Manager selection using Fuzzy TOPSIS method

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Abstract. Due to increasing competition in the global market, companies need employees especially managers who are knowledgeable and skillful to compete in the world market. Proper selection of managers can ensure the accomplishment of company goals. This study aims to propose Fuzzy Technique for order preference by similarity to ideal solution (TOPSIS) method in hiring new personnel for the middle level manager position in a company. The aim of the study is to assess the alternatives and criteria weights for selecting the middle level manager in a company by using Fuzzy TOPSIS method. A real-life data about the middle level manager selection problem in a company is implemented to demonstrate the application of Fuzzy TOPSIS method. There are three decision makers, three selected alternatives (A1, A2, A3) and twelve chosen criteria in the study. The best alternative is the alternative which is close to fuzzy positive ideal solution (FPIS) and far from fuzzy negative ideal solution (FNIS). Other than that, the sensitivity analysis is performed to validate the results of the study by shifting the weight of each criterion to zero to check whether there is any influence on the final ranking of the alternatives. The findings showed that the ranking order is A1 > A2 > A3. This shows that A1 is the most preferable candidate for the middle level manager position in the company.

1. Introduction
In the era of competitive world market, companies depend mostly on the commitment and devotion of their personnel to survive in the business [1]. The selection of qualified employees, especially managers is the key to the success of an organization [2]. Managers play a vital role in controlling and administering an organisation or groups of staff. The decisions made by managers determine the growth or the downfall of an organisation. Thus, it is crucial for a manager to have fundamental skills and knowledge to face any difficulties in the business world [3]. Therefore, a proper recruitment and selection process of managers is paramount for an organisation to achieve its goals.

The method applied in this study is Fuzzy Technique for order preference by similarity to ideal solution (TOPSIS) which is one of the Multiple Criteria Decision-Making (MCDM) tools. MCDM techniques can be implemented in solving many decision-making problems. By using this method, the decision maker(s) will select, assess, or rank the alternatives according to the weight of its criteria (attributes) [4].

In 1981, Hwang and Yoon introduced a technique that is very helpful in solving MCDM problems which is the TOPSIS method [5]. The concept of TOPSIS is the optimal alternative should be near to the positive ideal solution (PIS) and far from the negative ideal solution (NIS) [6]. However, this method
has its shortcomings. The uses of numerical values in the TOPSIS method is not suitable to represent realistic situations because human judgements are unclear and uncertain [7].

Subsequently, the extended version of TOPSIS namely Fuzzy TOPSIS has been developed to resolve MCDM problems in uncertain circumstances. In this method, linguistic variables are applied to assess the weights of all criteria and the ratings of all alternatives which are then transformed into triangular fuzzy numbers (TFNs) [8,9]. The decision makers’ preferences are being used in this method to evaluate the alternatives with respect to each criterion.

This study will focus on a real-life data about the middle level manager selection problem in a company. The objective of this study is to assess the alternatives and criteria weights for selecting the middle level manager in a company by using the Fuzzy TOPSIS method. This paper contains six sections. The first section is the introduction of the research. The second section contains the literature review and the background theory of fuzzy set theory, TOPSIS method and Fuzzy TOPSIS method. Next, section three is the methodology of Fuzzy TOPSIS method. Section four displays the results and discussion. The fifth section comprises the conclusion and recommendations of the research. Lastly, the sixth section has the acknowledgement.

2. Literature Review

This section includes the literature review of fuzzy set theory, TOPSIS method and Fuzzy TOPSIS method.

2.1. Fuzzy Set Theory

A fuzzy set can be described by a membership function that designates each object with a grade of membership between the range of zero and one. The notations of inclusion, union, intersection, etc. of sets had been extended by Zadeh [10]. In 1965, Zadeh proposed the fuzzy set theory [11]. It is the extension of the classical set theory that solves many problems with the imprecise and uncertain data [12]. Other than that, the fuzzy set theory implements linguistic terms for the purpose of describing the choice of decision makers [13].

TFNs can be described as \((a_1, a_2, a_3)\) where \(a_1\) is the smallest feasible value, \(a_2\) is the most favorable value, and \(a_3\) is the largest feasible value [14]. Equation (2.1) shows the membership function \(\mu_a(x)\) of TFNs while figure 1 depicts the TFNs, \(\tilde{a}\) [9].

\[
\mu_a(x) = \begin{cases} 
0 & x < a_1 \\
\frac{x - a_1}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\
\frac{a_3 - x}{a_3 - a_2}, & a_2 \leq x \leq a_3 \\
0 & x > a_3
\end{cases}
\]  

(2.1)

![Figure 1. The TFNs, \(\tilde{a}\).](image-url)
Let \( \bar{a} = (a_1, a_2, a_3) \) and \( \bar{b} = (b_1, b_2, b_3) \) be the two TFNs. The main operations between two TFNs are described as [13]:

Addition of two TFNs
\[
\bar{a} + \bar{b} = (a_1 + b_1, a_2 + b_2, a_3 + b_3), \quad a_i \geq 0, \quad b_i \geq 0
\]
(2.2)

Multiplication of two TFNs
\[
\bar{a} \times \bar{b} = (a_1 \times b_1, a_2 \times b_2, a_3 \times b_3), \quad a_i \geq 0, \quad b_i \geq 0
\]
(2.3)

Subtraction of two TFNs
\[
\bar{a} - \bar{b} = (a_1 - b_1, a_2 - b_2, a_3 - b_3), \quad a_i \geq 0, \quad b_i \geq 0
\]
(2.4)

Division of two TFNs
\[
\frac{\bar{a}}{\bar{b}} = (\frac{a_1}{b_1}, \frac{a_2}{b_2}, \frac{a_3}{b_3}), \quad a_i \geq 0, \quad b_i \geq 0
\]
(2.5)

Inverse of a triangular fuzzy number
\[
\bar{a}^{-1} = (\frac{1}{a_1}, \frac{1}{a_2}, \frac{1}{a_3}), \quad a_i \geq 0
\]
(2.6)

Symmetric image
\[
\bar{a} = (-a_1, -a_2, -a_3), \quad a_i \geq 0
\]
(2.7)

The fuzzy set theory has some advantages such as it can consider scarce information and the evolution of existing knowledge. Next, imprecise input and a few rules to include problems with great complexity are allowed. As for its drawbacks, fuzzy set theory systems are tough to develop and before it is able to be used in the real world, it can require a lot of simulations in many cases [12]. Yet, the fuzzy set theory is accepted because of its benefits and for the fact that it has been applied to various fields such as mathematics, life sciences, and physical sciences [15].

2.2. TOPSIS

TOPSIS is an MCDM method that is frequently implemented: it was first established by Hwang and Yoon in 1981 and continued by Yoon in 1987 [16]. The performance of alternatives can be assessed by using this technique based on the similarity with an ideal solution [17].

The fundamental of TOPSIS is that the distance of the alternative being chosen is the farthest from the NIS and the nearest from the PIS. For the NIS, cost attributes should be maximised while benefit attributes should be minimised. In contrast, benefit attributes should be maximised and cost attributes should be minimised for the PIS [18]. In the past, many studies were performed to implement the application of the TOPSIS method.

Table 1 below illustrates the applications of TOPSIS in solving MCDM problems. These studies show that this method can be used as a single and combined approach to solve the problems. Bulgurcu [19] applied TOPSIS method to evaluate the financial performance of thirteen technology firms listed in Istanbul Stock Exchange Market. Meanwhile Zhongyou [20] implemented this method to assess the foreign players in Chinese Basketball Association (CBA) Games. On the other hand, Kamalakannan et al. [21] used TOPSIS method to solve the supplier selection problem. The findings were then compared with the findings obtained by using AHP method. Some researchers are interested to hybrid the TOPSIS method with the other method to solve the MCDM problems. For instance, Chu and Su [22] applied the combination of AHP and entropy methods to compute the weights of the evaluation criteria and TOPSIS method to select the fixed seismic shelter for evacuation in cities.
Table 1. Applications of TOPSIS.

| Author            | Title                                                                 | Approach            |
|-------------------|----------------------------------------------------------------------|---------------------|
| Bulgurcu [19]     | Application of TOPSIS Technique for Financial Performance Evaluation of Technology Firms in Istanbul Stock Exchange Market. |                     |
| Zhongyou [20]     | Study on the Application of TOPSIS Method to the Introduction of Foreign Players in CBA Games. | Single Approach     |
| Kamalakannan et al. [21] | Evaluation and selection of suppliers using TOPSIS. |                     |
| Chu and Su [22]   | The application of TOPSIS method in selecting fixed seismic shelter for evacuation in cities. | Combined Approach   |

The TOPSIS method is known because of its ability to rank the alternatives in MCDM problems and there are many advantages in applying this method. The advantages of using the TOPSIS approach are its ability to rank the best alternatives rapidly and deal with conflicting situations. Next, the judgement data are allowed to be placed directly without having to involve complicated calculations [23].

Despite its advantages, the method also has some shortcomings. In the classical TOPSIS, the personal judgements of decision makers are represented by numerical values [17]. However, this method is inefficient to estimate the people’s choices with crisp data because human judgements are vague and uncertain [8]. Therefore, the Fuzzy TOPSIS method is recommended to overcome the shortcomings of TOPSIS.

2.3. Fuzzy TOPSIS

The Fuzzy TOPSIS method is a technique that was extended from the concept of TOPSIS to tackle numerous MCDM problems in an uncertain environment [8]. Fuzzy numbers were first applied by Chen and Hwang in 1992 to the TOPSIS method to establish the Fuzzy TOPSIS method. A vertex method was presented by Chen in 2000 to compute the distance between two TFNs [4].

In this method, TFNs will represent the decision makers’ views regarding attributes and alternatives. Then, the alternatives will be ranked based on the distance that is nearest to ideal solutions and the selection will be based on the ranking result [24]. The principle of the Fuzzy TOPSIS method is identical to the TOPSIS method but in a vague environment [18].

There are many advantages of using the Fuzzy TOPSIS method to deal with MCDM problems. Firstly, the Fuzzy TOPSIS method was introduced to reconcile the uncertainty that regularly arises in information from human judgement [18]. In addition, it has been found that various uncertain situations that have been modelled by using TFNs generate a better result in solving MCDM problems. Furthermore, the Fuzzy TOPSIS method is also easy and not complicated to use for solving MCDM problems with imprecise data [23].

There are a few examples of the application of the Fuzzy TOPSIS method as presented in table 2 below. A survey of previous literature shows that this method can be used as a single approach to solve the MCDM problems such as evaluating the shopping websites and investigating the factors which help to improve the competitive advantage of those selected websites [25] and assessing and ranking the domestic Turkish air carriers which are Turkish Airlines, Onut Air, Pegasus and Atlas Jet based on the criteria most important to the success in the domestic airline industry [26]. This method can be hybridized with other MCDM methods. Rajak and Shaw [23] applied AHP method and Fuzzy TOPSIS method to assess the performance of different mobile health (mHealth) applications. mHealth
applications is a system based innovative mobile application used by its users to regulate their health better. AHP method was implemented to evaluate the weights of criteria and sub-criteria, and the Fuzzy TOPSIS method was implemented to rank the mHealth applications. Meanwhile, Sengül et al. [27] used the integration of the Interval Fuzzy Shannon’s Entropy to evaluate the weights of the criteria and Fuzzy TOPSIS method to rank the renewable energy supply systems in Turkey.

Table 2. Application of Fuzzy TOPSIS.

| Author            | Title                                                                 | Approach          |
|-------------------|------------------------------------------------------------------------|-------------------|
| Sun and Lin [25]  | Using Fuzzy TOPSIS method for evaluating the competitive advantages of shopping websites. |                  |
| Torlak et al. [26]| Analyzing business competition by using fuzzy TOPSIS method: An example of Turkish domestic airline industry. | Single Approach   |
| Rajak and Shaw [23]| Evaluation and selection of mobile health (mHealth) applications using AHP and Fuzzy TOPSIS. | Combined Approach |
| Sengül et al. [27]| Fuzzy TOPSIS method for ranking renewable energy supply systems in Turkey. |                  |

As a conclusion, the Fuzzy TOPSIS method is suitable and efficient in resolving MCDM problems under a fuzzy environment as it applies the concept of the fuzzy set theory.

2.4. Evaluation Criteria

This study will focus on the middle level manager selection problem in a company. The company wanted to hire new personnel for the middle level manager position. There are many criteria that can be used as guideline in evaluating and selecting the manager. In a journal written by Kelemenis et al. [3], twelve criteria had been used to select the middle level manager in the company as shown in table 3. The same list of criteria is also considered by other researchers in hiring new personnel.

Table 3. Criteria for the selection of personnel.

| Criteria                          | Golec and Kahya [28] | Jereb et al. [29] | Güngör et al. [1] | Dağdeviren [30] | Chien and Chen [31] |
|-----------------------------------|-----------------------|-------------------|--------------------|-----------------|---------------------|
| Creativity/Innovation (C1)        | •                     |                   |                    |                 |                     |
| Problem solving/decision making (C2) | •                     | •                 | •                  | •               |                     |
| Conflict management/negotiation (C3) | •                     |                   | •                  |                 |                     |
| Empowerment/delegation (C4)       | •                     |                   | •                  |                 |                     |
| Strategic planning (C5)           | •                     | •                 | •                  |                 |                     |
| Specific presentation skills (C6) | •                     |                   |                    |                 |                     |
| Communication skills (C7)         | •                     | •                 | •                  | •               | •                   |
| Team management (C8)              | •                     | •                 | •                  |                 |                     |
Table 3. (continued).

| Criteria                          | Golec and Kahya [28] | Jereb et al. [29] | Güngör et al. [1] | Dağdeviren [30] | Chien and Chen [31] |
|----------------------------------|----------------------|-------------------|-------------------|------------------|---------------------|
| Diversity management (C9)        | •                    |                   |                   |                  |                     |
| Self-management (C10)            |                      | •                 |                   |                  |                     |
| Professional experience (C11)    |                      |                   | •                 |                  | •                   |
| Educational background (C12)     | •                    | •                 |                   | •                |                     |

From table 3, it can be seen that Golec and Kahya [28] used the same criteria as Kelemenis et al. [3] in evaluating the candidates except for ‘self-management’, ‘personal experience’, and ‘educational background’. Besides, most of the researchers which were Golec and Kahya [28], Jereb et al. [29], and Güngör et al. [1] included ‘problem solving/decision making’ and ‘communication skills’ as the criteria to evaluate the candidates. In addition, Güngör et al. [1] and Chien and Chen [31] proposed ‘professional experience’ and ‘educational background’ as the evaluation criteria for the selection of personnel in their paper. Other than that, the evaluation criteria recommended by Dağdeviren [30] in his paper were ‘communication skills’, ‘diversity management’, and ‘professional experience’.

3. Methodology

This section presents the framework and the implementation of Fuzzy TOPSIS method.

3.1. Fuzzy TOPSIS Framework

The Fuzzy TOPSIS method is the extension of the TOPSIS method implemented for the assessment and ranking of alternatives under uncertain circumstances [32]. In this method, criteria weights and alternatives ratings are represented in linguistic variables which are then transformed to TFNs [9]. In this technique, the optimal alternatives should be close to the fuzzy positive ideal solution (FPIS) and far from the fuzzy negative ideal solution (FNIS) [33]. The steps listed below shows the procedures of the Fuzzy TOPSIS method in evaluating the importance of criteria weights and the ranking of alternatives [13].

Step 1: Design the hierarchical diagram.

Step 2: Conduct the data scaling process for criteria and alternatives. The decision maker(s) assigned the importance to the criteria and rated the alternatives using linguistic variables presented in table 4 and table 5 respectively [3].

Table 4. Linguistic variables and TFNs for criteria.

| Importance                | TFNs          |
|---------------------------|---------------|
| Definitely low (DL)       | (0, 0, 0.1)   |
| Extremely low (EL)        | (0, 0.1, 0.2) |
| Very low (VL)             | (0.1, 0.2, 0.3)|
| Low (L)                   | (0.2, 0.3, 0.4)|
| Medium low (ML)           | (0.3, 0.4, 0.5)|
| Medium (M)                | (0.4, 0.5, 0.6)|
| Medium high (MH)          | (0.5, 0.6, 0.7)|
| High (H)                  | (0.6, 0.7, 0.8)|
| Very high (VH)            | (0.7, 0.8, 0.9)|
| Extremely high (EH)       | (0.8, 0.9, 1) |
| Definitely high (DH)      | (0.9, 1, 1)  |
Table 5. Linguistic variables and TFNs for alternatives.

| Rating                  | TFNs          |
|-------------------------|---------------|
| Definitely poor (DP)    | (0, 0, 1)     |
| Extremely poor (EP)     | (0, 1, 2)     |
| Very poor (VP)          | (1, 2, 3)     |
| Poor (P)                | (2, 3, 4)     |
| Medium poor (MP)        | (3, 4, 5)     |
| Fair (F)                | (4, 5, 6)     |
| Medium good (MG)        | (5, 6, 7)     |
| Good (G)                | (6, 7, 8)     |
| Very good (VG)          | (7, 8, 9)     |
| Extremely good (EG)     | (8, 9, 10)    |
| Definitely good (DG)    | (9, 10, 10)   |

Step 3: Compute the aggregated fuzzy weight of each criterion, $\tilde{w}_j$, of the kth decision maker described as:

$$\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$$

where

$$w_{j1} = \min_k \{w_{jk}^k\}, \quad w_{j2} = \frac{1}{K} \sum_{k=1}^{K} w_{jk}^k, \quad w_{j3} = \max_k \{w_{jk}^k\}; \quad j = 1, 2, \ldots, n \text{ criteria}$$

Step 4: Design the fuzzy decision matrix, $\hat{D}$ which made up of alternatives, $i$ and criteria, $j$ as follows:

$$\hat{D} = A_i \begin{bmatrix} \tilde{x}_{i1} & \tilde{x}_{i2} & \ldots & \tilde{x}_{in} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{mi} & \tilde{x}_{m2} & \ldots & \tilde{x}_{mn} \end{bmatrix}; \quad i = 1, 2, \ldots, m \text{ (alternatives)}, \quad j = 1, 2, \ldots, n \text{ (criteria)}$$

Let $\tilde{x}_{ij}$ be the aggregated fuzzy ratings of alternative, $i$ with respect to each criterion, $j$ in a group of $K$ decision makers whereas $\tilde{x}_{ij}$ is calculated as follows:

$$\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$$

where $a_{ij} = \min_k \{a_{ik}^k\}$, $b_{ij} = \frac{1}{K} \sum_{k=1}^{K} b_{ik}^k$, $c_{ij} = \max_k \{c_{ik}^k\}$

and $x_{ij}^k = (a_{ik}^k, b_{ik}^k, c_{ik}^k)$

Step 5: Normalise the fuzzy decision matrix using:

$$\tilde{r}_j = \begin{bmatrix} a_{ij}^+ & b_{ij}^+ & c_{ij}^+ \\ a_{ij}^- & b_{ij}^- & c_{ij}^- \end{bmatrix}$$

and $c_j = \max_i \{c_{ij}^+\}$ (benefit criteria)

$$a_j^+ = \min_i \{a_{ij}^+\}$$ (cost criteria)

Step 6: Develop the weighted normalised fuzzy decision matrix, $\tilde{V}$ by multiplying the normalised fuzzy decision matrix, $\tilde{r}_j$ with the weights of evaluation criteria, $\tilde{w}_j$ as follows:
$V = \left[ \bar{v}_{ij} \right]_{mn}$, $i = 1, 2, \ldots, m$ alternatives, $j = 1, 2, \ldots, n$ criteria where $\bar{v}_{ij} = \bar{r}_{ij} \times \bar{w}_j$ (3.6)

Step 7: Find the FPIS, $A^*$ and FNIS, $A^-$ using:

$A^* = \left( \bar{v}_{i1}^*, \bar{v}_{i2}^*, \ldots, \bar{v}_{in}^* \right)$ where $\bar{v}_{ij}^* = \max_j \{ v_{ij} \}$

$A^- = \left( \bar{v}_{i1}^-, \bar{v}_{i2}^-, \ldots, \bar{v}_{in}^- \right)$ where $\bar{v}_{ij}^- = \min_i \{ v_{ij} \}$ (3.7) (3.8)

Step 8: Compute the distance of each alternative, $(d_i^*, d_i^-)$ where $i = 1, 2, 3, \ldots, m$ from the FPIS and the FNIS by applying the equations below:

$d_i^* = \sum_{j=1}^{n} d(\bar{v}_{ij}, \bar{v}_{ij}^*)$ (3.9)

$d_i^- = \sum_{j=1}^{n} d(\bar{v}_{ij}, \bar{v}_{ij}^-)$ (3.10)

where the distance between two fuzzy numbers $\bar{a}$ and $\bar{b}$, $d(\bar{a}, \bar{b})$ can be calculated using:

$d(\bar{a}, \bar{b}) = \sqrt{\frac{1}{3} \left[ (a_1 - b_1)^2 + (a_2 - b_2)^2 + (c_1 - c_2)^2 \right]}$ (3.11)

Step 9: Compute the closeness coefficient, $CC_i$ using:

$CC_i = \frac{d_i^-}{d_i^- + d_i^*}, \quad i = 1, 2, 3, \ldots, m$ (3.12)

Step 10: Rank the alternative based on the closeness coefficient of each alternative to the ideal solution in decreasing order. The best alternative with a higher value of $CC_i$ is the closest to the FPIS and the farthest from the FNIS.

3.2. The implementation of Fuzzy TOPSIS

In this study, a real-life data about the middle level manager selection problem in an IT Greek Firm was applied to demonstrate the application of Fuzzy TOPSIS method [3]. In an organisation, the levels of management can be classified into three categories which are top level, middle level, and low level. Middle level management mostly deals with executing the plans and policies made by the top level management. There were three (3) decision makers, three (3) selected alternatives, and twelve (12) selected criteria in the paper. The decision makers team were the “Systems and Solution Marketing Manager” (D1), General Director of the “Subsidiaries Function” (D2), and Director of the Human Resource (HR) department (D3). Three final candidates for the position which were Candidate 1 (A1), Candidate 2 (A2), and Candidate 3 (A3) were chosen through the recruitment process. The candidates were selected by sorting through the candidates’ CVs and conducting two rounds of semi-structured interview session. The selection process also included a case interview based on a real business situation.

In addition, all criteria were classified as the benefit criteria. The chosen criteria were Creativity/Innovation (C1), Problem solving/Decision making (C2), Conflict management/Negotiation (C3), Empowerment/Delegation (C4), Strategic planning (C5), Specific presentation skills (C6), Communication skills (C7), Team management (C8), Diversity management (C9), Self-management (C10), Professional experience (C11) and Educational background (C12).

Figure 2 depicts the decision hierarchical structure for the problem. The judgments of the decision makers about the criteria are presented in table 6. Meanwhile, the conversion of the linguistic variables of the criteria to the TFNs by using the scales from table 4 and the aggregated fuzzy weights of importance criteria, $w_j$ are presented in table 7. Table 8 depicts the ratings of the alternatives while table 9 shows the fuzzy decision matrix, $\bar{D}$ and the aggregated fuzzy ratings of alternative, $i$ with respect to each criterion, $j$ in a group of $K$ decision makers.
Figure 2. The decision hierarchical structure.

Table 6. Assignation of importance to criteria by the decision makers.

|   | C1  | C2  | C3  | C4  | C5  | C6  | C7  | C8  | C9  | C10 | C11 | C12 |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| DM1 | M   | VH  | VH  | H   | VH  | H   | H   | H   | VH  | M   | M   |     |
| DM2 | M   | MH  | MH  | H   | VH  | M   | M   | H   | M   | EH  | EH  |     |
| DM3 | EH  | H   | VH  | M   | M   | EH  | EH  | EH  | VH  | M   | M   |     |

Table 7. The aggregated fuzzy weight of each criterion.

|   | C1          | C2          | C3          | C4          | C5          | C6          |
|---|-------------|-------------|-------------|-------------|-------------|-------------|
| DM1 | (0.4, 0.5, 0.6) | (0.7, 0.8, 0.9) | (0.7, 0.8, 0.9) | (0.6, 0.7, 0.8) | (0.7, 0.8, 0.9) | (0.6, 0.7, 0.8) |
| DM2 | (0.4, 0.5, 0.6) | (0.5, 0.6, 0.7) | (0.5, 0.6, 0.7) | (0.6, 0.7, 0.8) | (0.7, 0.8, 0.9) | (0.4, 0.5, 0.6) |
| DM3 | (0.8, 0.9, 1)  | (0.6, 0.7, 0.8) | (0.7, 0.8, 0.9) | (0.4, 0.5, 0.6) | (0.4, 0.5, 0.6) | (0.8, 0.9, 1)  |

Table 8. The ratings of the alternatives.

|   | C1  | C2  | C3  | C4  | C5  | C6  | C7  | C8  | C9  | C10 | C11 | C12 |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| D1 | G   | G   | VG  | MG  | G   | VG  | G   | VG  | G   | VG  | EG  | EG  |
| A2 | DG  | MG  | MG  | G   | MG  | EG  | EG  | DG  | G   | G   | G   | G   |
| A3 | G   | DG  | G   | G   | EG  | MG  | MG  | MG  | G   | DG  | G   | G   |
| A1 | VG  | G   | G   | F   | G   | VG  | G   | G   | VG  | DG  | DG  | DG  |
| D2 | A2  | EG  | MG  | F   | G   | G   | EG  | DG  | DG  | G   | MG  | G   |
| A3 | G   | EG  | VG  | MG  | EG  | F   | F   | G   | EG  | VG  | G   | MG  |
| A1 | G   | G   | VG  | MG  | EG  | G   | EG  | G   | G   | DG  | DG  | DG  |
| D3 | A2  | EG  | G   | F   | G   | MG  | EG  | EG  | EG  | MG  | MG  | G   |
| A3 | VG  | EG  | VG  | G   | EG  | MG  | F   | G   | EG  | VG  | G   | MG  |
Table 9. The aggregated fuzzy rating of the alternatives.

| \( \hat{w}_j \) | \( \hat{w}_j \) | \( \hat{w}_j \) | \( \hat{w}_j \) | \( \hat{w}_j \) | \( \hat{w}_j \) |
|---------------|---------------|---------------|---------------|---------------|---------------|
| \( \frac{2}{5}, \frac{19}{30}, \frac{4}{5} \) | \( \frac{1}{2}, \frac{7}{10}, \frac{9}{10} \) | \( \frac{1}{2}, \frac{11}{15}, \frac{9}{10} \) | \( \frac{2}{5}, \frac{19}{30}, \frac{4}{5} \) | \( \frac{2}{5}, \frac{7}{10}, \frac{9}{10} \) | \( \frac{2}{5}, \frac{7}{10}, \frac{1}{5} \) |
| C1            | C2            | C3            | C4            | C5            | C6            |
| A1 (6, \frac{22}{3}, 9) | (6, 7, 8) | (6, \frac{22}{3}, 9) | (4, \frac{17}{3}, 7) | (6, 7, 8) | (7, \frac{25}{3}, 10) |
| A2 (8, \frac{28}{3}, 10) | (5, \frac{19}{3}, 8) | (4, \frac{16}{3}, 7) | (6, 7, 8) | (5, \frac{19}{3}, 8) | (8, 9, 10) |
| A3 (6, \frac{22}{3}, 9) | (8, \frac{28}{3}, 10) | (6, \frac{23}{3}, 9) | (5, \frac{20}{3}, 8) | (8, 9, 10) | (4, \frac{17}{3}, 7) |

| \( \hat{w}_j \) | \( \hat{w}_j \) | \( \hat{w}_j \) | \( \hat{w}_j \) | \( \hat{w}_j \) | \( \hat{w}_j \) |
|---------------|---------------|---------------|---------------|---------------|---------------|
| \( \frac{2}{5}, \frac{7}{10}, \frac{1}{5} \) | \( \frac{3}{5}, \frac{23}{30}, \frac{1}{3} \) | \( \frac{2}{2}, \frac{9}{5}, \frac{1}{10} \) | \( \frac{2}{2}, \frac{9}{5}, \frac{1}{10} \) | \( \frac{2}{19}, \frac{1}{5}, \frac{1}{5} \) | \( \frac{2}{5}, \frac{7}{10}, \frac{1}{5} \) |
| C7            | C8            | C9            | C10           | C11           | C12           |
| A1 (6, 7, 8) | (6, \frac{22}{3}, 9) | (6, 7, 8) | (6, \frac{23}{3}, 9) | (8, \frac{29}{3}, 10) | (8, \frac{29}{3}, 10) |
| A2 (8, \frac{28}{3}, 10) | (8, \frac{29}{3}, 10) | (5, \frac{20}{3}, 8) | (5, \frac{19}{3}, 8) | (6, 7, 8) | (6, 7, 8) |
| A3 (4, \frac{16}{3}, 7) | (5, \frac{20}{3}, 8) | (6, \frac{25}{3}, 10) | (7, \frac{26}{3}, 10) | (6, 7, 8) | (5, \frac{19}{3}, 8) |

4. Results and Discussion
The findings and sensitivity analysis performed are discussed in this section.

4.1. Results
An empirical data about the middle level manager selection problem in a company was used to demonstrate the application of the Fuzzy TOPSIS method. In this method, the values of the closeness coefficient, \( CC_i \), determined the ranking of the candidates. The \( CC_i \) values of the alternative are illustrated in graphical representation as presented in figure 3 below.

![Figure 3](image_url)
Meanwhile, table 10 depicts the final ranking of the candidates for the middle level manager position by using the Fuzzy TOPSIS method and the final ranking from a study by Kelemenis et al. [3].

| Alternatives | $d^+_i$ | $d^-_i$ | $CC_i$ | Ranking | Ranking from Kelemenis et al. [3] |
|--------------|---------|---------|--------|---------|----------------------------------|
| A1           | 1.0104  | 1.0782  | 0.5162 | 1       | 1                                |
| A2           | 1.1036  | 0.9363  | 0.4590 | 2       | 2                                |
| A3           | 1.1730  | 0.8667  | 0.4249 | 3       | 3                                |

This study used the classical Fuzzy TOPSIS method to select the middle level manager in a company while the extension of the Fuzzy TOPSIS method by Kelemenis et al. [3] was applied in incorporating the relative importance of the decision makers per criterion, the similarity-proximity degree among the decision makers and the veto thresholds to calculate the data. As shown in table 10 and figure 3, both methods were being used to compute the data generated in exactly the same ranking order for alternatives which is A1 > A2 > A3. The outcome revealed that A1 was selected as the most suitable candidate to fill in the middle level manager position in the company because it has the highest value of $CC_i$ compared to the other alternatives. The higher the value of $CC_i$, the more preferred the alternative is compared to the others [34]. Furthermore, the alternative will have a higher priority when its $CC_i$ value is closer to one [35]. A higher value of $CC_i$ means that the alternative has a shorter distance from the FPIS and a farther distance from the FNIS [33]. In general, the proposed method which is the Fuzzy TOPSIS method produced satisfactory results as it generated the same ranking order for alternatives as Kelemenis et al. [3].

4.2. Sensitivity Analysis

Sensitivity analysis is a graphical representation in which it reflects the volatility of the result when the input data has been modified [9]. In this study, the sensitivity analysis is performed by shifting the weight of each criterion to zero [36,37]. Twelve states were conducted for this sensitivity analysis. The results are illustrated in table 11 and figure 4 as below.

| State | Criteria being dropped | Alternatives Scores ($CC_i$) | Ranking |
|-------|------------------------|------------------------------|---------|
| 1     | C1                     | A1 0.5433 A2 0.4299 A3 0.4477 | A1 > A3 > A2 |
| 2     | C2                     | A1 0.5474 A2 0.5039 A3 0.3687 | A1 > A2 > A3 |
| 3     | C3                     | A1 0.4729 A2 0.5012 A3 0.3721 | A2 > A1 > A3 |
| 4     | C4                     | A1 0.5427 A2 0.4305 A3 0.4085 | A1 > A2 > A3 |
| 5     | C5                     | A1 0.5449 A2 0.4994 A3 0.3743 | A1 > A2 > A3 |
| 6     | C6                     | A1 0.4695 A2 0.3875 A3 0.4811 | A3 > A1 > A2 |
| 7     | C7                     | A1 0.5338 A2 0.3819 A3 0.4854 | A1 > A3 > A2 |
| 8     | C8                     | A1 0.5350 A2 0.3987 A3 0.4722 | A1 > A3 > A2 |
| 9     | C9                     | A1 0.5404 A2 0.4888 A3 0.3876 | A1 > A2 > A3 |
| 10    | C10                    | A1 0.5154 A2 0.4941 A3 0.3809 | A1 > A2 > A3 |
| 11    | C11                    | A1 0.4766 A2 0.4975 A3 0.4606 | A2 > A1 > A3 |
| 12    | C12                    | A1 0.4702 A2 0.4884 A3 0.4664 | A2 > A1 > A3 |
Figure 4. The radar diagram of the sensitivity analysis.

The radar diagram in figure 4 shows the $CC_i$ value of each alternative at twelve different states where the outcome which is the $CC_i$ value of the alternatives changed when the weight of each criterion was shifted to zero. The findings revealed that out of the twelve states, $A_1$ had the maximum scores in eight states (state 1, 2, 4, 5, 7, 8, 9, and 10). However, $A_1$ was ranked second for the other four states (state 3, 6, 11, and 12). In addition, $A_3$ obtained the minimum scores in eight out of twelve states (state 2, 3, 4, 5, 9, 10, 11, and 12). In contrast, $A_3$ was ranked second in states 1, 7, and 8 while ranked first in state 6 as depicted in table 11. Hence, it can be validated that $A_1$ was the most preferred alternative while $A_3$ was the least preferred alternative as $A_1$ was ranked first while $A_3$ was ranked third among the other alternatives in most of the states.

5. Conclusion and Recommendations

In this study, a real-life data about the middle level manager selection problem in a company was applied to demonstrate the application of the Fuzzy TOPSIS method. Generally, the assessment and selection process of managers is ambiguous and vague as it involves decision makers’ opinion. Hence, the fuzzy set theory is extremely helpful in solving these problems as the linguistic variables of the decision makers’ preference are converted into TFNs to evaluate the criteria weights and the ratings of all alternatives with respect to each criterion. The findings revealed that the ranking order for alternatives is $A_1 > A_2 > A_3$. From the results obtained, $A_1$ was the most preferred candidate and $A_3$ was the least preferred candidate for the middle level manager position in the company. This is because $A_1$ had the highest value of $CC_i$ and $A_3$ had the lowest value of $CC_i$ compared to other alternatives. Therefore, the purpose of this study which is to assess the alternatives and criteria weights for selecting the middle level manager in a company by using the Fuzzy TOPSIS method has been achieved.

Hatami-Marbini and Kangi [38] stated that the lack of conservation of fuzziness up to the end of the computation process will have an adverse effect on the final results as there is a lot of information lost. Thus, in order to handle this shortcoming of the Fuzzy TOPSIS method, it is recommended that Guha and Chakraborty’s method called the fuzzy distance measure to be applied between two generalized fuzzy numbers in the Fuzzy TOPSIS method for future researches where the fuzzy distance measurement between fuzzy numbers will be calculated as fuzzy numbers instead of crisp values [38,39]. Other than that, future researches also can be carried out by integrating the interval-valued intuitionistic fuzzy AHP (IVIF-AHP) and interval-valued intuitionistic fuzzy TOPSIS (IVIF-TOPSIS) approach. For this method, the IVIF-AHP approach can be used to calculate the weight of each criterion while the IVIF-TOPSIS approach is used to assess and rank the alternatives [40]. The use of the IVIF is recommended because it has a stronger ability and flexibility to represent ambiguity and hesitancy compared to the fuzzy and intuitionistic fuzzy (IF) approach [41]. Furthermore, the proposed model in this study is suitable to be applied in solving various MCDM problems, especially in the selection...
problems such as the selection of suppliers, locations, best students, and other selection problems where the data is inaccurate and uncertain.

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