillings suppliers. Composite dental fillings are one of the most widely used materials in the dental sector, and they are a tooth-colored blend of plastic and ceramic used to repair cracks and cavities in infected teeth. In this study, the decision of selection of the potential suppliers is carried out by direct interview with a group of dentists, in which five international dental composite fillings suppliers (first tier suppliers) are identified for the evaluation purpose, and they are described as ($A_1, A_2, A_3, A_4, A_5$).

### 3.1 Evaluation Criteria

Six evaluation criteria have been defined by direct interviews with a group of dentists to rank the suppliers of dental composite fillings. The selected criteria are price, quality, accessibility, usability, esthetic, and durability, where the description of each criterion is listed in Table 3.

**Table 3:** The evaluation criteria and their description

| Symbol | Criteria | Description |
|---|---|---|
| $C_1$ | Price | the price of the dental composite fillings |
| $C_2$ | Quality | the quality of the dental composite fillings |
| $C_3$ | Accessibility | ease of obtaining the product (product availability) and its availability in the local market |
| $C_4$ | Usability | the ease of using the composite filling while filling the tooth by the dentist |
| $C_5$ | Esthetic | the aesthetic appearance or consistency of the color of the composite filling with the color of the tooth |
| $C_6$ | Durability | the strength of the composite filling |

### 3.2 Data Collection

A questionnaire is applied to 12 dentists considered experts using a google form. The experts (dentists) consist of 2 specialist dentists and 10 general dentists. The questionnaire included two general sections. The first section for criteria evaluation involves a pairwise comparison of the selected criteria with linguistic terms, which is converted to numerical scales using Table 1. The fuzzy comparison matrix is aggregated using geometric mean in Equation 1. Thus, the aggregated fuzzy comparison matrix of criteria is listed in Table 4.

**Table 4:** Aggregated (TFN) criteria weights

| $C_e$ | | $C_1$ | | | $C_2$ | | | $C_3$ | | | $C_4$ | | | $C_5$ | | | $C_6$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $C_1$ | 1.00 | 1.00 | 1.00 | 0.32 | 0.41 | 0.67 | 0.53 | 0.68 | 1.18 | 0.31 | 0.39 | 0.64 | 0.20 | 0.28 | 0.38 | 0.55 | 0.72 | 1.12 |
| $C_2$ | 1.49 | 2.47 | 3.13 | 1.00 | 1.00 | 1.00 | 1.43 | 1.82 | 3.02 | 0.93 | 1.08 | 2.18 | 0.65 | 0.84 | 1.43 | 0.85 | 1.12 | 1.99 |
| $C_3$ | 0.81 | 1.42 | 1.83 | 0.33 | 0.55 | 0.70 | 1.00 | 1.00 | 1.00 | 1.02 | 1.34 | 2.34 | 0.52 | 0.70 | 1.08 | 0.48 | 0.60 | 1.13 |
| $C_4$ | 1.56 | 2.55 | 3.24 | 0.46 | 0.93 | 1.08 | 0.43 | 0.74 | 0.98 | 1.00 | 1.00 | 1.00 | 0.61 | 0.78 | 1.45 | 0.24 | 0.30 | 0.50 |
| $C_5$ | 2.78 | 3.87 | 5.09 | 0.70 | 1.18 | 1.55 | 0.93 | 1.42 | 1.93 | 0.69 | 1.28 | 1.63 | 1.00 | 1.00 | 1.00 | 0.56 | 0.69 | 1.42 |
| $C_6$ | 0.89 | 1.39 | 1.82 | 0.50 | 0.89 | 1.18 | 0.89 | 1.67 | 2.10 | 1.98 | 3.32 | 4.09 | 0.70 | 1.44 | 1.77 | 1.00 | 1.00 | 1.00 |

The second section of the questionnaire is for alternatives (suppliers) rating, which involves the assessment of the alternatives (suppliers) over each criterion through linguistic terms, which is converted to numerical scales using Table 3, then the decision matrix is aggregated using Equation 7. Thus the aggregated decision matrix of supplier assessments is shown in Table 5.

**Table 5:** Aggregated (TFN) supplier assessments

| | | A1 | | | A2 | | | A3 | | | A4 | | | A5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *C1* | 3.75 | 6.25 | 8.33 | 3.96 | 6.46 | 8.54 | 4.58 | 7.08 | 9.58 | 2.71 | 5.21 | 7.71 | 3.54 | 6.04 | 8.33 |
| *C2* | 4.38 | 6.88 | 9.17 | 3.54 | 6.04 | 8.33 | 3.13 | 5.63 | 7.71 | 4.38 | 6.88 | 8.96 | 4.58 | 7.08 | 8.96 |
| *C3* | 3.54 | 6.04 | 8.54 | 3.96 | 6.46 | 8.75 | 3.54 | 6.04 | 8.33 | 4.17 | 6.46 | 8.54 | 3.96 | 6.46 | 8.75 |
| *C4* | 3.54 | 5.83 | 8.13 | 3.33 | 5.83 | 8.13 | 3.33 | 5.83 | 8.33 | 3.96 | 6.46 | 8.75 | 3.33 | 5.83 | 8.13 |
| *C5* | 4.79 | 7.29 | 9.58 | 3.54 | 6.04 | 8.33 | 3.54 | 6.04 | 8.13 | 4.17 | 6.67 | 8.75 | 4.79 | 7.29 | 8.96 |
| *C6* | 4.38 | 6.88 | 9.17 | 3.75 | 6.25 | 8.75 | 3.33 | 5.63 | 8.13 | 3.75 | 6.25 | 8.54 | 4.58 | 7.08 | 8.75 |

### 3.3 Criteria Evaluation using F-AHP

Criteria weights are evaluated by adopting the Fuzzy AHP (Buckley's method) through the following steps:

1) Calculation of the fuzzy geometric mean value $(\boldsymbol{R_i})$ of $\boldsymbol{i^{th}}$ the criterion is in Table 4, using Equation 2.
2) Calculation of the fuzzy weights $(\widetilde{\boldsymbol{w}}_{\boldsymbol{i}})$, using Equation 3, thus, the fuzzy $(\boldsymbol{R_i})$ values and fuzzy weights $(\widetilde{\boldsymbol{w}}_{\boldsymbol{i}})$ values are listed in Table 6.

**Table 6:** Fuzzy geometric mean $(R_i)$ and fuzzy weights $(\widetilde{w}_i)$ values

| $C_e$ | Fuzzy geometric mean $(R_i)$ | Fuzzy weights $(\widetilde{w}_i)$ |
|---|---|---|
| $C_1$ | 0.42, 0.53, 0.77 | 0.05, 0.08, 0.17 |
| $C_2$ | 1.01, 1.29, 1.97 | 0.12, 0.20, 0.44 |
| $C_3$ | 0.64, 0.87, 1.24 | 0.07, 0.14, 0.27 |
| $C_4$ | 0.60, 0.86, 1.17 | 0.07, 0.14, 0.26 |
| $C_5$ | 0.94, 1.34, 1.81 | 0.11, 0.21, 0.40 |
| $C_6$ | 0.91, 1.47, 1.79 | 0.10, 0.23, 0.39 |

3) Calculation the non-fuzzy weights by using the center of area (COA) method in Equation 4. Therefore the vector of criteria weight will be:

$$w_i = (0.10, 0.25, 0.16, 0.15, 0.24, 0.24)^T$$

4) Lastly, normalizing the non-fuzzy weights $(w_i)$ using Equation 5. Thus, the normalized criteria weights $(w_i')$ are listed in Table 7:

**Table 7:** Normalized criteria weights

| $C_e$ | Criteria | Normalized criteria weights $(w_i')$ |
|---|---|---|
| $C_1$ | Price | 0.09 |
| $C_2$ | Quality | 0.22 |
| $C_3$ | Accessibility | 0.14 |
| $C_4$ | Usability | 0.13 |
| $C_5$ | Esthetic | 0.21 |
| $C_6$ | Durability | 0.21 |

As mentioned in Table 7, the most important criterion is the quality criterion, which weighs 0.22, followed by esthetic and durability, with a weight of 0.21 for both. Finally, the least significant criterion is the price, with a weight of 0.09.

### 3.4 Supplier Ranking using F-TOPSIS

After evaluating criteria weights using F-AHP, potential suppliers are ranked using F-TOPSIS based on criteria weights through the following steps:

1) Normalizing the fuzzy decision matrix, the benefits and cost criteria of the decision matrix in Table 5 are normalized using Equations (9 a) and (9 b), respectively. In this study, all criteria are benefit type except (C1) is cost type. Table 8 shows the normalized supplier evaluation matrix (decision matrix).

**Table 8:** Normalized decision matrix

| | A1 | | | A2 | | | A3 | | | A4 | | | A5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C1*** | 0.33 | 0.43 | 0.72 | 0.32 | 0.42 | 0.68 | 0.28 | 0.38 | 0.59 | 0.35 | 0.52 | 1.00 | 0.33 | 0.45 | 0.76 |
| ***C2*** | 0.48 | 0.75 | 1.00 | 0.39 | 0.66 | 0.91 | 0.34 | 0.61 | 0.84 | 0.48 | 0.75 | 0.98 | 0.50 | 0.77 | 0.98 |
| ***C3*** | 0.40 | 0.69 | 0.98 | 0.45 | 0.74 | 1.00 | 0.40 | 0.69 | 0.95 | 0.48 | 0.74 | 0.98 | 0.45 | 0.74 | 1.00 |
| ***C4*** | 0.40 | 0.67 | 0.93 | 0.38 | 0.67 | 0.93 | 0.38 | 0.67 | 0.95 | 0.45 | 0.74 | 1.00 | 0.38 | 0.67 | 0.93 |
| ***C5*** | 0.50 | 0.76 | 1.00 | 0.37 | 0.63 | 0.87 | 0.37 | 0.63 | 0.85 | 0.43 | 0.70 | 0.91 | 0.50 | 0.76 | 0.93 |
| ***C6*** | 0.48 | 0.75 | 1.00 | 0.41 | 0.68 | 0.95 | 0.36 | 0.61 | 0.89 | 0.41 | 0.68 | 0.93 | 0.50 | 0.77 | 0.95 |

2) The weighted normalized decision matrix $\widetilde{V}$ is evaluated by multiplying the normalized weight of the criteria in Table 7 and the normalized decision matrix in Table 8 using Equation 10. Therefore, the results of the weighted normalized decision matrix are shown in Table 9.

**Table 9:** Weighted normalized decision matrix

| | A1 | | | A2 | | | A3 | | | A4 | | | A5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C1*** | 0.03 | 0.04 | 0.07 | 0.03 | 0.04 | 0.06 | 0.03 | 0.03 | 0.05 | 0.03 | 0.05 | 0.09 | 0.03 | 0.04 | 0.07 |
| ***C2*** | 0.11 | 0.17 | 0.22 | 0.09 | 0.15 | 0.20 | 0.08 | 0.14 | 0.19 | 0.11 | 0.17 | 0.22 | 0.11 | 0.17 | 0.22 |
| ***C3*** | 0.06 | 0.10 | 0.14 | 0.06 | 0.10 | 0.14 | 0.06 | 0.10 | 0.13 | 0.07 | 0.10 | 0.14 | 0.06 | 0.10 | 0.14 |
| ***C4*** | 0.05 | 0.09 | 0.12 | 0.05 | 0.09 | 0.12 | 0.05 | 0.09 | 0.12 | 0.06 | 0.10 | 0.13 | 0.05 | 0.09 | 0.12 |
| ***C5*** | 0.11 | 0.16 | 0.21 | 0.08 | 0.13 | 0.18 | 0.08 | 0.13 | 0.18 | 0.09 | 0.15 | 0.19 | 0.11 | 0.16 | 0.20 |
| ***C6*** | 0.10 | 0.16 | 0.21 | 0.09 | 0.14 | 0.20 | 0.08 | 0.13 | 0.19 | 0.09 | 0.14 | 0.20 | 0.11 | 0.16 | 0.20 |

3) The fuzzy positive $(H^*)$ and negative $(H^-)$ the ideal solution are calculated using Equations (11 a) and (11 b), respectively. Thus, Table 10 shows the fuzzy positive and negative ideal solution values.

**Table 10:** The fuzzy positive and negative ideal solution

| Criteria | $H^*$ | $H^-$ |
|---|---|---|
| C1 | 0.09 | 0.03 |
| C2 | 0.22 | 0.08 |
| C3 | 0.14 | 0.06 |
| C4 | 0.13 | 0.05 |
| C5 | 0.21 | 0.08 |
| C6 | 0.21 | 0.08 |

4) Determine the distance of $i^{th}$ alternative to the fuzzy positive $(H^*)$ and fuzzy negative $(H^-)$ ideal solution: the distances $D_i^*$ and $D_i^-$ are calculated using Equations (12 a) and (12 b) respectively.

5) Determine the closeness coefficient of each supplier using Equation 13, then, the results of $(CC_i)$ are compared, where the supplier with the highest value of $(CC_i)$ is the highest-ranked. The results of $D_i^*$ and $D_i^-$, the final result of $(CC_i)$ and supplier ranking are listed in Table 11.

**Table 11:** Closeness coefficient and ranking of each supplier

| Suppliers | $D_i^*$ | $D_i^-$ | Closeness Coefficient $(CC_i)$ | Ranking |
|---|---|---|---|---|
| A1 | 0.365 | 0.405 | 0.526 | 2 |
| A2 | 0.413 | 0.357 | 0.463 | 4 |
| A3 | 0.442 | 0.323 | 0.423 | 5 |
| A4 | 0.369 | 0.401 | 0.521 | 3 |
| A5 | 0.353 | 0.401 | 0.532 | 1 |

According to the results of supplier ranking using F-TOPSIS in Table 11, supplier A5 ranks first because it has a highest $(CC_i)$ value of 0.532. The second-ranked alternative is supplier A1, with a value of $(CC_i)$ of 0.526 followed by A4, A2, and A3 with the $(CC_i)$ values of 0.521, 0.463, and 0.423, respectively. Thus, the final rank of the alternative is A5>A1>A4>A2>A3.

## 4. Conclusion

The supplier selection process is an essential part of the supply chain due to its impact on an organization's final products or services, as in the health sector, it affects the health of the patient and the effectiveness and quality of services. This study developed a supplier ranking model using the integrated fuzzy (AHP-TOPSIS) method. The model was applied to the dental sector to rank suppliers of dental composite fillings. Five international suppliers were selected, and six evaluation criteria were identified through direct interviews with a group of experts. The importance of criteria and the assessment of suppliers were collected through a questionnaire that was applied to 12 experts (dentists). The F-AHP method was used to evaluate criteria weights then the evaluated criteria weights were applied to calculate the closeness coefficient for supplier ranking using F-TOPSIS. The criteria evaluation results indicated that quality is the most important criterion, followed by esthetic and durability criteria. The supplier ranking results indicated that supplier A5 is the most appropriate supplier, with a value of $(CC_i)$ (0.532) followed by supplier A1 with a $(CC_i)$ value (0.526). This study sets out the criteria for selecting dental materials and equipment suppliers. The results will help dental materials and equipment manufacturers assess and improve the quality of their products and services. Furthermore, the criteria and the decision-making process can be applied by other clinics (private and public) as guides for choosing the best dental materials and equipment suppliers.

### Author contribution

All authors contributed equally to this work.

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## Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

## Conflicts of interest

The authors declare that there is no conflict of interest.

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