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Evaluation of Supplier in Lean Manufacturing Environment using Neutrosophic Sets and Systems

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Abstract**: Supplier selection is one of the most important decision making activities of organizations. Proper supplier selection will lead to achieve short-term and long-term goals of organization efficiently. Nowadays organizations focus mainly on minimization of waste in every aspect which in turn increases the importance of implementing lean principles. This present work involves finding the relative importance of criteria required to determine the rank of lean suppliers using most advanced Multi Criteria Decision making method i.e. Neutrosophic Sets and Systems. It is found that Delivery Performance ranked as the first criterion among the six criteria and it is followed by technology capability, quality, cost / price, flexibility and reliability. Finally, supplier ranking have been achieved and future scope of the present work is discussed.
Keywords: Neutrosophic Sets and Systems, Lean, Linguistic Ratings, Supplier Selection

I. INTRODUCTION

Purchased raw materials, instruments, machines represents 40 to 60 % of the sales of any organization's end products (Ballow, 1999). Which means the profit of the organization is sensitive with purchasing i.e. a small reduction in cost of purchased products can affect the profit positively.

Organizations strive to implement lean manufacturing system because of its benefits i.e. even though the aim of Lean manufacturing is to "waste minimization" it leads the organization to achieve following benefits such as easy management, improved customer service, fewer defects, improved quality and financial benefits. "Lean is a very basis of supply chain management" argued by Agus and Hajinoor, 2012. Implementing Lean in automotive manufacturing, shop floor operations and in entire supply chain requires extensive research. This work focuses mainly on supplier selection process of a Lean manufacturing firm.

Supplier selection process involves consideration of multiple criteria, a group of decision maker with number of supplier alternatives. So, supplier selection is considered as a Multi Criteria Group Decision Making (MCDM) problem in supply chain. In the present work we consider four decision makers and four alternate suppliers. For a long time Fuzzy is considered as the best technique to solve the decision making problems involving multi criteria. In this work Interval Valued Neutrosophic Sets and Systems is used which is an extension of fuzzy- logic. IVNS consider the indeterminacy of decision maker while intuitionist fuzzy allows some indeterminacy. IVNS removes the dependency of membership's components on one other, which in turn gives the decision makers the freedom to choose. The main objective of present work is to perform a comparative evaluation of supplier selection processes in lean manufacturing environment using an advanced MCDM approach i.e. Neutrosophic Sets and Systems. To achieve the objective following steps should be followed:

A. Identify the supplier selection processes used by the company.
B. Identify key performance measures.
C. Recognize in which criteria the company focuses.
D. Identify the company's best alternative supplier.

II. LITERATURE REVIEW

Supplier selection is considered as one of the important decision making problems in supply chain. Many researches have been done on supplier selection arena using different techniques and procedures. Bevilacqua and Petroni (2010)[1] developed a model for evaluating supplier using fuzzy-logic which reduces the uncertainty inherent in evaluation of weights of criteria and helped in determination of impact of each supplier contribution on the criteria. Yigin et al. (2007)[2] selected automotive sector to design a supply chain management and developed an expert system tools to select the supplier in that supply chain management area. Ozkarahan (2007)[3] introduced multi criteria sorting method based on PROMETHEE methodology which assess supplier's co-design capabilities, overall performances, reasons for difference in performances and then implemented supplier development programs to achieve strategic sourcing. Chan et al. (2008)[4] discussed the fuzzy based Analytical Hierarchy Process in selection of global supplier by considering both qualitative and quantitative factors involved. Kuo and Lin (2012)[5] considered green indicators in protection of environment issues and used Analysis Network Process(ANP) with Data Envelopment Analysis(DEA) in evaluating supplier. Jassbi et al (2014)[6] proposed a model using DMCDM and successfully implemented it in evaluating supplier in an automotive industry. Nuri et al. (2015)[7] chose a furniture manufacturing firm which applies lean production to apply fuzzy-AHP method in evaluating criteria ranking for supplier selection and found that "Delivery performance" as the most prioritized criteria. Shobha and Subramanya et al. 2016[8] compared the rankings of supplier obtained by applying Analytical Hierarchy Processing(AHP), Fuzzy Approach and Analytical Network Process(ANP) in order to study the merits and demerits of each method in evaluating supplier. Samaranache (1999, 2005)[9] presented the distinctions between neutrosophic sets and systems and Intuitionistic fuzzy method. Generalized the fuzzy logic, intuitionistic fuzzy logic and Interval valued fuzzy logic to the neutrosophic sets (NS). Wang (2010)[10] develop Single Valued Neutrosophic Sets (SVNS) and Ye (2013)[11] presented correlation coefficient of single valued neutrosophic sets(SVNSs) based on the correlation coefficient of intuitionistic fuzzy sets. Based on the above researches, the present work is to evaluate the supplier in lean manufacturing environment using advanced MCDM method i.e. Interval Neutrosophic Sets and Systems.

III. METHODOLOGY

The present work is carried out in a steel processing industry producing Cold Rolled Steel Strips, Precision Tubes, Railway wagons Coaches, Pre-Engineered Building Systems, Sheet Metal Components, Road Safety Systems ,etc. The company's annual production capacity is more than 350,000 MTPA. The company have many suppliers for steel out of which four supplier were selected by screening (S_1, S_2, S_3, S_4) for evaluation and four decision makers (DM_1, DM_2, DM_3, DM_4) were selected for giving weights and ratings for the criteria and supplier's contribution to the criteria respectively. Initially, pre-defined linguistic Variables associated with Interval Valued Neutorsophic numbers for weights and ratings are shown in Table 1

TABLE 1: PRE-DEFINED VARIABLES ASSOCIATED WITH IVN NUMBERS

Very Low (VL)	([0.1,0.2], [0.4,0.4], [0.5,0.6])
Low (L)	([0.3,0.4], [0.3,0.3], [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])

A. *IVNS (Interval Valued Neutrosophic Sets and Systems)*

To handle the indeterminate information and inconsistent information which exist commonly in real situations, Smarandache firstly presented a neutrosophic set from philosophical point of view, which is a powerful general formal framework and generalized the concept of the classic set, fuzzy set, interval-valued fuzzy set, intuitionistic fuzzy set, interval-valued intuitionistic fuzzy set, paraconsistent set, dialetheist set, paradoxist set, and tautological set.

1) *Definition: Neutrosophic Set (NS):* Let X be a space of points (objects) and $x \in X$. A Neutrosophic set A in X is defined by a truth membership function (x), an indeterminacy membership function $I(x)$ and a falsity membership function $F_A(x)$. (x), $I(x)$ and $F_A(x)$ are real standard or real nonstandard subsets of $]0^-,1^+[$. That is $T_A(x)$: $X \rightarrow]0^-,1^+[$, $I_A(x)$: $X \rightarrow]0^-,1^+[$ and $F_A(x)$:$X \rightarrow]0^-,1^+[$. There is no restriction on the sum of (x),$I_A(x)$ and $F_A(x)$, so $0^- \leq \sup T_A(x) \leq \sup I_A(x) \leq \sup F_A(x) \leq 3^+$.
2) *Definition: Compliments of NS:* The complement of a neutrosophic set A is denoted by A^c and is defined as $T_A{}^c(x) = \{1^+\} \ominus(x)$, $I_{A^c}(x) = \{1^+\} \ominus I_A(x)$ and $F_{A^c}(x) = \{1^+\} \ominus F_A(x)$ for all $x \in X$.
3) *Definition: Interval Neutrosophic Sets (INS) :* 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 $\tilde{A} = \{\langle x, u_{\tilde{A}}(x), w_{\tilde{A}}(x), v_{\tilde{A}}(x) \rangle : x \in X\}$ Where $u_{\tilde{A}}(x)$:$X \rightarrow int[0,1]$, $w_{\tilde{A}}(x)$:$X \rightarrow int[0,1]$ and $v_{\tilde{A}}(x)$:$X \rightarrow int[0,1]$ with $0 \leq \sup u_{\tilde{A}}(x) + \sup w_{\tilde{A}}(x) + \sup v_{\tilde{A}}(x) \leq 3$ for all $x \in X$. The intervals $u_{\tilde{A}}(x)$, $w_{\tilde{A}}(x)$ and $v_{\tilde{A}}(x)$ denote the truth membership degree, the

indeterminacy membership degree and the falsity membership degree of x to $\tilde{A}$, respectively. For convenience, if let $u_{\tilde{A}}(x) = [u_{\tilde{A}}^{-}(x), u_{\tilde{A}}^{+}(x)]$, $w_{\tilde{A}}(x) = [w_{\tilde{A}}^{-}(x), w_{\tilde{A}}+(x)]$ and $v_{\tilde{A}}(x) = [v_{\tilde{A}}-(x), v_{\tilde{A}}+(x)]$, then $\tilde{A}=\{\langle x, [u_{\tilde{A}}-(x),u_{\tilde{A}}+(x)], [w_{\tilde{A}}-(x),w_{\tilde{A}}+(x)], [v_{\tilde{A}}-(x),v_{\tilde{A}}+(x)]\rangle: x\in X\}$ with the condition, $0\leq \sup u_{\tilde{A}}+(x)+\sup w_{\tilde{A}}+(x)+\sup v_{\tilde{A}}+(x)\leq 3$ for all $x\in X$. Here, we only consider the sub-unitary interval of [0,1]. Therefore, an INS is clearly neutrosophic set.

4) *Definition: Compliment of INS:* The complement of an INS $\tilde{A}$ is denoted by $\tilde{A}^c$ and is defined as $u_{\tilde{A}^c}(x) = v_{A}(x)$, $(w_{\tilde{A}}-)^c(x)=1-w_{\tilde{A}}^{+}(x)$, $(w_{\tilde{A}}^{+})^c(x)=1-w_{\tilde{A}}^{-}(x)$ and $v_{\tilde{A}^c}(x)=u_{A}(x)$ for all $x\in X$. That is, $\tilde{A}^c=\{\langle x, [v_{\tilde{A}}^{-}(x),v_{\tilde{A}}^{+}(x)], [1-w_{\tilde{A}}^{+}(x), 1-w_{\tilde{A}}^{-}(x)],[u_{\tilde{A}}^{-}(x),u_{\tilde{A}}^{+}(x)]\rangle:x\in X\}$.

5) *Definition: Geometric Weighted Average Operator for INS :* Let $\tilde{A}_k$ $(k=1,2,\ldots,n)\in$ INS(X). The interval neutrosophic weighted geometric average operator is defined by $G_\omega=(\tilde{A}1,\tilde{A}2,\ldots,\tilde{A}n) = \prod_{k=1}^{n} A_k^{w_k}=$

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

(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 G_ω is called a geometric average for INSs. 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.

6) *Definition: INS Score function :* 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

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

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

7) *Definition: INS Distance measuring functions:* The Euclidian distance between x and is defined as follows.

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

(Equation 3)

B. The IVNS based Ranking Procedure

Supplier selection in lean manufacturing system using Neutrosophic sets and systems involves two major steps, shown in figure1 and figure 2

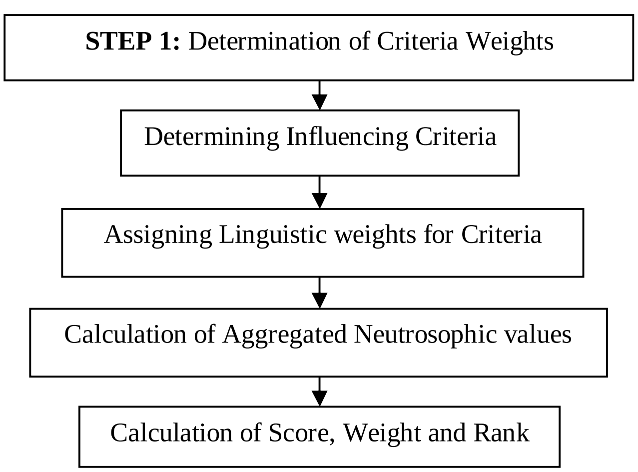

Fig 1: Determination of Criteria Weights `

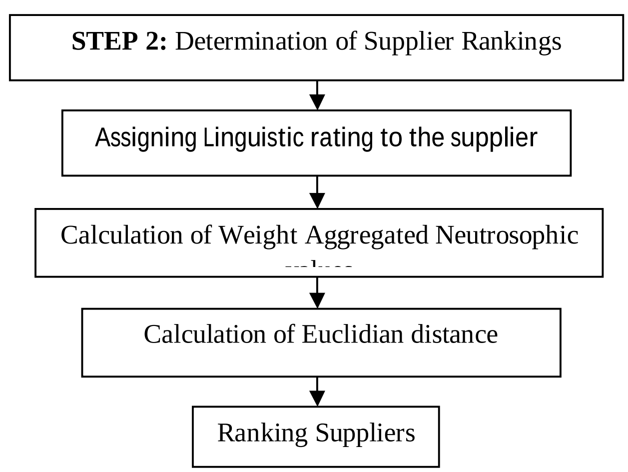

Fig 2 : Determination of Supplier Rankings

The application of a Interval Valued Neutrosophic sets algorithm implies that the relative importance of each attribute and the impact of each alternative supplier are defined using linguistic variables shown in table 1.

1) *Determining Influencing Criteria:* Four experts were formed as a panel to review the supply chain literatures and came up with "six critical" criteria that are considered in evaluating lean supplier. Those are Cost, Quality, Delivery Performance, Reliability, Flexibility and Technology Capability. Each criterion has been divided into sub-criteria to increase the sensitivity of the results.(Table 2)

TABLE 2: CRITERIA AND SUB- CRITERIA SELECTED FOR LEAN SUPPLIER EVALUATION

Goal	Criteria	Sub-Criteria
Supplier evaluation in Lean SC	Cost, C_1	Product cost, C_{11}
		Transportation cost, C_{12}
		Inventory cost, C_{13}
		Quotation behavior, C_{14}
		Payment, C_{15}
	Quality, C_2	Product Quality, C_{21}
		Lot acceptance rate, C_{22}
		Parts scrap rate, C_{23}
	Delivery performance, C_3	Delivery rate on time, C_{31}
		Delivery cycle time, C_{32}
		Delivery of a quality product, C_{33}
		Frequent deliveries, C_{34}
		Changeable order acceptance rate, C_{35}
	Reliability, C_4	Delivery reliability, C_{41}
		Efficiency of order processing, C_{42}
		Incremental improvement, C_{43}
		Product liability, C_{44}
	Flexibility, C_5	Product volume changes, C_{51}
		Production flexibility, C_s
		Short set-up time, C_{53}
		Short delivery lead time, C_{54}
		Conflict resolution, C_{55}
	Technology Capability, C_6	Design capability, C_{61}
		Manufacturing adaption level, C_{62}
		Capability of R&D, C_{63}
		Production techniques level, C_{64}

2) *Assigning Linguistic weights for Criteria:* Decision makers of the panels are assigned weights for each criterion based on their importance in lean supply (Table 3).

TABLE 3: LINGUISTIC WEIGHTS FOR EACH CRITERION GIVEN BY DM'S

Performance indicators/Criteria	Linguistic weights			
	DM1	DM2	DM3	DM4
Product cost, C_{11}	G	VG	VG	VG
Transportation cost, C_{12}	E	G	VG	AA
Inventory cost, C_{13}	VG	VG	A	AA
Quotation behavior, C_{14}	BA	L	G	L
Payment, C_{15}	L	VL	A	A
Product Quality, C_{21}	VG	E	G	VG
Lot acceptance rate, C_{22}	G	E	G	VG

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Parts scrap rate,C_{23}	AA	VG	L	L
Delivery rate on time,C_{31}	E	E	VG	E
Delivery cycle time,C_{32}	VG	VG	G	E
Delivery of a quality product,C_{33}	E	E	VG	E
Frequent deliveries,C_{34}	G	VG	G	G
Changeable order acceptance rate,C_{35}	G	VG	AA	G
Delivery reliability,C_{41}	AA	VG	G	E
Efficiency of order processing,C_{42}	G	L	VG	G
Incremental improvement,C_{43}	L	VG	VL	L
Product liability,C_{44}	L	VL	E	AA
Product volume changes, C_{51}	G	VG	A	VG
Production flexibility,C_{52}	VG	E	AA	E
Short set-up time, C_{53}	G	A	VL	A
Short delivery lead time, C_{54}	VG	AA	G	G
Conflict resolution, C_{55}	A	VL	G	L
Design capability, C_{61}	G	VG	AA	VG
Manufacturing adaption level, C_{62}	E	E	VG	E
Capability of R&D,C_{63}	VG	VG	G	G
Production techniques level, C_{64}	VG	VG	AA	G

3) *Calculation of Aggregated Neutrosophic values:* Using geometric weighted average (GWA) operator linguistic values each criterion is aggregated (Table 4).

TABLE 4: AGGREGATED VALUES FOR EACH CRITERIA

Sub-Criteria	Aggregated Neutrosophic values					
Product cost,C_{11}	0.5733	0.6735	0.1000	0.2000	0.0260	0.1261
Transportation cost,C_{12}	0.5384	0.6402	0.0760	0.1761	0.0788	0.1793
Inventory cost,C_{13}	0.4899	0.5916	0.1261	0.2263	0.1056	0.2063
Quotation behavior,C_{14}	0.3409	0.4427	0.2293	0.2762	0.2031	0.3036
Payment,C_{15}	0.2632	0.3761	0.2800	0.3265	0.2887	0.3914
Product Quality,C_{21}	0.5958	0.6964	0.0760	0.1761	0.0260	0.1261
Lot acceptance rate,C_{22}	0.5692	0.6701	0.0760	0.1761	0.0513	0.1515
Parts scrap rate,C_{23}	0.3834	0.4865	0.2063	0.2517	0.1541	0.2546
Delivery rate on time,C_{31}	0.6735	0.7737	0.0260	0.1261	0	0.1000
Delivery cycle time,C_{32}	0.5958	0.6964	0.0760	0.1761	0.0260	0.1261
Delivery of a quality product,C_{33}	0.6735	0.7737	0.0260	0.1261	0	0.1000
Frequent deliveries,C_{34}	0.5233	0.6236	0.1000	0.2000	0.0760	0.1761
Changeable order acceptance rate,C_{35}	0.4949	0.5958	0.1000	0.2000	0.1028	0.2031
Delivery reliability,C_{41}	0.5384	0.6402	0.0760	0.1761	0.0788	0.1793
Efficiency of order processing,C_{42}	0.4606	0.5635	0.1548	0.2263	0.1028	0.2031
Incremental improvement,C_{43}	0.2711	0.3869	0.2828	0.3036	0.2479	0.3519
Product liability,C_{44}	0.3027	0.4229	0.2159	0.2584	0.2479	0.3519
Product volume changes, C_{51}	0.5180	0.6192	0.1261	0.2263	0.0788	0.1793
Production flexibility,C_{52}	0.5856	0.6880	0.0513	0.1515	0.0543	0.1548
Short set-up time, C_{53}	0.2991	0.4162	0.2333	0.3036	0.2674	0.3707
Short delivery lead time, C_{54}	0.4949	0.5958	0.1000	0.2000	0.1028	0.2031
Conflict resolution, C_{55}	0.2783	0.3936	0.2584	0.3036	0.2674	0.3707
Design capability, C_{61}	0.5180	0.6192	0.1000	0.2000	0.0788	0.1793
Manufacturing adaption level, C_{62}	0.6735	0.7737	0.0260	0.1261	0	0.1000
Capability of R&D,C_{63}	0.5477	0.6481	0.1000	0.2000	0.0513	0.1515
Production techniques level, C_{64}	0.5180	0.6192	0.1000	0.2000	0.0788	0.1793

TABLE 5: LEAN ATTRIBUTE AGGREGATION

Criteria	Aggregated neutrosophic values
Cost,C_1	0.4231 0.5316 0.1661 0.2430 0.1458 0.2475
Quality,C_2	0.5066 0.6100 0.1216 0.2021 0.0788 0.1793
Delivery performance,C_3	0.5875 0.6887 0.0662 0.1663 0.0419 0.1421
Reliability,C_4	0.3777 0.4929 0.1859 0.2425 0.1731 0.2761
Flexibility,C_5	0.4163 0.5294 0.1576 0.2393 0.1595 0.2620
Technology Capability,C_6	0.5609 0.6622 0.0820 0.1821 0.0528 0.1531

4) *Calculation of Score, Weight and Rank:* Using the score formula given in equation 2, we calculated the score of each criterion and then weight and rank shown in table 6.

TABLE 6: SCORE, WEIGHT AND RANK OF EACH ATTRIBUTE

Attribute	Score	Weight	Rank
Cost,C_1	0.4966	0.1456	4
Quality,C_2	0.6033	0.1769	3
Delivery performance,C_3	0.6984	0.2048	1
Reliability,C_4	0.4518	0.1413	6
Flexibility,C_5	0.4924	0.1444	5
Technology Capability,C_6	0.6677	0.1958	2

Performance indicators/Attributes	Suppliers	Linguistic ratings			
		DM1	DM2	DM3	DM4
Cost,C_1	S1	G	AA	A	AA
	S2	VG	VG	VG	E
	S3	G	VG	G	G
	S4	VG	VG	G	G
Quality,C_2	S1	E	E	VG	E
	S2	E	VG	E	E
	S3	E	VG	VG	VG
	S4	VG	VG	VG	G
Delivery Performance,C_3	S1	VG	VG	G	VG
	S2	E	E	VG	E
	S3	VG	G	AA	G
	S4	VG	VG	G	VG
Reliability,C_4	S1	VG	E	VG	VG
	S2	E	VG	E	VG
	S3	G	VG	G	G
	S4	G	VG	G	AA
Flexibility,C_5	S1	AA	VG	G	G
	S2	E	E	VG	E
	S3	VG	G	VG	G
	S4	G	G	VG	G
Technology Capability,C_6	S1	VG	VG	G	G
	S2	E	VG	G	VG
	S3	VG	VG	VG	E
	S4	AA	A	AA	G

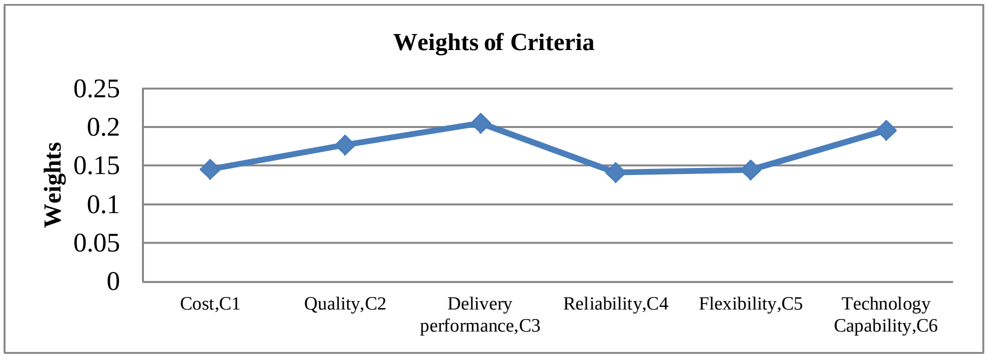

Fig 3: Weights calculated for each criterion

From Table 6, The ranking of criteria are determined as: {Delivery performance, Technology capability, Quality, Cost, Flexibility and Reliability}. Weights of each criterion describes their importance in lean supplier evaluation(Figure 3).

5) *Assigning Linguistic rating to the supplier :* Decision makers of the panels are assigned ratings for individual supplier's contribution to each criteria (Table 7).

TABLE 7: LINGUISTIC RATING OF EACH SUPPLIER BASED ON THEIR SATISFACTORY TOWARDS EACH CRITERIA GIVEN BY DM'S

6) *Calculation of Weight Aggregated neutrosophic value:* Using geometric weighted average (GWA) operator linguistic values each supplier is aggregated (Table 4).

TABLE 8: AGGREGATED VALUES OF SUPPLIER RATINGS

Supplier	Criteria	Aggregated neutrosophic values					
S_1	C_1	0.4229	0.5233	0.1261	0.2263	0.1761	0.2762
	C_2	0.6735	0.7737	0.0260	0.1261	0	0.1000
	C_3	0.5733	0.6735	0.1000	0.2000	0.0260	0.1261
	C_4	0.6236	0.7238	0.0760	0.1761	0	0.1000
	C_5	0.4949	0.5958	0.1000	0.2000	0.1028	0.2031
	C_6	0.5477	0.6481	0.1000	0.2000	0.0513	0.1515
S_2	C_1	0.6236	0.7238	0.0760	0.1761	0	0.1000
	C_2	0.6735	0.7737	0.0260	0.1261	0	0.1000
	C_3	0.6735	0.7737	0.0260	0.1261	0	0.1000
	C_4	0.6481	0.7483	0.0513	0.1515	0	0.1000
	C_5	0.6735	0.7737	0.0260	0.1261	0	0.1000
	C_6	0.5958	0.6964	0.0760	0.1761	0.0260	0.1261
S_3	C_1	0.5233	0.6236	0.1000	0.2000	0.0760	0.1761
	C_2	0.6236	0.7238	0.0760	0.1761	0	0.1000
	C_3	0.4949	0.5958	0.1000	0.2000	0.1028	0.2031
	C_4	0.5233	0.6236	0.1000	0.2000	0.0760	0.1761
	C_5	0.5477	0.6481	0.1000	0.2000	0.0513	0.1515
	C_6	0.6236	0.7238	0.0760	0.1761	0	0.1000
S_4	C_1	0.5477	0.6481	0.1000	0.2000	0.0513	0.1515
	C_2	0.5733	0.6735	0.1000	0.2000	0.0260	0.1261
	C_3	0.5733	0.6735	0.1000	0.2000	0.0260	0.1261
	C_4	0.4949	0.5958	0.1000	0.2000	0.1028	0.2031
	C_5	0.5233	0.6236	0.1000	0.2000	0.0760	0.1761
	C_6	0.4229	0.5233	0.1261	0.2263	0.1761	0.2762

Criteria weights(C1,C2,C2,C3,C4,C5) = [0.1456,0.1769,0.2048,0.1413,0.1444,0.1958] from Table 6 Criteria weights are aggregated with neutrosophic values of the suppliers Table 9.

TABLE 9: WEIGHTED NEUTROSOPHIC VALUES EACH SUPPLIER.

Supplier	Criteria	Weighted neutrosophic values					
S_1	C_1	0.0315	0.0422	0.8864	0.9171	0.9038	0.9278
	C_2	0.0631	0.0829	0.8085	0.8864	0	0.8745
	C_3	0.0484	0.0631	0.8745	0.9105	0.8085	0.8864
	C_4	0.0553	0.0722	0.8606	0.9038	0	0.8745
	C_5	0.0390	0.0514	0.8745	0.9105	0.8759	0.9113
	C_6	0.0452	0.0590	0.8745	0.9105	0.8412	0.8959
S_2	C_1	0.0553	0.0722	0.8606	0.9038	0	0.8745
	C_2	0.0631	0.0829	0.8085	0.8864	0	0.8745
	C_3	0.0631	0.0829	0.8085	0.8864	0	0.8745
	C_4	0.0590	0.0772	0.8412	0.8959	0	0.8745
	C_5	0.0631	0.0829	0.8085	0.8864	0	0.8745
	C_6	0.0514	0.0671	0.8606	0.9038	0.8085	0.8864
S_3	C_1	0.0422	0.0553	0.8745	0.9105	0.8606	0.9038
	C_2	0.0553	0.0722	0.8606	0.9038	0	0.8745
	C_3	0.0390	0.0514	0.8745	0.9105	0.8759	0.9113
	C_4	0.0422	0.0553	0.8745	0.9105	0.8606	0.9038
	C_5	0.0452	0.0590	0.8745	0.9105	0.8412	0.8959
	C_6	0.0553	0.0722	0.8606	0.9038	0	0.8745
S_4	C_1	0.0452	0.0590	0.8745	0.9105	0.8412	0.8959
	C_2	0.0484	0.0631	0.8745	0.9105	0.8085	0.8864
	C_3	0.0484	0.0631	0.8745	0.9105	0.8085	0.8864
	C_4	0.0390	0.0514	0.8745	0.9105	0.8759	0.9113
	C_5	0.0422	0.0553	0.8745	0.9105	0.8606	0.9038
	C_6	0.0315	0.0422	0.8864	0.9171	0.9038	0.9278

7) *Calculation Euclidian distance of each supplier from PIS and NIS:* PIS and NIS of each supplier is calculated by using the following equations 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})]} 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})]} Where, i - column numbers j – criteria number

TABLE 10: POSITIVE AND NEGATIVE SOLUTIONS OF EACH SUPPLIER

Supplier	PIS	NIS
1	(0.0631 0.0829) (0.8085 0.8864) (0 0.8745)	(0.0315 0.0422) (0.8864 0.9171) (0.9038 0.9278)
2	(0.0631 0.0829) (0.8085 0.8864) (0 0.8745)	(0.0514 0.0671) (0.8606 0.9038) (0.8085 0.8864)
3	(0.0553 0.0722) (0.8606 0.9038) (0 0.8745)	(0.0514 0.0671) (0.8606 0.9038) (0.8085 0.8864)
4	(0.0484 0.0631) (0.8745 0.9105) (0.8085 0.8864)	(0.0315 0.0422) (0.8864 0.9171) (0.9038 0.9278)

TABLE 11: EUCLIDEAN DISTANCES OF SUPPLIERS FROM PIS AND NIS

S_1	PIS Distance	0.3718	0	0.3315	0.0231	0.3594	0.3449
	NIS Distance	0	0.3718	0.0442	0.3701	0.0151	0.0305
S_2	PIS Distance	0.0231	0	0	0.0142	0	0.3310
	NIS Distance	0.3301	0.3310	0.3310	0.3303	0.3310	0
S_3	PIS Distance	0.3517	0	0.3581	0.3517	0.3436	0
	NIS Distance	0.0073	0.3581	0	0.0073	0.0160	0.3581
S_4	PIS Distance	0.0141	0	0	0.0300	0.0228	0.0442
	NIS Distance	0.0305	0.0442	0.0442	0.0151	0.0220	0

8) *Ranking Suppliers:* Formula for calculating rank of supplier is

$$\text{RCC} = \frac{\text{Sum of Euclidian distance from PIS}}{\text{Sum of Euclidian distance from PIS} + \text{Sum of Euclidian distance from NIS}}$$

TABLE 12: RANKING OF SUPPLIERS

Supplier	RCC	Rank
1	0.6478	3rd
2	0.1822	1st
3	0.6529	4th
4	0.4189	2nd

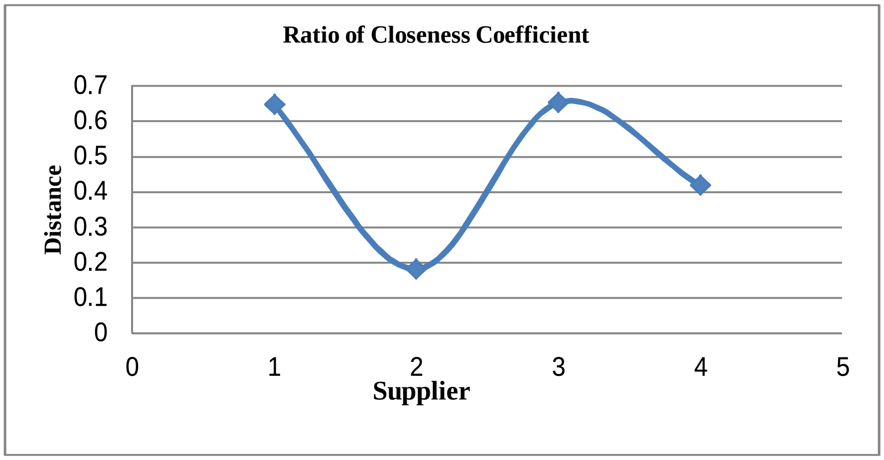

Fig 4: Ranking of suppliers

From Table 11, supplier-2, whose RCC (Ratio of Closeness Coefficient) value is minimum i.e. supplier 2 is close to the PIS (Positive Ideal Solution) and determined as the best alternative. The ranking of supplier alternatives is determined as: {$S_2 < S_4 < S_1 < S_3$} showed in fig 4.

IV. RESULTS AND DISCUSSIONS

Lean manufacturing enterprises will be capable of delivery higher quality products at significantly low costs and shorter lead time. They will be able to eliminate waste from the manufacturing process which increases the labour and equipment effectiveness. Lean has been developed primarily within a manufacturing environment the ideas behind lean are as applicable to service industries and even the various service departments within a manufacturing company. Four suppliers, four decision makers and six criteria are considered for evaluating supplier. Step 1 determines the weights for each criterion using neutrosophic sets. It was found that Delivery performance plays important role in supplier selection (Table 6). Step 2 involves determining the rank of suppliers according to their closeness to the positive ideal solutions using RCC and determined that selecting supplier 2 can lead the company to achieve leanness quickly.

V. FUTURE SCOPE

Application of lean philosophy in suppler evaluation is considered one of the important decision making problem in industries and need a lot of researches. This study determines supplier alternative by considering six criteria, four decision makers and four supplier alternatives.

A. This work can be extended by:

1) Comparing with fuzzy-AHP technique
2) Increasing more areas of criteria with the concern sub-criterions
3) Making a Panel with more Decision Makers to achieve sensitive results

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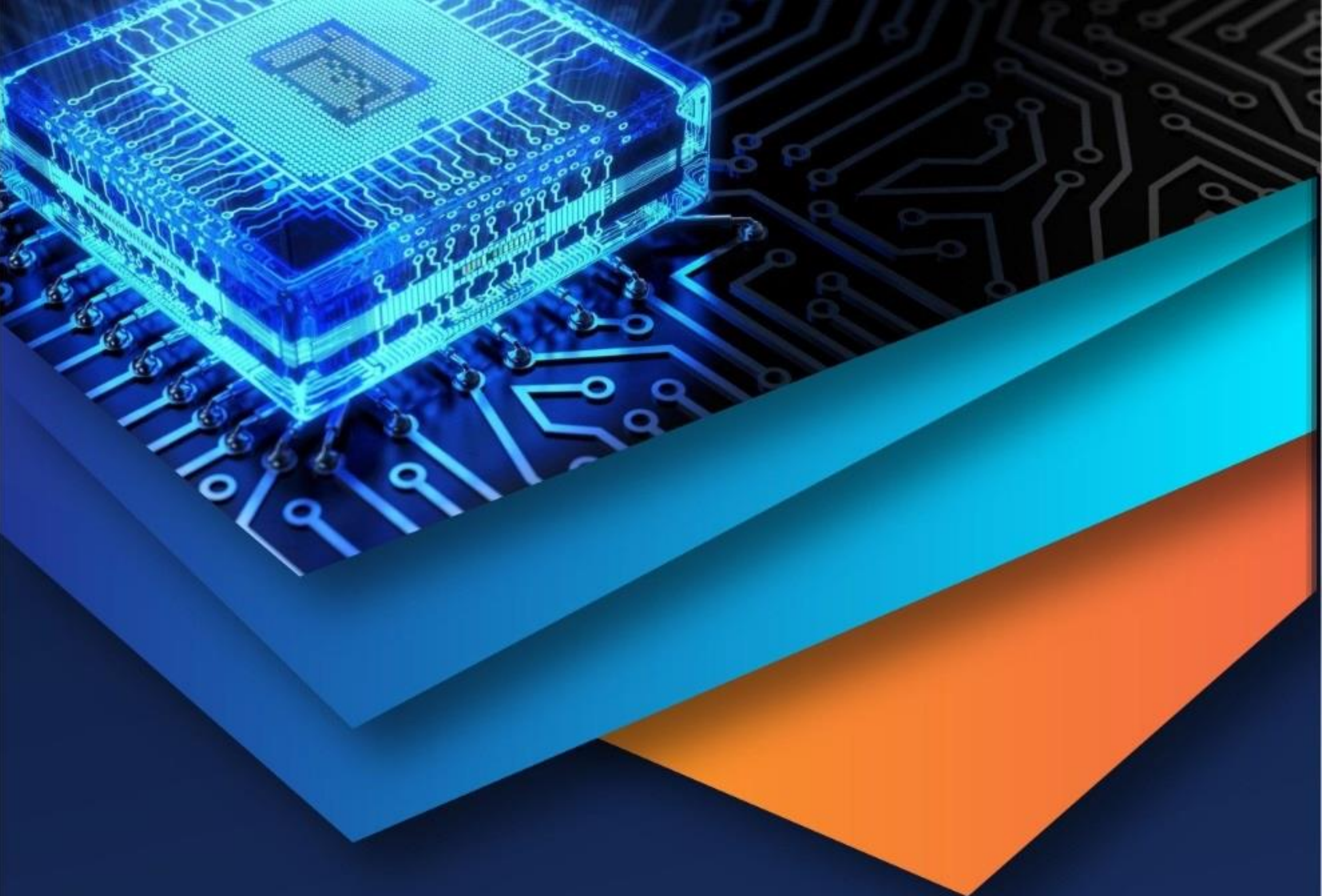

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