ANALYSIS OF SUPPLIER'S PERFORMANCE THROUGH FPIR/FNIR AND MEMBERSHIP DEGREE TRANSFORMATION

S.Hemalatha[1] K. Ram Babu[2] K.Narayana Rao[3] K.Venkatasubbaiah[4]

[1]Department of Mechanical Engg, Lendi Institute of Engineering and Technology,   Vizianagaram- 535 005
[2]Department of Mechanical Engg, Andhra University, Visakhapatnam-530 007
[3]Government Model Residential Polytechnic, Paderu-531024
[4]Department of Mechanical Engg, Andhra University, Visakhapatnam-530 007

ABSTRACT

In today's highly competitive business environment, evaluation of suppliers is the prime function of the purchasing department of the organization. It is due to the fact that high percentage of the material cost for manufacturing of a product is involved. Identification of decision criteria and methods for supplier evaluation are appearing to be the important research area in the literature. In this paper, hybrid methodology of Fuzzy positive Ideal rating /Fuzzy Negative Ideal rating and Membership Degree Transformation- M (1, 2, 3) is proposed for evaluation of supplier's performance. A wide literature review is made and six selection criteria namely: Cost, Quality, Service, Business performance, Technical Capability and Delivery performance are considered for evaluation. A detailed application of the proposed methodology is illustrated. The proposed methodology is useful not only to judge the overall performance of the supplier but also to know which criteria/sub-criteria need to be improved.

KEYWORDS

Membership Degree transformation; Fuzzy positive Ideal Rating; Fuzzy Negative Ideal Rating; Supplier performance;

1. INTRODUCTION

The traditional business functions need to be coordinated to achieve customer satisfaction, value, profitability, and competitive advantage for individual companies and the entire supply chain. One of the functions that have been singled out as important in the coordination processes of the individual firms and supply chain is purchasing.

Cheraghi et al (2002) presented the critical success factors (CSFs) for supplier selection reported in the literature emanating from the seminal work of Dickson (1966) and provide an update based on reviewing more than 110 research papers. The authors indicated significant change in the relative importance of various critical success factors in the research reported during 1966-1990 versus 1990-2001. Supplier selection and their performance evaluation is one of the important

drivers of supply chain performance. Uses of suitable criteria with appropriate methodologies are necessary for performance evaluation of a supplier. In the literature, it is observed that supplier selection and evaluation methods were based on quoted price, quality, business relations, lead time etc., constitute a multi-criteria or multi-objective decision making problem. The overall objective of the supplier selection process is to identify, evaluate, contract with the suppliers and optimum quota allocation to the suppliers. Boer et al (2001) made a review on decision methods on supplier selection based on academic literature. Byun (2001) presented Analytical Hierarch Process (AHP) approach for vendor selection and identified supplier reliability, product quality and supplier experiences are the critical factors for effective supplier selection in Korean automobiles. Muralidharan et al (2002) suggested guidelines for comparing supplier attributes using a five-point rating scale and developed aggregation technique for combining group member's preferences into one consensus for supplier rating. In the supplier selection process, organizations judge the supplier's ability to meet the requirements of the organization to survive in the intensely competitive global economy. Dulmin and Mininno (2003) used multi-criteria decision analysis method in supplier selection problem using PROMETHEE and GAIA methodology. Rajkumar and Ray (2004) identified attributes and factors relevant for performance evaluation of suppliers through fuzzy inference system of the MATLAB fuzzy logic tool box. Venkatasubbaiah and Narayana Rao (2004) considered thirty three sub-criteria under six main criteria reported in the literature in four decision hierarchy levels for supplier selection using AHP. Very often, experts opinion is the prominent characteristic of multi-criteria decision making problems and this impreciseness of human's judgments can be handled through the fuzzy sets theory developed by Zadeh (1965). Fuzzy set theory effectively incorporates imprecision and subjectivity into the model formulation and solution process. Chen et al (2006) adopted TOPSIS concept in fuzzy environment to incorporate imprecision and subjectivity into the model formulation and solution process to determine the ranking order of the suppliers. The author considered the factors such as quality, price, and flexibility and delivery performance. Lee et al (2007) adopted Fuzzy Analytic Hierarchy Process (FAHP) to analyze the importance of multiple factors by incorporating the experts' opinions to select Thin Film Transistor Liquid Crystal Display (TFT-LCD) suppliers. Narayana Rao et al (2007) illustrated fuzzy outranking technique for selection of supplier using minimum and gamma operators for aggregating the concordance and discordance indices of the alternative suppliers to arrive the ranking of suppliers with credibility values. Shouhua Yuan et al (2008) proposed DEA, AHP and fuzzy set theory to evaluate the overall performance of suppliers of a manufacturing company. Enyinda et al (2010) adopted analytic hierarchy process (AHP) model and implemented using Expert Choice Software for a supplier selection problem in a generic pharmaceutical organization. Elanchezhian et al (2010) adopted analytical network process (ANP) and TOPSIS method for select the best vendor. Jitendra Kumar and Nirjhar Roy (2010), adopted a hybrid model using analytic hierarchy process (AHP) and neural networks (NNs) theory to assess vendor performance. Yucel and Guneri (2011) assessed the supplier selection factors through fuzzy positive ideal rating and negative ideal rating to handle ambiguity and fuzziness in supplier selection problem and developed a new weighted additive fuzzy programming approach. Yang and Jiang (2012) proposed AHM (Analytic Hierarchy Method) and $M(1,2,3)$ methodology to evaluate the supply chains' overall performance. Durga Prasad et al (2012) proposed and illustrated the methodology for evaluating the efficiency and performance of the suppliers using Data Envelopment Analysis (DEA) technique. Amindoust (2012) proposed and illustrated ranking methodology in fuzzy environment with sustainable supplier selection criteria/sub-criteria. Abbasi et al (2013) proposed a framework and applied QFD/ANP to rank the relative importance of the key attributes in selection of suppliers. Galankashi et al (2013) presented supplier Selection for Electrical Manufacturing Companies Based on Different Supply Chain Strategies using AHP. Eshtehardian et al (2013),

presented a decision support system to the supplier selection in the construction and civil engineering companies using AHP and ANP simultaneously. Om pal et al (2013) presented review on supplier selection criteria and methods basing on research reported in the supply chain management area. Deshmukh and Vasudevan (2014) explored criteria that are important for green supplier selection, as evident in literature and gathered from discussions with experts. Ergün and Atalay (2014) proposed FAHP and FTOPSIS for evaluation of suppliers of an electronic company.

From the review of literature, it is observed that there is limited research in group decision approach for prioritizing the supplier selection criteria in fuzzy environment. Further, classification of a supplier belongs to a particular class basing on the data mining technology is also limited. In lieu of this, a hybrid methodology is proposed for evaluation of supplier's performance and illustrated by considering the supplier of a pharmaceutical company. In the methodology, Fuzzy positive Ideal Rating and Fuzzy Negative Ideal rating approach is adopted to find out the importance weights of criteria/sub-criteria.   Then, Membership transformation method – M(1,2,3) is adopted to find out the grade of overall performance of a supplier. Proposed methodology is explained in section two. Numerical Illustration is presented in section three. Results and discussion is made in section four. Finally, the conclusions are summarized with future scope in section five.

2. METHODOLOGY

Step 1: Establish Evaluation Index System of Supplier Performance

An Organization has to identify criteria for supplier selection to evaluate whether the supplier fits its competitive strategy and supply chain strategy .The total performance of the supplier depends on the capabilities in each criteria/sub criteria and the relative importance given to them.

Step 2: Determine importance weights of the criteria/sub criteria

Fuzzy Positive Ideal Rating (FPIR) and Fuzzy Negative Ideal Rating (FNIR) are used to compute the weights of the criteria/sub criteria (Yucel and Guneri, 2011).

Step 3: Membership Transformation through "Effective, Comparison and Composition"

Membership transformation method – M(1,2,3) proposed by Hua and Ruan (2009) as discussed in the following steps   is adopted to determine the evaluation matrix of the alternative.

Step 3.1: Determine Evaluation Membership $\mu_{jk}(Q)$

Percentage of satisfaction among the domain experts under each class is considered as evaluation matrix of each criterion.

$\mu_{jk}(Q)$ =membership of jth sub-criteria of the criteria group 'Q' belonging to the kth fuzzy membership class.

Step 3.2: Determine Distinguishable Weights ($\alpha_j(Q)$)

Distinguishable weight represents the normalized and quantized value obtained from the following relation.

$$\alpha_j(Q) = v_j(Q) / \sum_{j=1}^{m} v_j(Q) \qquad\qquad (j=1..m)$$

Where

$$v_j(Q) = 1 - (1/\log(p)) * H_j(Q)$$

$$H_j(Q) = -\sum_{k=1}^{p} \mu_{jk}(Q) * \log \mu_{jk}(Q)$$

$v_j(Q)$ = weight of the jth sub criteria of the evaluation criteria object 'Q' obtained from uncertainty in the payoff information of the sub criteria

$H_j(Q)$ = Measure of uncertainty in the payoff information of the jth sub criteria of the evaluation criteria object 'Q'

Step 3.3: Determine Comparable sum Vector $M_k(Q)$

Comparable value of the sub criteria under the given criteria is determined from the following relation

$$M_k(Q) = \sum_{j=1}^{m} \beta_j(Q) * \alpha_j(Q) * \mu_{jk}(Q)$$

$\beta_j(Q)$ = Importance Weight Vector of sub-criteria

Step 3.4: Determine Membership Vector $\mu_k(Q)$

Membership vector of the object 'Q' belonging to class 'k' is determined from the following relation.

$$\mu_k(Q) = M_k(Q) / \sum_{k=1}^{p} M_k(Q)$$

Step 3.5: Determine Evaluation Matrix of the alternative U(S)

Membership matrix of all the criteria of the object 'Q' is determined and evaluation matrix is formed as shown below.

$$U(S)= \begin{pmatrix} \mu(C1) \\ \mu(C2) \\ \mu(C3) \\ \mu(C4) \\ .. \\ .. \end{pmatrix}$$

Step 4: Determine Final membership Vector $\mu(S)$

Once the evaluation matrix of the goal and the weights of the each criterion are known the procedure is repeated from the step 3.1 to 3.5 is repeated to obtain the final membership vector of the goal.

Step 5: Determine the grade of overall Performance (K_O)

Overall performance of the alternative is determined by applying confidence recognition rule (Confidence degree: $\lambda > 0.7$)

$$K_O = \min \{k| \sum_{k=1}^{k} \mu_k(S) \geq \lambda \}$$

3. NUMERICAL ILLUSTRATION

In this paper, supplier performance evaluation using proposed methodology is illustrated with a numerical example. Supplier's performance metrics taken from the literature (Venkatasubbaiah et al., 2004; Lee et al., 2007; Narayana rao et al., 2007) are considered for performance evaluation of supplier. The evaluation hierarchy is organized into three layers namely, Goal, Criterion layer and sub-criterion layer as shown in fig 1.
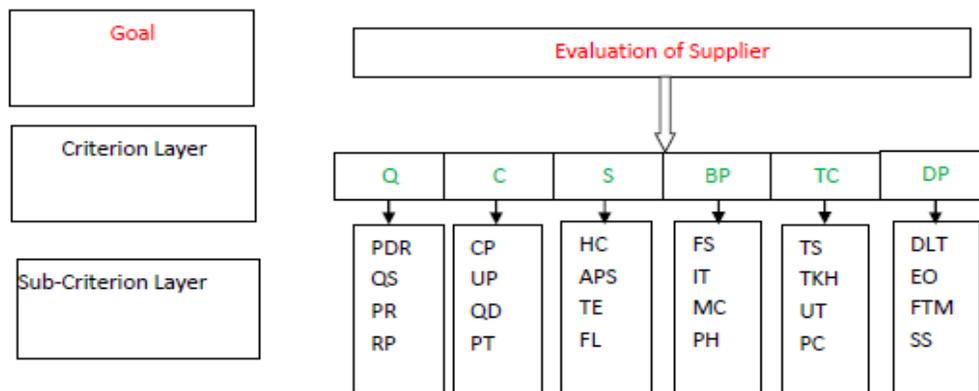
Figure 1: Hierarchy of Evaluation Index System of Supplier performance

Evaluation of supplier performance is considered as goal. Supplier evaluation criteria namely, Quality (Q), Cost (C), Service (S), Business performance (BP), Technical Capability (TC) and Delivery are considered at criterion level. Sub-criteria under each criterion are given below.
Sub-criteria under Quality (Q): Product durability and Reliability (PDR); Quality systems (QS); Percent Rejection (PR); Reputation and Position in the market (RP);

Sub-criteria under Cost (C): Competitive Pricing (CP); Unit Price (UP); Quantity Discount (QD); Payment Terms (PT);

Sub-criteria under Service (S): Handling of Complaints (HC); Availability of product/service (APS); Training equipment (TE); Flexibility (FL);

Sub-criteria under Business Performance (BP): Financial Stability (FS); IT usage (IT); Management Capability (MC); Personnel Capability (PC);

Sub-criteria under Technical Capability (TC): Technical Support (TS); Technology Know How (TKH); Understanding of Technology (UT); Performance History (PH);

3.6 Sub-criteria under Delivery Performance (DP): Delivery of Lead Time (DLT); Expeditation of Orders (EO); Flexible Transportation Modes (FTM); Safety and Security of Components (SS); Necessary data on the relative importance of criteria/sub-criteria gathered from discussions with the managers of Purchasing, Logistics, Quality Control and Production departments of a pharmaceutical company. These industries need to improve their supply chain performance by concentrating on supplier issues to face with the uncertainty within the business environment.

3.1 Relative weights of the criteria/sub-criteria

 Relative weights of criteria/sub-criteria are determined as discussed in step 2 of the methodology section. Data is collected by discussion with the managers of Purchasing, Logistics, Quality Control and Production departments to assess the relative importance of the criteria on the supplier performance. Degree of relative importance of criteria is presented with the linguistic variables: Nill-NL;Very Low- VL; Low-L; Medium Low- ML; M- Medium; Medium High-MH; High- H;Very High- VH; Full- F; Aggregated responses of the importance of criteria and sub-criteria in terms of the linguistic variables by the employees of different departments are shown in the table 1.

The study considered the above criteria/sub-criteria from the literature and these are prioritized. Relative weights of criteria and sub-criteria are determined from the aggregated responses shown table 1 and table 2 respectively through Fuzzy Positive Ideal Rating (FPIR) and Fuzzy Negative Ideal Rating (FNIR) approach as discussed in step 2 of the methodology section. Relative weights of criteria and sub-criteria are shown in table 3.From table 3 it is observed that Quality criterion is highly prioritized followed by Technical capability, Delivery Performance, Cost, Service and Business Performance. This is due to the fact that the pharmaceutical company considers Quality is the most important criterion that must be evaluated for successful selection of the supplier. Technical Capability criterion is ranked second since it is an obvious consideration for any pharmaceutical company. Relative weights of the criteria/sub-criteria are shown in fig 2

Table 1: Aggregated Responses on Criteria

Criteria	Departments			
	Purchasing (PU)	Logistics (LO)	Quality Control (QC)	Production (PR)
Quality (Q)	E	F	E	E
Cost (C)	D	D	E	F
Service (S)	D	D	D	E
Business performance (BP)	G	G	G	F
Technical Capability (TC)	H	H	H	G
Delivery Performance (DP)	F	E	F	E

Table 2: Aggregated Responses of   Sub-criteria

Criteria	Sub-Criteria	Departments			
		PU	LO	QC	PR
Q	PDR	H	H	VH	VH
	QS	M	VH	VH	MH
	PR	M	M	M	M
	RP	MH	M	M	MH
C	CP	VH	VH	VH	H
	UP	MH	M	H	MH
	QD	H	MH	H	MH
	PT	VH	MH	VH	H
S	HC	M	M	M	ML
	APS	M	MH	M	VH
	TE	H	M	M	M
	FL	VH	VH	H	MH
BP	FS	H	VH	VH	H
	IT	MH	M	M	MH
	MC	M	VH	H	M
	PH	M	M	ML	ML
TC	TS	H	VH	VH	VH
	TKH	M	VH	VH	MH
	UT	M	M	M	M
	PC	MH	M	M	MH
DP	DLT	M	M	M	M
	EO	H	VH	VH	VH
	FTM	ML	M	M	ML
	SS	H	VH	M	VH

Table 3: Relative weights of the criteria/sub criteria

Criteria	Weight	Sub-criteria	Weight	Criteria	Weight	Sub-criteria	Weight
		CP	0.2787			TS	0.3093
		UP	0.214			TKH	0.2555
		QD	0.2431			UT	0.2029
C	0.1542	PT	0.2642	TC	0.2025	PC	0.2323
		HC	0.1941			PDR	0.2585
		APS	0.3019			QS	0.2238
		TE	0.2361			PR	0.2053
S	0.1388	FL	0.2679	Q	0.2219	PC	0.3124
		FS	0.3148			DLT	0.2105
		IT	0.2282			EO	0.3244
		MC	0.2553			FTM	0.1878
BP	0.1239	PH	0.2017	DP	0.1587	SS	0.2774

Table 4: Evaluation Responses and Memberships

Criteria	Sub-Criteria	Evaluation Responses					Evaluation Memberships				
		VS	SA	GE	DS	VD	VS	SA	GE	DS	VD
C	CP	13	12	20	19	11	0.1733	0.1600	0.2667	0.2533	0.1467
	UP	14	9	32	14	6	0.1867	0.1200	0.4267	0.1867	0.0800
	QD	11	17	23	14	10	0.1467	0.2267	0.3067	0.1867	0.1333
	PT	9	10	30	17	9	0.1200	0.1333	0.4000	0.2267	0.1200
S	HC	13	17	20	18	7	0.1733	0.2267	0.2667	0.2400	0.0933
	APS	13	12	30	9	11	0.1733	0.1600	0.4000	0.1200	0.1467
	TE	12	8	32	11	12	0.1600	0.1067	0.4267	0.1467	0.1600
	FL	11	15	26	12	11	0.1467	0.2000	0.3467	0.1600	0.1467
BP	FS	13	12	25	16	9	0.1733	0.1600	0.3333	0.2133	0.1200
	IT	9	24	23	11	8	0.1200	0.3200	0.3067	0.1467	0.1067
	MC	27	14	15	12	7	0.3600	0.1867	0.2000	0.1600	0.0933
	PH	24	17	16	6	12	0.3200	0.2267	0.2133	0.0800	0.1600
TC	TS	23	17	13	12	10	0.3067	0.2267	0.1733	0.1600	0.1333
	TKH	20	20	16	12	7	0.2667	0.2667	0.2133	0.1600	0.0933
	UT	30	10	15	7	13	0.4000	0.1333	0.2000	0.0933	0.1733
	PC	21	20	10	18	6	0.2800	0.2667	0.1333	0.2400	0.0800
Q	PDR	25	17	6	15	12	0.3333	0.2267	0.0800	0.2000	0.1600
	QS	18	16	15	13	13	0.2400	0.2133	0.2000	0.1733	0.1733
	PR	15	10	25	11	14	0.2000	0.1333	0.3333	0.1467	0.1867
	PC	15	13	28	12	7	0.2000	0.1733	0.3733	0.1600	0.0933
DP	DLT	21	12	25	10	7	0.2800	0.1600	0.3333	0.1333	0.0933
	EO	19	7	27	13	9	0.2533	0.0933	0.3600	0.1733	0.1200
	FTM	13	15	22	13	12	0.1733	0.2000	0.2933	0.1733	0.1600
	SS	16	9	26	11	13	0.2133	0.1200	0.3467	0.1467	0.1733
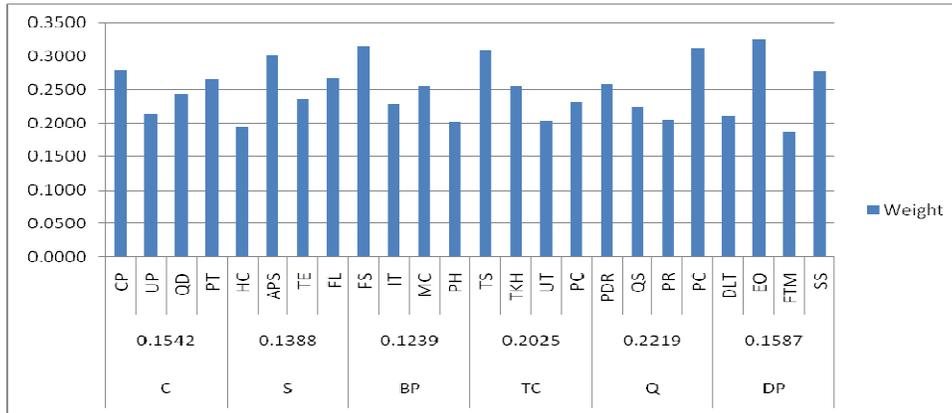
Figure 2: Relative weights of the criteria/sub-criteria

3.2 Evaluation Membership

Data on the given supplier performance sub-criteria is obtained from 75 employees of production, Logistics, Quality control and Marketing & sales departments of the pharmaceutical company. No of employees responded regarding the satisfaction levels in five classes and the membership values are shown in table 4.

3.3 Evaluation matrix

Evaluation Matrix is determined as discussed in step 3 of methodology section. Evaluation matrix of supplier's performance is shown below.

$$U(S) = \begin{pmatrix} \mu(C) \\ \mu(S) \\ \mu(BP) \\ \mu(TC) \\ \mu(Q) \\ \mu(DP) \end{pmatrix} = \begin{pmatrix} 0.1530 & 0.1400 & 0.3896 & 0.2093 & 0.1081 \\ 0.1632 & 0.1583 & 0.3779 & 0.1576 & 0.1429 \\ 0.2365 & 0.2420 & 0.2606 & 0.1422 & 0.1187 \\ 0.3324 & 0.2039 & 0.1825 & 0.1503 & 0.1309 \\ 0.2581 & 0.1901 & 0.2357 & 0.1751 & 0.1411 \\ 0.2458 & 0.1234 & 0.3459 & 0.1566 & 0.1283 \end{pmatrix}$$

3.4 Final membership Vector

Final membership vector of the supplier's performance is determined as discussed in step 4 of the methodology section. The Final membership vector of the supplier's performance is shown below.

$$\mu(S) = \begin{pmatrix} 0.2218 & 0.1639 & 0.3182 & 0.1699 & 0.1262 \end{pmatrix}$$

3.5 Grade of Overall Performance of the supplier

From the numerical illustration, according to the final membership vector, it is observed that the overall performance of the supplier belongs to the 'General' level with the confidence level of 70.39% (22.18%+16.39%+31.82%).

4. RESULTS AND DISCUSSION

Evaluation membership of supplier's performance is shown in fig 2. From the figure, it is understood that Technical Capability (TC) of the supplier is showing relatively high confidence level of performances of 33.24% in 'Very Satisfied' level. Cost (C), Service (S), Supplier performance in respect of Business performance (BP), Technical Capability (TC), Quality (Q), and Delivery Performance (DP) are showing confidence levels of 38.96%, 37.79%, 26.06%, 18.25%, 23.57% and 34.59% respectively in 'General' level.
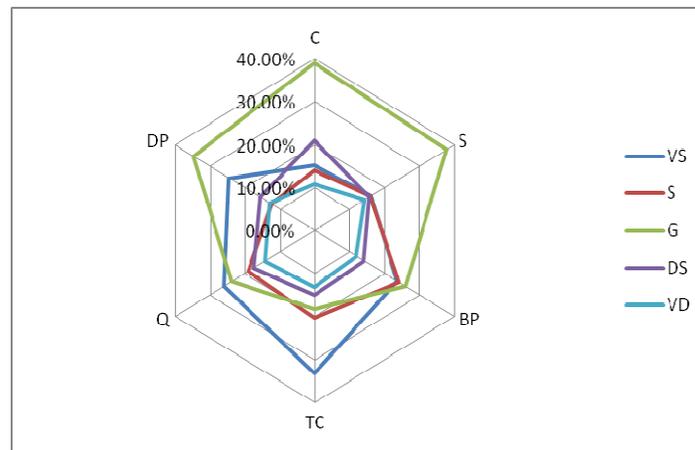
Figure 2: Evaluation memberships of supplier's performance criteria

From the results of the final membership values, it can be judged that the performance of the supplier is considered as 'General' level as the obtained confidence level (70.39%) is more than the minimum confidence level of 70%. Overall confidence level with 'Very Satisfied' is only 22.18% indicates that the supplier should improve the performance from every criteria. In the context of supplier evaluation for a pharmaceutical company, the suppliers need to improve quality, technical capability and delivery performance such that the purchasing company will be capable of rapidly responding to changes to their customer demands. Implementing continuous quality improvement methods, making use of latest equipments and machines, implementing new thoughts in business processes will be useful to improve the supplier's performance

5. CONCLUSIONS

The proposed methodology is a hybrid methodology that combined the FPIR/FNIR approach with Membership transformation method – M (1,2,3) to evaluate the performance of supplier. The proposed methodology is useful not only to judge the overall performance of the supplier but also to know which criteria/sub-criteria need to be increased. The proposed hybrid method is useful to evaluate the supplier's performance as it is affected by the subjective judgment involved in

measuring of the criteria/sub-criteria by the stake holders. The methodology maybe extended for the supplier evaluation and selection basing on the supply chain strategy (Lean, Agile and Leagile). To this effect, it requires critical judgment to assess the relative weights among the criteria basing on lean, agile and leagile supply chain strategies. Also, the study can be extended to other areas of decision making in evaluation and ranking of alternatives. Also, the performance of the proposed method can be improved by reducing the subjective judgment in prioritizing the factors/sub-factors.

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