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An Integrated MCGDM Approach based Lean Faclitator Selection under Neutrosophic Environment

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Abstract— In today's practical work environment group decision making is essential to choose best alternative from set of alternatives which are characterized by multiple criteria. In manufacturing environment frequent group decision making is common practice which involves conflicting and multiple criteria problems. In present Competitive world manufacturing advantage can be achieved by lean practices. The effective implementation of lean tools in any manufacturing industry requires efficient facilitator. Selection of lean facilitator is a complex multi criteria scenario. The proposed work paves a new integrated approach for user at ease of functioning and generating accurate results. The integrated approach combines AHP most popular method for deriving criteria weights and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) chosen as best recommended method to rank alternatives. The proposed work is carried out under Neutrosophic environment which can express incomplete, indeterminate and inconsistent information. Used predefine Interval Neutrosophic Values (INV) associates with linguistic attributes. The INV basic aggregating operators and score functions are applied in evaluating the AHP weights. Euclidean distances, and developed a MCGDM method based on similarity degree estimates rank of alternatives through TOPSIS. Concern topic reviews are also presented in this paper.

Index Terms— AHP, Interval Neutrosophic Values, MCGDM, Lean Facilitator, TOPSIS, Fuzzy Sets, Intuitionistic Fuzzy Sets

1 Introduction

Multi Criteria Decision Making (MCDM) is a strategy of evaluating practical complex situations based on various qualitative or quantitative criteria in certain or uncertain environments to recommend best choice among available alternatives. Several comparative studies [1a] have been taken to demonstrate its vast applicability [1b, 1c, 1d, 1e]. Briefing MCDM methods [1] will give clear understanding over techniques available [2] and benefits [1a]. More than one decision maker involve in decision making process stated as Multi Criteria Group Decision Making (MCGDM).

Analytical Hierarchy Process is most popular tool for complex decision making developed by Saaty [3a]. Compares relative priorities of criteria [4] gives weights of each criteria [3] and best supports complex MCDM problems. It is versatile tool [5] having wide flexibility of handle number of attributes in hierarchical manner [6].

In real world decision making conflicting, inconsistent, indeterminate information cannot be expressed in terms of crisp values. Fuzzy Set (FS) theory [7] gives truth function which describes decision maker acceptance value to alternative categorized by an attribute. But the constraint lies, it doesn't represent false function. Atanassov introduce Intuitionistic Fuzzy Sets (IFS) [8,9] which can represent truth membership function T(x) as well as falsity membership function F(x), they satisfy the condition $T(x), F(x) \in [0,1]$ and $0 \leq T(x)+F(x) \leq 1$. In IFS the indeterminate function is rest of truth and false functions 1-T(x)-F(x) that is indeterminate and inconsistence functions are not clearly defined. Smarandache [10] generalize FS, IFS, and Interval Valued Intuitionistic Fuzzy Set (IVIFS) [9] so on as Neutrosophic Set (NS) by adding indeterminate information. In NS the truth membership, indeterminacy membership, false membership functions are completely independent.

Recently, NS became interesting area for researcher to convert qualitative information into quantitative values which can express supporting, nondeterministic, rejection values in

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terms of NS Values. Wang [12] propose Single Valued Neutrosophic Sets (SVNS) and Ye [13] gaves correlation coefficient and weighted correlation coefficient in SVNS. Similar to IVIFS. Wang proposed Interval Neutrosophic Sets (INS) [14] in which the truth membership, indeterminacy membership, false membership functions were extended to interval values. Ye [15] given similarity measures between INSs based on Hamming and Euclidean distances demonstrate with a MCDM problem.

However, the proposed work is predefines INS values to represent linguistic attributes and derives the weight of criteria with aid of AHP and rank the alternatives by TOPSIS. In order to derive weights some of basic aggregation operations need to perform, given by [16]. As well as INS score and accuracy functions [17] are used to derive AHP weights. TOPSIS was developed by Hwang and Yoon [18]. It has extensive applicability of solving complex MCDM problems [19-26]. Based on INS Euclidean distances using similarity measuring [27] method rank the alternatives.

The rest of paper organized as follows. Section 2 basic definitions of Neutrosophic sets, briefing aggregation operators and score, distance measuring functions are given. In Section 3 methodology adopted is discussed. In Section 4 evaluation of case study with proposed method. In Section 5 conclusions are given.

2 Some Basic Theories on Nuetrosophic Environment

2.1 Interval Neutrosophic Sets (INS) [14]

The real scientific and engineering applications can be expressed as INS values.

Let X be a space of points (objects) and Int [0,1] be the set of all closed subsets of [0,1]. An INS $\tilde{A}$ in X is defined with the form $\tilde{A}=\{\langle x, u_A(x), w_A(x), v_A(x)\rangle : x \in X\}$

Where $u_A(x)$:$X\rightarrow$int[0,1], $w_A(x)$:$X\rightarrow$int[0,1] and $v_A(x)$:$X\rightarrow$int[0,1] with $0\leq \sup u_A(x)+\sup w_A(x)+\sup v_A(x)\leq 3$ for all $x \in X$. The intervals $u_A(x)$, $w_A(x)$ and $v_A(x)$ denote the truth membership degree, the indeterminacy membership degree and the falsity membership degree of x to $\tilde{A}$, respectively.

For convenience, if let $u_A(x) = [u_A^-(x), u_A^+(x)]$, $w_A(x) = [w_A^-(x), w_A+(x)]$ and $v_A(x) = [v_A-(x), v_A+(x)]$, then $\tilde{A}=\{\langle x, [u_A-(x),u_A+(x)], [w_A-(x),w_A+(x)], [v_A-(x),v_A+(x)]\rangle : x\in X\}$

With the condition, $0\leq \sup u_A+(x)+\sup w_A+(x)+\sup v_A+(x)\leq 3$ for all $x\in X$. Here, we only consider the sub-unitary interval of [0,1]. Therefore, an INS is clearly neutrosophic set.

2.2 Compliment of INS [15]

The complement of an INS $\tilde{A}$ is denoted by $\tilde{A}^c$ and is defined as $u_A{}^c(x) = v(x)$, $(w_A-)^c(x)=1-w_A{}^+(x)$, $(w_A{}^+)^c(x)=1-w_A{}^-(x)$ and $v_A{}^c(x)=u(x)$ for all $x\in X$. That is, $\tilde{A}^c=\{\langle x,[v_A{}^-(x),v_A{}^+(x)],[1-w_A{}^+(x),1-w_A{}^-(x)],[u_A{}^-(x),u_A{}^+(x)]\rangle : x\in X\}$.

2.3 INS Subsets [15]

An interval neutrosophic set $\tilde{A}$ is contained in the other INS $\tilde{B}$, $\tilde{A} \subseteq \tilde{B}$, if $u\ -(x) \leq u\ -(x)$, $u\ +(x) \leq u\ +(x)$, $w\ -(x) \geq w\ -(x)$, $w_A+(x) \geq w_B+(x)$ and $v_A-(x) \geq v\ -(x)$, $v\ +(x) \geq v\ +(x)$ for all $x\in X$.

2.4 INS E [15]

Two INSs $\tilde{A}$ and B are equal, can be written as $\tilde{A} = \tilde{B}$, if $\tilde{A} \subseteq \tilde{B}$ and $\tilde{B} \subseteq \tilde{A}$.

2.5 A W A GE OPERATOR FOR INS [16]

Let $\tilde{A}_k$ $(k=1, 2,\ldots,n) \in$ INS(X). The interval neutrosophic weighted average operator is defined by $F_\omega = (\tilde{A}_1,\tilde{}_2,\ldots,\tilde{A}_n) = \sum_{k=1}^{n} w_k A_k$=1

=

$$\left(\left[1-\prod_{k=1}^{n}\left(1-u^-{}_{A_k}(x)\right)^{w_k}, 1-\prod_{k=1}^{n}\left(1-u^+{}_{A_k}(x)\right)^{w_k}\right], \left[\prod_{k=1}^{n}\left(w^-{}_{A_k}(x)\right)^{w_k}, \prod_{k=1}^{n}\left(w^+{}_{A_k}(x)\right)^{w_k}\right], \left[\prod_{k=1}^{n}\left(v^-{}_{A_k}(x)\right)^{w_k}, \prod_{k=1}^{n}\left(v^+{}_{A_k}(x)\right)^{w_k}\right]\right)$$

(Equation: 1)

Where ω_k is the weight of $\tilde{A}_k$ $(k=1,2,\ldots,n)$, $\omega_k\in[0,1]$ and $\sum_{k=1}^{n} w_k = 1$. Principally, assume $\omega_k=1/n$ $(k=1,2,\ldots,n)$, then F_ω is called an arithmetic average operator for INSs.

2.6 Geometric Weighted Average Operator for INS [16]

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Let $\tilde{A}_k$ (k=1,2,…,n) ∈ INS(X). The interval neutrosophic weighted geometric average operator is defined by $G_\omega=(\tilde{A}1,\tilde{A}2,\ldots,\tilde{A}n)$ = $\prod_{k=1}^{n} A_k^{w_k}$=

$$\left(\left[\prod_{k=1}^{n}\left(u^-_{\tilde{A}_k}(x)\right)^{w_k},\prod_{k=1}^{n}\left(u^+_{\tilde{A}_k}(x)\right)^{w_k}\right],\quad \left[1-\prod_{k=1}^{n}\left(1-w^-_{A_k}(x)\right)^{w_k},1-\prod_{k=1}^{n}\left(1-w^+_{A_k}(x)\right)^{w_k}\right], \atop \left[1-\prod_{k=1}^{n}\left(1-v^-_{A_k}(x)\right)^{w_k},\quad \left(1-\prod_{k=1}^{n}\left(1-v^+_{A_k}(x)\right)^{w_k}\right)\right]\right)$$

(Equation: 2)

Where ωk is the weight of $\tilde{A}_k$ (k=1,2,…,n), ω_k ∈ [0,1] and $\sum_{k=1}^{n} w_k = 1$. Principally, assume $\omega_k=1/n$ (k=1,2,…,n), then G_ω is called a geometric average for INSs.

The above aggregation operators remain INS values. The emphasis on above definitions 2.13 and 2.14 can be defined as the arithmetic weighted average operator gives group influence and geometric weighted average operator gives individual influence. So, the geometric weighted average (GWA) operator more sensitive comparatively. For this reason the current work is carried out with GWA.

2.8 INS Score function [17]

Let $\tilde{A}$ = ([a, b], [c, d], [e, f]) be an interval valued neutrosophic number, a score function L of an interval valued neutrosophic value, based on the truth-membership degree, indeterminacy membership degree and falsity membership degree is defined by

$(\tilde{A}) = \frac{2+a+b-2c-2d-e-f}{4}$ **(Equation: 3)**

where $L(\tilde{A}) \in [-1,1]$.

2.9 INS Accuracy function [17]

Let A = ([a, b], [c, d], [e, f]) be an interval valued neutrosophic number. Then an accuracy function N of an interval neutrosophic value, based on the truth membership degree, indeterminacy membership degree and falsity membership degree is defined by

$(\tilde{A})=1/2(a+b-d(1-b)-c(1-a)-f(1-c)-e(1-d))$ **(Equation: 4)**

where $L(\tilde{A}) \in [-1,1]$.

2.10 INS Ranking [27]

Suppose that $\tilde{A}_1$ = ([a_1, b_1], [c_1, d_1], [e_1, f_1]) and $\tilde{A}_2$ = ([a_2, b_2], [c_2, d_2], [e_2, f_2]) are two interval valued neutrosophic sets Then we define the ranking method as follows:

(i) If L $(\tilde{A}_1)$ > L $(\tilde{A}_2)$, then $\tilde{A}_1 > \tilde{A}_2$.

(ii) If L $(\tilde{A}_1)$ = L $(\tilde{A}_2)$ and N $(\tilde{A}1)$ > N $(\tilde{A}2)$, then $\tilde{A}_1 > \tilde{A}_2$.

2.11 INS Distance measuring functions [27]

Let x = ([$T_1{}^L$,$T_1{}^U$],[$I_1{}^L$, $I_1{}^U$],[$F_1{}^L$, $F_1{}^U$]) , and y = ([$T_2{}^L$,$T_2{}^U$],[$I_2{}^L$, $I_2{}^U$],[$F_2{}^L$, $F_2{}^U$]) be two INVs, then

(1) The Hamming distance between x and y is defined as follows **(Equation: 5)**

$$d_H(x,y) = \frac{1}{6}\left(\begin{matrix} |T_1^L - T_2^L| + |T_1^U - T_2^U| + |I_1^L - I_2^L| + \\ |I_1^U - I_2^U| + |F_1^L - F_2^L| + |F_1^U - F_2^U| \end{matrix} \right)$$

(2) The Euclidian distance between x and is defined as follows. **(Equation: 6)**

$$d_E(x,y) = \sqrt{\frac{1}{6}\left(\begin{matrix} (T_1^L - T_2^L)^2 + (T_1^U - T_2^U)^2 + (I_1^L - I_2^L)^2 + \\ (I_1^U - I_2^U)^2 + (F_1^L - F_2^L)^2 + (F_1^U - F_2^U)^2 \end{matrix} \right)}$$

3. Methodology Adopted

Step 1: Define a Multi Criteria Decision Making problem

Step 2: Obtain relative prioritized matrix of Criteria from each decision maker

Step 3: Use INS GWA **(Equation: 2)** operator to aggregate each decision matrix into a group decision matrix

Step 4: Derive weights of criteria aid of score function **(Equation: 4)** after row aggregation.

Step 5: Establish Criteria-Alternative group decision matrix using predefined attribute INS values

Step 6: Find Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS) form step 5.

Step 7: Measure Euclidean distances (Equation: 6) of each alternative form PIS and NIS.

Step 8: Rank the alternatives based on Closeness Coefficient (CC) values. (Lower the CC value higher will be the rank)

4. Case Study

Step 1:

In dynamic global competition Lean implementation is key strategy for achieving organizational goals. The effective lean implementation can accomplish only by efficient Lean facilitator. Selection of Lean facilitator is a complex decision making problem characterized by

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multiple criteria within several possibilities. The Lean facilitator is responsible for reducing or minimizing waste in overall plant and eliminating non value adding activities and maximizing total plant productivity resulting profits to the organization.

As stated above the Lean facilitator selection is multi criteria group decision making problem. It illustrates as follows.

Group of Decision Makers (DM) are:

{DM1, DM2, DM3}

DM1: Top Management, DM2: Professional Consultant, DM3: Operational Head

Set of Criteria in order to select the alternatives are:

{C1, C2, C3, C4, C5}

C1. Educational Qualification: The knowledge acquired through education is basic to understand fundamental concepts of Lean tools and techniques; this represents potential knowledge of the candidate. The relevant qualification will enhance candidate confidence in lean implementation.

C2. Process Knowledge: In order to apply the right Lean tool at the right place/ Process, the knowledge of process in the organization plays a vital role, so that Lean facilitator can apply right instrument of lean as per necessity.

C3. Leadership Quality: Lean facilitator should own the process of implementation and need to organize, control and guide teams of different levels of management and operators towards common goal. His leadership traits like communication, self-motivation showing the direction and giving right solution to the constraints at the right time plays vital role of success.

C4. Experience/ Achievements: The experience refers to the live scenarios faced in previous assignments/ projects and achievements reflects the level of accomplishment through received rewards and appreciation by management, peers etc., Which has significant weightage while choosing a right candidate for lean facilitator at the organization in live scenario which gives higher operational achievements.

C5. Report Writing: An effective documentation skill in lean practices reduces the repeatability of tedious flow and information. Reporting of right information from the data will reduce the time and increases the effectiveness.

To maintain confidentiality the facilitators are named as {F1, F2, F3, F4, and F5}

Table 1: Predefined Linguistic Variables associated with Interval Valued Neutorsophic numbers

Very Low (VL)	**([0.1,0.2], [0.4,0.5], [0.5,0.6])**
Low (L)	**([0.3,0.4], [0.3,0.4], [0.2,0.3])**
Below Average(BA)	**([0.3,0.4], [0.2,0.3], [0.3,0.4])**
Average (A)	**([0.4,0.5], [0.2,0.3], [0.2,0.3])**
Above Average (AA)	**([0.4,0.5], [0.1,0.2], [0.2,0.3])**
Good (G)	**([0.5,0.6], [0.1,0.2], [0.1,0.2])**
Very Good (VG)	**([0.6,0.7], [0.1,0.2], [0.0,0.1])**
Excellent (E)	**([0.7,0.8], [0.0,0.1], [0.0,0.1])**

Note: The methodology simulated using MATLAB software

STEP 2:

Table 2: Relative prioritized criteria matrix of decision makers

Priorities	**DM1**	**DM2**	**DM3**
Education Knowledge	G	G	E
Leadership Quality	VG	E	G
Process Knowledge	E	E	AA
Experience/Achievements	VG	AA	G
Report Writing	E	G	VG

STEP 3:

Table 3: Aggregated Criteria matrix

Education Knowledge	([0.5593 0.6604] [0.0678 0.1680] [0.0678 0.1680])
Leadership Quality	([0.5944 0.6952] [0.0678 0.1680] [0.0345 0.1347])
Process Knowledge	([0.5809 0.6840] [0.0345 0.1347] [0.0717 0.1723])
Experience/Achievements	([0.4932 0.5944] [0.1000 0.2000] [0.1037 0.2042])
Report Writing	([0.5944 0.6952] [0.0678 0.1680] [0.0345 0.1347])

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STEP 4:

Table 4: Score and Weights of each criterion

Criteria	Score	Weights
Education Knowledge	0.6701	0.1984
Leadership Quality	0.7042	0.2085
Process Knowledge	0.7043	0.2085
Experience/Achievements	0.5949	0.1761
Report Writing	0.7042	0.2085

STEP 5:

Table 5: Criteria-Alternative group decision matrix

Alternatives	**Education Knowledge**			**Leadership Quality**			**Process Knowledge**			**Experience /Achievements**			**Report Writing**		
DM's	**DM1**	**DM2**	**DM3**	**DM1**	**DM2**	**DM3**	**DM1**	**DM2**	**DM3**	**DM1**	**DM2**	**DM3**	**DM1**	**DM2**	**DM3**
Facilitator 1	**VG**	**VG**	**G**	G	VG	VG	VG	VG	G	G	VG	G	G	VG	G
Facilitator 2	**G**	**AA**	**VG**	G	AA	VG	A	AA	G	G	AA	G	G	AA	AA
Facilitator 3	**G**	**VG**	**G**	G	AA	G	VG	G	AA	G	G	VG	G	AA	G
Facilitator 4	**G**	**G**	**G**	AA	A	AA	VG	G	VG	G	AA	G	AA	A	AA
Facilitator 5	**VG**	**G**	**G**	G	G	AA	VG	VG	G	G	G	AA	E	G	VG

STEP 6:

For instance first column Positive and Negative Ideal solutions are given.

Positive Ideal Solution (PIS):

For all j {[max (a_{ij}) max(b_{ij})] [min(c_{ij}) min(d_{ij})] [min(e_{ij}) min(f_{ij})]}

([0.1316 0.1693] [0.6766 0.7610] [0.5649 0.7116])

Negative Ideal Solution (NIS): For all j {[min (a_{ij}) min(b_{ij})] [max(c_{ij}) max(d_{ij})] [max(e_{ij}) max(f_{ij})]}

([0.1089 0.1420] [0.6766 0.7610] [0.6808 0.7637])

STEP 7:

Euclidean distances: Derived from Equation 6

(First column only)

Table 6: Euclidean Distance from PIS

F1	**0**
F2	**0.0539**
F3	**0.0310**
F4	**0.0516**
F5	**0.0310**

Table7: Euclidean Distance from NIS

F1	**0.0539**
F2	**0**
F3	**0.0231**
F4	**0.0023**
F5	**0.0231**

STEP 8: Ranking of alternatives is based on ratio of closeness coefficient $Rcc_i = d_i^+ / d_i^+ - d_i^-$ **(Equation: 7)**

Rank order	Rcc_i
F1	**0.1016**
F5	**0.346**
F3	**0.5901**
F4	**0.7546**
F2	**0.8306**

5. CONCLUSION

The selection of lean facilitator is conflict multi criteria group decision making problem. It is evaluated by newly proposed approach which hybridized AHP weighting method and TOPSIS ranking method, gives best result as comparatively. In order to reduce fuzzy and vagueness of subjective data given by decision makers the interval valued neutrosophic numbers are used. The proposed method gives the flexibility to decision maker's own choice for criterion weights instead of deviational weights. TOPSIS used to rank the facilitator under neutrosopihic environment. Score function and Euclidean distances aided to evaluate ranks.

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