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# A Hybrid Approach of Neutrosophic with MULTIMOORA in Application of Personnel Selection

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**Abstract:** Personnel selection is an important key for the success of human resource management in organizations. The main challenge faces organization is to determine the most proper candidates. To match organization requirements, the decision-makers do their best to achieve the most appropriate solutions. The process of choosing between candidates is a very complex and confused task. The environment of decision making is a multi-criteria decision making (MCDM) of various and conflicting criteria and alternatives in addition to the environmental conditions of uncertainty and incomplete information. Hence, this paper contributes to support the personnel selection process with non-classical methods by the integration of neutrosophic theory with MULTIMOORA. .A case study is applied on Telecommunication Company in smart village Cairo Egypt. The case study applies the hybrid approach to attain to most appropriate solutions in the problem of personnel selection.

**Keywords:** Personnel selection, Multi-criteria decision making (MCDM), Neutrosophic Sets, MULTIMOORA.

## 1. Introduction

The competitiveness of organizations can be achieved by the ability of efficient employment [1]. For organization, the most effective part of Human Resource Management is the personnel selection process [2]. The classical methods are used in organizations to select candidates were not sufficient enough and need to be enhanced, to continue proceeding with globalization and rivalry [3]. The numerous and conflict personal criteria make the decision maker confused [4]. The fuzzy set theory appears as an important tool to provide a decision framework that incorporates imprecise judgments inherent in the personnel selection process [5, 6] The Analytical Hierarchy Process (AHP) is used to format the complex problems into a hierarchical form **of** criterions, alternatives, and goals to support decision makers in the selection process [7]. Classical AHP method has been stretched to numerous fuzzy versions, because of partial information and ambiguity. Although the theories of fuzzy have been developed and generalized but cannot deal with all kinds of uncertainties in real problems. Indeed, sure kinds of uncertainties, such as indeterminate and inconsistent information, cannot be managed. Therefore, some new theories are required to present the truth membership, indeterminacy membership and falsity membership simultaneously this called neutrosophic sets. Unlike fuzzy, the neutrosophic sets deal with uncertain, inconsistent, and incomplete information in many researches [32-40]. The personnel selection is a multi-criteria decision-making (MCDM) problem that contains multiple criterions, alternatives, and decision makers to obtain the best candidate to be hire in organization [8]. The use of neutrosophic in personnel selection aids decision makers in the case of uncertainty and inconsistent information to achieve organizations objectives [9]. Sometimes neither of candidates satisfies the vision and objectives of organizations. Therefore, in this study we extend the neutrosophic personnel selection with MULTIMOORA method to encompass the measurement value the method reference level.

The Multi-Objective Optimization by Ratio Analysis (MOORA) method has been introduced by [10]. The MOORA is composed of ratio system, reference point [11-13]. The method MOORA enhanced to MULTIMOORA by adding full Multiplicative Form and employing Dominance Theory to obtain a final rank [2]. The ordinary MULTIMOORA method has been proposed for usage with crisp numbers. MUTIMOORA can solve larger numbers of complex decision-making problems by adding several extensions to solve wide range of problems. The hybrid approach handles the current obstacles and challenges by recommending the most appropriate candidates in the environment of uncertainty and incomplete information.

The structure of this paper ordered as follows: section 2 illustrates some related studies of personnel selection. Section 3 represents the hybrid methodology of neutrosophic with MUTIMOORA method to aid decision makers to choose most appropriate candidate to achieve the goal of organization. Section 4 represents an empirical case study for the proposed hybrid approach. Section 5 summarizes the research key pints and the future trends.

## 2. Related Studies

The processes of personnel selection in organizations can be affected by many conditions e.g. change the nature of work, governmental regulations, client's behavior, development of new technology, and others [14-16]. The traditional methods are not appropriate enough to keep on globalization. Hence organizations needs to make enhancement on personnel selection problem especially in the field of the judgments of decision makers by integrating advanced tools to decision support system [17,18]. In [19-22] describe the method of AHP with a fuzzy multi-criteria decision making algorithms for solving the personnel selection problems. In [23-25] describe the fuzzy MCDM with TOPSIS method to solve personnel selection problem using linguistic and numerical scales with different data sources to permit decision makers to evaluate candidate's information. In [19] illustrate the AHP method combined with fuzzy to solve personnel selection problem for information systems.

The MULTIMOORA method is extended by researchers to handle several MCDM problems [26, 27]. In [2,] the use of MULTMOORA with a fuzzy MCDM were not the most appropriate methodology. Due to the situations of uncertainty and incomplete information, researches recommend to integrate neutrosophic sets in personnel selection problem [28, 29]. We propose to be the first to applying the neutrosophic sets with MULTIMOORA method to aid decision makers to achieve to the most appropriate candidates.

**3. Methodology**

A hybrid MULTIMOORA method with neutrosophic is applied in personnel selection problem to select the best candidate to hire in organization. The MULTIMOORA method is used to solve personnel selection problem. In Fig. 1 represents conceptual flow of personnel selection to obtain ideal solution. In Fig. 2 represents the structure of methodology phase to apply MULTIMOORA method with neutrosophic. The phases for the hybrid approach are mentioned as follows:


**Figure 1**. conceptual flow of personnel selection problem.

***Phase1:*** Acquire expert information in neutrosophic environment.

- Determine the study goal, criteria, and alternative.
- Use neutrosophic scale mentioned in Table 1 [30].
- Create pairwise matrix of decision making judgments using the following form:

$$C^M = \begin{bmatrix} B_{11}^M & \cdots & B_{1z}^M \\ \vdots & \ddots & \vdots \\ B_{y1}^M & \cdots & B_{yz}^M \end{bmatrix} \quad (1)$$

- Aggregate pairwise matrix by:

$$B_{uv} = \frac{\sum_{M=1}^{M} <(l_{uv}^M, m_{uv}^M, u_{uv}^M);\, T_{uv}^M, I_{uv}^M, F_{uv}^M>}{M} \quad (2)$$

Where, M represents number of decision makers, $l_{uv}^M, m_{uv}^M, u_{uv}^M$ are lower, middle and upper bound of neutrosophic number, $T_{uv}^M, I_{uv}^M, F_{uv}^M$ are truth, indeterminacy and falsity.

- Construct the initial pairwise comparison matrix as mentioned:

$$C = \begin{bmatrix} B_{11} & \cdots & B_{1z} \\ \vdots & \ddots & \vdots \\ B_{y1} & \cdots & B_{yz} \end{bmatrix} \quad (3)$$

- Convert neutrosophic scales to crisp values by using score function of $B_{uv}$ [31]:

$$\text{s}(B_{uv}) = \left|(l_{uv} * m_{uv} * u_{uv})^{\frac{T_{uv}+I_{uv}+F_{uv}}{9}}\right| \quad (4)$$

where l, m, u represents lower, middle and upper of the scale neutrosophic numbers.

***Phase2:*** Calculate weights of criteria.

- Compute the average of row

$$w_u = \frac{\sum_{v=1}^{z}(B_{uv})}{z}; u = 1,2,3, \dots \dots . y; v = 1,2,3, \dots \dots . z; \quad (5)$$

- The normalization of crisp value is calculated using the following equation

$$w_u^y = \frac{w_u}{\sum_{u=1}^{y} w_u}; u = 1,2,3, \dots \dots . y \quad (6)$$

***Phase3:*** *Evaluate expert judgement using consistency rate*

Check the conistency of matrix using table 2 and for detailed information in [31]

- Compute weighted columns by multiplying the weight of priority by each value in the pairwise comparison matrix [31].
- The weighted sum values are divided with the corresponding priority.
- Compute the mean of the previous step denoted as $\lambda_{max}$.
- Compute consistency index $CI = \frac{\lambda_{max} - \text{n}}{n-1}$ ,where n the number of criteria.
- Calculate consistency ratio by the use for the mentioned equation

$$CR = \frac{CI}{RI} \quad (7)$$

Where, CR is the consistency rate, CI is consistency Index. RI is the random index for consistency matrix as mentioned in Table 3.

***Phase4:*** *MULTIMOORA Method*

The decision judgments between criterions and alternatives will be collected and obtained by the use of form (1). Then, apply Equation (2) to make a general vision of aggregation of experts. Finally, apply Equation (4) to change neutrosophic scale values to crisp values. The MULTIMOORA method consists of: ratio system, reference point and full multiplicative form.

***Phase4.1:*** *Ratio System*

- The first step of ratio system is to calculate the normalize of the decision matrix as mentioned:

$$B_{uv}^{*} = \frac{B_{uv}}{\sqrt[2]{\sum_{u=1}^{y} B_{uv}^{2}}} \; u = 1,2,3, \dots \dots , y \; and \; v = 1,2,3 \dots \dots , z. \quad (8)$$

- Compute the beneficial criteria ($Y^{+}$) is the summation of beneficial criteria of weight normalized elements of matrix. Then non-beneficial criteria denoted as ($Y^{-}$). Finally subtract sum of beneficial criteria from sum of non-beneficial criteria. (NB. In this study all criterions are beneficial)

$$Y^{+} = \sum_{v=1}^{g} w_v B_{uv}^{*} \quad (9)$$

$$Y^{-} = \sum_{v=1}^{z} w_v B_{UV}^{*} \quad (10)$$

- The next formula represents number of criteria to be maximized and (z-g) represents number of criteria to be minimized.

$$Y^{*} = \sum_{v=1}^{g} w_v B_{uv}^{*} - \sum_{v=g+1}^{z} w_v B_{uv}^{*} \quad (11)$$

,where $w_v$ is the weight of criteria

- Finally, Rank the alternatives

***Phase4.2:*** *Reference point*

The second step of neutrosophic MULTIMOORA is reference point

- Compute reference point to be maximized

$$r_v = \max_u (w_v (B_z^*)_{uv}). \quad (12)$$

- Compute reference point to be minimized

$$r_v = \min_u (w_v (B_z^*)_{uv}). \quad (13)$$

- Compute deviation of reference point

$$\min_v \left( \max_u |(r_u - w_v (x_z^*)_{uv})| \right). \quad (14)$$

***Phase4.3:*** *Full multiplicative form*

The third step of neutrosophic MULTIMOORA is full multiplicative form

- Compute utility of the alternative

$$U_u = \frac{E_u}{F_u} \quad (15)$$

$$E_u = \prod_{v=1}^{g} w_v (B_Z^*)_{uv} \quad (16)$$

$$F_u = \prod_{v=g+1}^{g} w_v (B_Z^*)_{uv} \quad (17)$$

The first component $E_u$ represents the product of criteria of $u$th alternative to be maximized. The second component $F_u$ represents the product criteria of $u$th alternative to be minimized.

- Finally apply the dominance theory to obtain final rank

**Table1.** Neutrosophic triangular scale (linguistic terms)

| Saaty scale | Caption | Neutrosophic triangular scale |
|---|---|---|
| 1 | Evenly significant | $\tilde{1}$ = < <1 ,1, 1>;0.50, 0.50, 0.50> |
| 3 | A little significant | $\tilde{3}$ = < <2 ,3, 4>;0.30, 0.75, 0.70> |
| 5 | Powerfully significant | $\tilde{5}$ = < <4 ,5, 6>;0.80, 0.15, 0.20> |
| 7 | Completely Powerfully significant | $\tilde{7}$ = < <6 ,7 ,8>;0.90, 0.10, 0.10> |
| 9 | Absolutely significant | $\tilde{9}$ = < <9 ,9 ,0>;1.00, 0.00, 0.00> |
| 2 | Sporadic values between two close scales | $\tilde{2}$ = < <1 ,2, 3>;0.40, 0.60, 0.65> |
| 4 | | $\tilde{4}$ = < <3 ,4, 5>;0.35, 0.60, 0.40> |
| 6 | | $\tilde{6}$ = < <5 ,6, 7>;0.70, 0.25, 0.30> |
| 8 | | $\tilde{8}$ = < <7 ,8 ,9>;0.85, 0.10, 0.15> |

**Table 2**. The consistency rate for pair-wise comparison matrix

| N | 4 × 4 | 5 × 5 | N > 4 |
|---|---|---|---|
| $CR \leq$ | 0.58 | 0.90 | 1.12 |

**Table 3.** Random Consistency index for various criterions

| Size of matrix | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Random Consistency | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

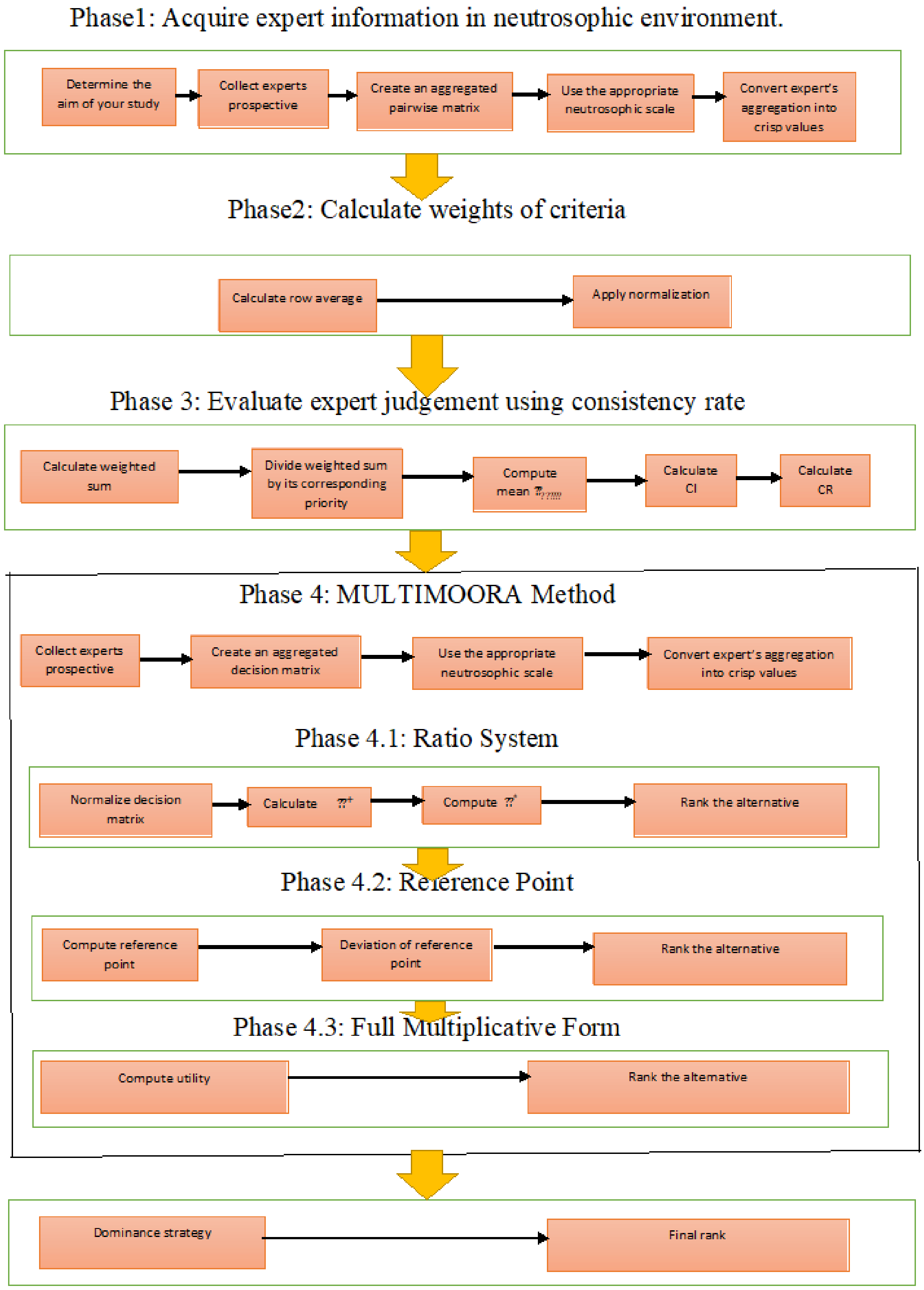


**Figure 2.** Personnel selection and MULTIMOORA method

## 4. An Empirical Case Study

In this section, the case study is about personnel selection in a telecommunication company in smart village in Egypt. The case study applies the hybrid methodology of neutrosophic with MULTIMOORA method. In order to make a general image for the telecommunication company, we adopt eight criterions, seven alternatives, and four decision makers. Figure 3 shows the relations between criterions and alternatives. The telecommunication goal is to hire best candidate to achieve competitive organization goals.

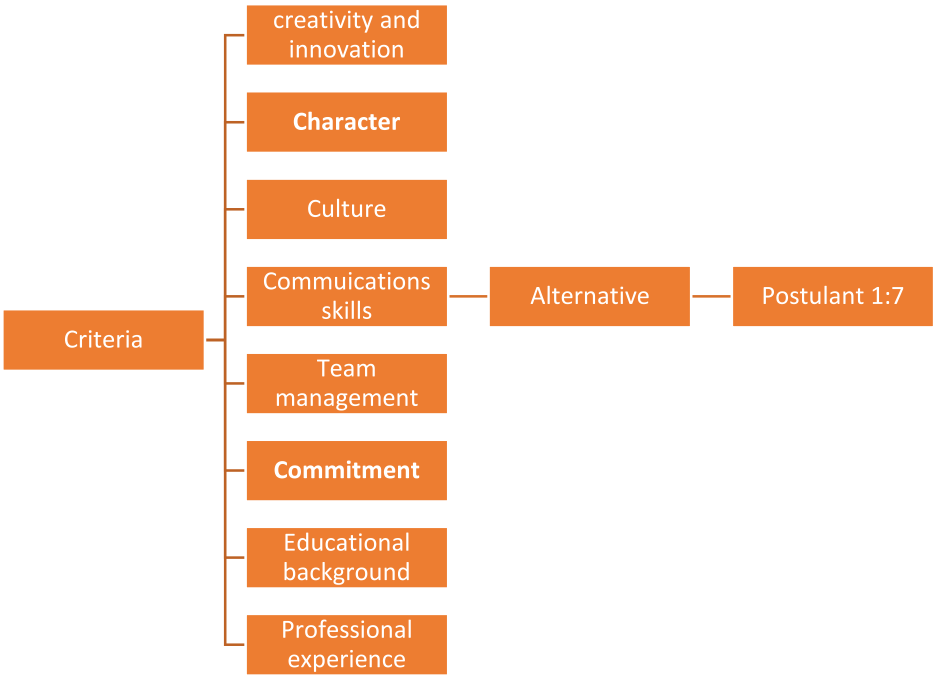


**Figure 3.** The AHP Structure for criteria and alternatives

***Phase 1:*** *Represent expert judgments in neutrosophic environment*

- Create neutrosophic triangular scale (linguistic term) in Table 1.
- Create the general vision pairwise comparison matrix of criteria in Table 4 in form (1).
- Aggregate pairwise comparison matrix of criteria using Equations (2) and form in (3).
- Convert aggregate pairwise comparison matrix of criteria to crisp value in Table 5 using Equation (4).

**Table 4.**The pairwise comparison matrix of criteria of decision maker judgments

| | | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|---|
| | C1 | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <7 ,8 ,9>;0.85, 0.10, 0.15> |
| | C2 | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> |
| | C3 | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <1, 1, 1 >;0.50, | < <1, 1, 1 >;0.50, | < <5 ,6, 7>;0.70, | < <4 ,5, 6>;0.80, | < <1 ,2, 3>;0.40, | < <4 ,5, 6>;0.80, | < <7 ,8 ,9>;0.85, |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DM1 | | | 0.50, 0.50> | 0.50, 0.50> | 0.25, 0.30> | 0.15, 0.20> | 0.60, 0.65> | 0.15, 0.20> | 0.10, 0.15> |
| | C4 | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> |
| | C5 | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1, 1, 1 >;0.50, 0.50, 0.50> |
| | C6 | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <1 ,2, 3>;0.40, 0.60, 0.65> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <1, 1, 1 >;0.50, 0.50, 0.50> |
| | C7 | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> |
| | C8 | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> |
| | | | | | | | | | |
| DM2 | C1 | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <1, 1, 1 >;0.50, 0.50, 0.50> |
| | C2 | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <3 ,4, 5>;0.35, 0.60, 0.40> |
| | C3 | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> |
| | C4 | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <3 ,4, 5>;0.35, 0.60, 0.40> |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | C5 | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> |
| | C6 | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <3 ,4, 5>;0.35, 0.60, 0.40> |
| | C7 | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> |
| | C8 | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | < <1, 1, 1 >;0.50, 0.50, 0.50> |
| | | | | | | | | | |
| **DM3** | C1 | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <3 ,4, 5>;0.35, 0.60, 0.40> |
| | C2 | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> |
| | C3 | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <1, 1, 1 >;0.50, 0.50, 0.50> |
| | C4 | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> |
| | C5 | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <5 ,6, 7>;0.70, 0.25, 0.30> |
| | C6 | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <3 ,4, 5>;0.35, 0.60, 0.40> |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | C7 | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> |
| | C8 | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | < <1, 1, 1 >;0.50, 0.50, 0.50> |
| | | | | | | | | | |
| **DM4** | C1 | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <1, 1, 1 >;0.50, 0.50, 0.50> |
| | C2 | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <1, 1, 1 >;0.50, 0.50, 0.50> |
| | C3 | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <3 ,4, 5>;0.35, 0.60, 0.40> |
| | C4 | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <3 ,4, 5>;0.35, 0.60, 0.40> |
| | C5 | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> |
| | C6 | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> |
| | C7 | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | < <1, 1, 1 >;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> |
| | C8 | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <1, 1, 1 >;0.50, 0.50, 0.50> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <3 ,4, 5>;0.35, 0.60, 0.40> | 1/< <7 ,8 ,9>;0.85, 0.10, 0.15> | 1/< <5 ,6, 7>;0.70, 0.25, 0.30> | 1/< <4 ,5, 6>;0.80, 0.15, 0.20> | < <1, 1, 1 >;0.50, 0.50, 0.50> |

**Table 5.** Crisp value of aggregated pairwise comparison matrix of criteria.

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| C1 | 1 | 1.88288 | 1.88288 | 1.85098 | 2.01946 | 2.04291 | 2.03948 | 1.76092 |
| C2 | 0.53110 | 1 | 1.77829 | 1.82446 | 1.94923 | 1.93354 | 1.53537 | 1.66246 |
| C3 | 0.53110 | 0.56233 | 1 | 2.05393 | 1.79510 | 2.02662 | 1.89927 | 1.95726 |
| C4 | 0.54025 | 0.54810 | 0.48687 | 1 | 2.01743 | 1.85375 | 1.82446 | 1.97178 |
| C5 | 0.48949 | 0.51302 | 0.55707 | 0.49568 | 1 | 1.88588 | 1.58172 | 2.01743 |
| C6 | 0.48949 | 0.51718 | 0.49343 | 0.53944 | 0.53025 | 1 | 1.71033 | 1.81143 |
| C7 | 0.49032 | 0.65130 | 0.52651 | 0.54810 | 0.63222 | 0.58468 | 1 | 1.89927 |
| C8 | 0.56788 | 0.60151 | 0.51091 | 0.50715 | 0.45991 | 0.55205 | 0.52651 | 1 |

***Phase 2:*** *Calculate weight of criteria* as mentioned in Fig. (4).

- Compute the average of row.

$$w_1 = 14.47951 \text{ w2} = 12.21445 \text{ w3} = 11.82561 \text{ w4} = 10.24264 \text{ w5} = 8.54029 \text{ w6} = 7.09155 \text{ w7} = 6.3324 \text{ w8} = 4.72592$$

- The normalization of crisp value is calculated.

$$w_1 = 0.1919026\ w_2 = 0.1618829\ w_3 = 0.1567294\ w_4 = 0.1357497\ w_5 = 0.1131878\ w_6 = 0.0939871\ w_7 = 0.0839257\ w_8 = 0.0626344$$

$$\sum w_i = 1\,.$$

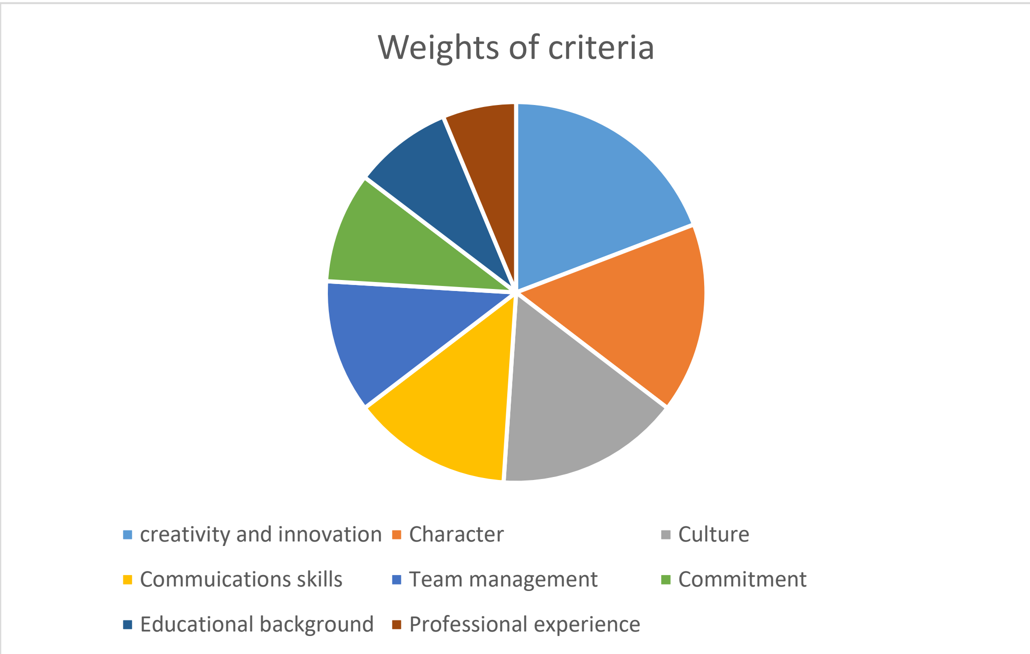


**Figure 4**. Pie chart weights of criteria

***Phase 3***: *Check consistency rate*

- Compute weighted sum

$$w_1 = 1.74501\ w_2 = 1.4254\ w_3 = 1.30403\ w_4 = 1.08356\ w_5 = 0.88104\ w_6 = 0.73916\ w_7 = 0.68578\ w_8 = 0.56598$$

- Divide weighted sum by weight of criteria

$$w_1 = 9.09320\ w_2 = 8.80513\ w_3 = 8.32026\ w_4 = 7.98204\ w_5 = 7.78387\ w_6 = 7.86448\ w_7 = 8.17127\ w_8 = 9.03624$$

- Divide summation of Weighted sum by the number of criteria 8
- Compute $\lambda_{max} = 8.38206$
- Compute $CI = \frac{\lambda_{max} - \mathrm{n}}{n-1} = \frac{8.38206 - 8}{8-1} = 0.05458$
- Compute $CR = \frac{\mathrm{CI}}{RI} = \frac{0.05458}{1.41} = 0.03870.$

Hence, the pair-wise comparison matrix is consistent and fellow the next phase of MULTIMOORA Method

***Phase 4:*** *MULTIMOORA Method Calculations*

- A session is performed with four decision makers and the collected judgments presented in table 6.
- Aggregate judgments of decision matrix of four decision makers using Equation (2).
- Compute crisp value of aggregated decision matrix using Equation (4) and mentioned in Table 7.

**Table 6.** The judgments for multiple decision makers

| | **Criteria/ Alternatives** | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|---|
| | A1 | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,2, 3>;0.40, 0.60, 0.65> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> |
| **DM1** | A2 | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <7 ,8 ,9>;0.85, 0.10, 0.15> |
| | A3 | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> |
| | A4 | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,2, 3>;0.40, 0.60, 0.65> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <1 ,2, 3>;0.40, 0.60, 0.65> | < <1 ,2, 3>;0.40, 0.60, 0.65> | < <1 ,1, 1>;0.50, 0.50, 0.50 |
| | A5 | < <7 ,8 ,9>;0.85, | < <1 ,1, 1>;0.50, | < <1 ,1, 1>;0.50, | < <4 ,5, 6>;0.80, | < <4 ,5, 6>;0.80, | < <7 ,8 ,9>;0.85, | < <7 ,8 ,9>;0.85, | < <4 ,5, 6>;0.80, |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0.10, 0.15> | 0.50, 0.50> | 0.50, 0.50> | 0.15, 0.20> | 0.15, 0.20> | 0.10, 0.15> | 0.10, 0.15> | 0.15, 0.20> |
| | A6 | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20 | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> |
| | A7 | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> |
| | | | | | | | | | |
| | A1 | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> |
| **DM2** | A2 | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <5 ,6, 7>;0.70, 0.25, 0.30> |
| | A3 | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> |
| | A4 | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,2, 3>;0.40, 0.60, 0.65> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <1 ,2, 3>;0.40, 0.60, 0.65> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> |
| | A5 | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> |
| | A6 | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> |
| | A7 | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <1 ,1, 1>;0.50, 0.50, 0.50> |
| | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DM3 | A1 | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> |
| | A2 | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> |
| | A3 | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,2, 3>;0.40, 0.60, 0.65> |
| | A4 | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,2, 3>;0.40, 0.60, 0.65> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> |
| | A5 | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> |
| | A6 | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> |
| | A7 | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <1 ,1, 1>;0.50, 0.50, 0.50> |
| | | | | | | | | | |
| DM4 | A1 | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <5 ,6, 7>;0.70, 0.25, 0.30> |
| | A2 | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <5 ,6, 7>;0.70, 0.25, 0.30> |
| | A3 | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <5 ,6, 7>;0.70, 0.25, 0.30> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A4 | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,2, 3>;0.40, 0.60, 0.65> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,2, 3>;0.40, 0.60, 0.65> | < <1 ,2, 3>;0.40, 0.60, 0.65> |
| | A5 | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <3 ,4, 5>;0.35, 0.60, 0.40> | < <1 ,1, 1>;0.50, 0.50, 0.50> |
| | A6 | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> |
| | A7 | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <1 ,1, 1>;0.50, 0.50, 0.50> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <7 ,8 ,9>;0.85, 0.10, 0.15> | < <4 ,5, 6>;0.80, 0.15, 0.20> | < <4 ,5, 6>;0.80, 0.15, 0.20> |

**Table 7.** The aggregated pairwise matrix for multiple decision maker's judgments

| **Criteria/ Alternatives** | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| A1 | 1.88288 | 1.96309 | 2.01160 | 1.93540 | 1.88606 | 1.99504 | 1.99504 | 2.03414 |
| A2 | 1.38248 | 2.00514 | 1.97958 | 2.073329 | 1.98669 | 2.25679 | 2.073329 | 2.12321 |
| A3 | 1.88288 | 2.06542 | 1.985350 | 1.95726 | 1.99504 | 2.03414 | 1.382488 | 2.063838 |
| A4 | 1.98669 | 1.96418 | 1.77208 | 1.55075 | 1.99504 | 1.73960 | 1.21198 | 1.11336 |
| A5 | 1.77829 | 1.75314 | 1.382488 | 1.77829 | 1.617809 | 1.915488 | 2.042910 | 1.88288 |
| A6 | 1.61780 | 1.98669 | 1.88288 | 1.38248 | 1.38248 | 1.93354 | 1.986697 | 1.996661 |
| A7 | 1.88288 | 1.88288 | 1.93354 | 1 | 1.762838 | 1.93354 | 1.97178 | 1.617809 |

**Phase 4.1:** The ratio system

- Calculate normalization of decision matrix in using Equation (8), and mentioned in Table 8.
- Calculate $Y^+$ (weight normalized) using Equation (9) in Table 9.
- $Y^- = 0$ because all criteria are beneficial.
- The ranks of ratio system ranking are mentioned in Table 10.

**Table 8.** The normalization matrix

| **Criteria/** Alternatives | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| A1 | 0.39896 | 0.38088 | 0.40856 | 0.42899 | 0.39241 | 0.38124 | 0.41009 | 0.41269 |
| A2 | 0.29293 | 0.38904 | 0.40205 | 0.45956 | 0.41335 | 0.43126 | 0.42618 | 0.43076 |
| A3 | 0.39896 | 0.40074 | 0.40322 | 0.43383 | 0.41508 | 0.38872 | 0.24817 | 0.41872 |
| A4 | 0.42095 | 0.38109 | 0.35991 | 0.34373 | 0.41508 | 0.33243 | 0.24912 | 0.22588 |
| A5 | 0.37680 | 0.34015 | 0.28078 | 0.39416 | 0.33659 | 0.36604 | 0.41993 | 0.38200 |
| A6 | 0.34279 | 0.38546 | 0.38241 | 0.30643 | 0.28763 | 0.36949 | 0.40837 | 0.40509 |
| A7 | 0.39896 | 0.36532 | 0.39270 | 0.22165 | 0.36677 | 0.36949 | 0.40530 | 0.32822 |

**Table 9.** The $Y^+$ (Weighted normalized)

| **Criteria/ Alternatives** | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| A1 | 0.076561 | 0.061657 | 0.064033 | 0.058235 | 0.044416 | 0.035831 | 0.034417 | 0.025848 |
| A2 | 0.056214 | 0.062978 | 0.063013 | 0.062385 | 0.046786 | 0.040532 | 0.035767 | 0.026980 |
| A3 | 0.076561 | 0.064872 | 0.063196 | 0.058892 | 0.046981 | 0.036534 | 0.020827 | 0.026226 |
| A4 | 0.080781 | 0.061691 | 0.056408 | 0.046661 | 0.046981 | 0.031244 | 0.020907 | 0.014147 |
| A5 | 0.072308 | 0.055064 | 0.044006 | 0.053507 | 0.038097 | 0.034403 | 0.035242 | 0.023926 |
| A6 | 0.065782 | 0.062399 | 0.059934 | 0.041597 | 0.032556 | 0.034727 | 0.034272 | 0.025372 |
| A7 | 0.076561461 | 0.059139061 | 0.061547635 | 0.030088921 | 0.041513889 | 0.034727294 | 0.034015086 | 0.020557863 |

**Table 10.** The ranks of Ratio system

| Alternatives | $Y^*$ | Ranking |
|---|---|---|
| A1 | 0.401001 | 1 |
| A2 | 0.394658 | 2 |
| A3 | 0.394094 | 3 |
| A4 | 0.358825 | 4 |
| A5 | 0.356557 | 7 |
| A6 | 0.356643 | 6 |
| A7 | 0.358151 | 5 |

**Phase 4.2:** *The reference point*

- Calculate Reference point $r_v$ using Eq. (12) in table 11
- Calculate deviations from reference point using Eq. (14) in table 12
- The Reference point ranking mentioned in table 13.

**Table 11**. Reference point

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| $R_j$ | 0.080781399 | 0.064872953 | 0.064033364 | 0.062385132 | 0.046981992 | 0.040532877 | 0.035767455 | 0.026980394 |

**Table 13.** Deviations from reference point.

| Criteria/Alternative | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| A1 | 0.004219938 | 0.003214994 | 0.00000000 | 0.004149868 | 0.002565967 | 0.004701235 | 0.001350365 | 0.001131803 |
| A2 | 0.02456737 | 0.00189403 | 0.001020309 | 0.00000000 | 0.000195815 | 0.00000000 | 0.00000000 | 0.00000000 |
| A3 | 0.004219938 | 0.00000000 | 0.000836935 | 0.00349284 | 0.00000000 | 0.003998211 | 0.014939614 | 0.000754118 |
| A4 | 0.00000000 | 0.003180999 | 0.007624886 | 0.015723888 | 0.00000000 | 0.009288745 | 0.014859885 | 0.012832536 |
| A5 | 0.008472499 | 0.009808485 | 0.020026883 | 0.00887803 | 0.00888411 | 0.006129839 | 0.000524536 | 0.003054053 |
| A6 | 0.014999107 | 0.00247357 | 0.004098474 | 0.020787351 | 0.014425785 | 0.005805583 | 0.001494717 | 0.001607825 |
| A7 | 0.004219938 | 0.005733892 | 0.002485729 | 0.032296211 | 0.005468103 | 0.005805583 | 0.001752369 | 0.006422531 |

**Table13.** Rank reference point

| Alternative | Max value (Deviations from reference point) | Rank reference point |
|---|---|---|
| A1 | 0.004701235 | 7 |
| A2 | 0.02456737 | 2 |
| A3 | 0.014939614 | 6 |
| A4 | 0.015723888 | 5 |
| A5 | 0.020026883 | 4 |
| A6 | 0.020787351 | 3 |
| A7 | 0.032296211 | 1 |

***Phase 4.3:*** *Full multiplicative form*

- Compute utility of the alternative using Equation (15), (16) and (17) in Table 14.
- The full Multiplicative form ranking in Table 15.

According to Table 16 and Fig. 5, the final rank recommends alternative one as the best alternative, while alternative four as the worst alternative.

**Table 14.** Utility and Rank of full multiplicative form.

| Alternatives | Utility ($U_u$) | Rank Multiplicative form |
|---|---|---|
| A1 | 2.49235E-11 | 2 |
| A2 | 2.54691E-11 | 1 |
| A3 | 1.73317E-11 | 3 |
| A4 | 5.69554E-12 | 7 |
| A5 | 1.03618E-11 | 4 |
| A6 | 1.00614E-11 | 5 |
| A7 | 8.45311E-12 | 6 |

**Table15.** The final rank according to the proposed hybrid methodology

| Alternatives | Ratio system | Reference point | Full multiplicative | (Final Rank) |
|---|---|---|---|---|
| A1 | 1 | 7 | 2 | 1 |
| A2 | 2 | 2 | 1 | 2 |
| A3 | 3 | 6 | 3 | 3 |
| A4 | 4 | 5 | 7 | 7 |
| A5 | 7 | 4 | 4 | 4 |
| A6 | 6 | 3 | 5 | 6 |
| A7 | 5 | 1 | 6 | 5 |

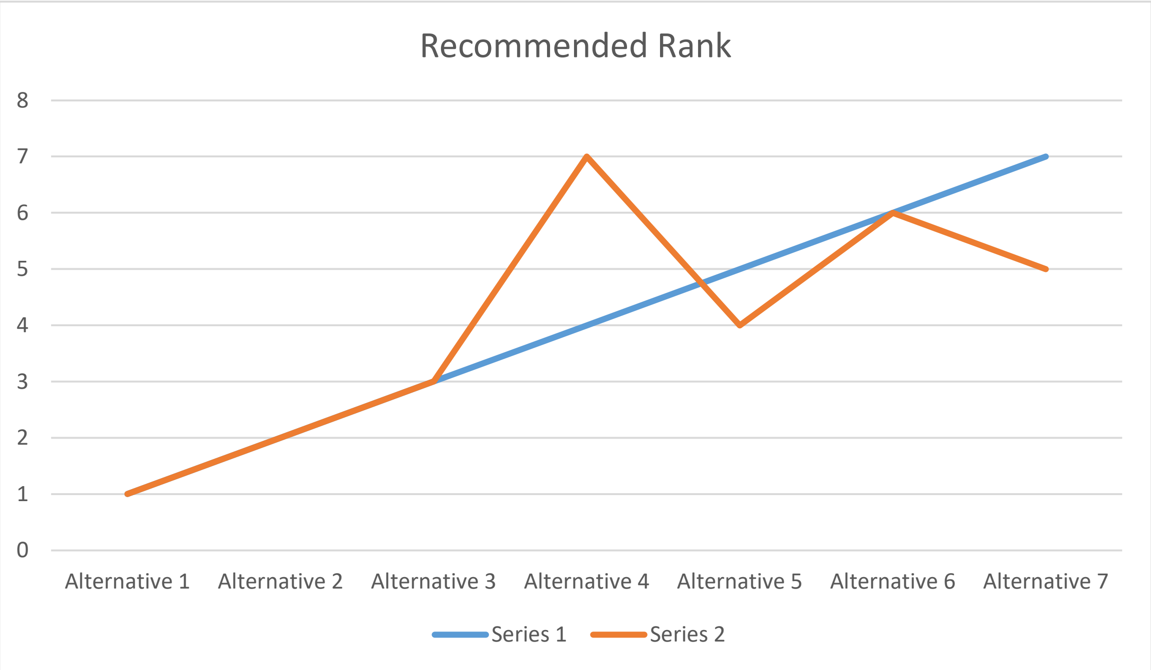


**Figure 5**. The final rank recommendation

## 5. Conclusions

Personnel selection is an important issue that effect on the competitive advantages for organizations. Decision makers take decisions for complex problems with various criterions and alternatives with surrounded environment of uncertain and incomplete information. The traditional methods cannot achieve to the proper solutions. In addition fuzzy cannot handle the conditions of uncertainty and inconsistency. The study proposes to use neutrosophic sets to handle the environmental conditions of uncertainty and inconsistent information, in addition extend study with MULTIMOORA method to choose the most appropriate candidate. A case study is applied on smart village Cairo, Egypt, on Telecommunication Company shows the effectiveness for the proposed method and provides final decision to hire the most appropriate candidate for attaining success of enterprises. The future work includes evolutionary algorithms for selecting the most effective criterions. In addition, applies other methodologies e.g. DEMTAL to improve the selection process.

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**Conflicts of Interest**

The authors declare no conflict of interest.

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