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Integrating fuzzy quality function deployment and linear goal programming for supplier selection

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A B S T R A C T

Supply chain management (SCM) has recently received considerable attention in business management literature. Many companies consider a well-designed SCM and implement it to their systems to increase the performance of production systems. Supplier selection is a fundamental aspect of SCM, which heavily contributes to the overall supply chain performance. SCM is a complicated decision-making problem including both quantitative and qualitative factors. In this paper, we try to determine criteria, indicated by experts for selection of suitable suppliers. The proposed study obtains weight of each criterion by Fuzzy Linear Goal Programming (FLGP) technique. We rank the suppliers by Fuzzy Quality Function Deployment (FQFD) method. The study is executed for a PETROCHEMICAL Co. to evaluate and select the best suppliers.

1. Introduction

Supplier Selection (SC) is the process of choosing suppliers based on a number of criteria, compatible with firms' conditions. SC is one of the most important tasks of Supply Chain Management (SCM) in today's competitive world, but SCM success is the most important point to grow and progress among other competitors (Khaleie et al., 2012). The primary objective of each organization is to maximize its interests and minimize its costs. Thus, selection of suitable suppliers plays essential role in the supply chain network of each organization as it demands trading off among cardinal and ordinal preferences of decision makers (DM) through an optimal procedure (Bhattacharya et al., 2010). Supplier selection process is the most significant variable in management of modern supply chain networks as, it helps achieving high quality products and customer satisfaction (González et al., 2004). In this paper, important topics for selection of suppliers in a supply chain are presented. Then, a procedure is proposed to select suppliers for a company in a supply chain. In section 2, we review the related literature. In section 3, combination of Fuzzy Quality Function Deployment (FQFD) and Fuzzy Linear Goal Programming (FLGP) for selection of suppliers will be described. In this section, an example with a data set for a company is used to show usage of the proposed method. Finally, the results are presented in section IV.

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2. Materials and methods

2.1. Quality function deployment (QFD)

As mentioned previously, proposed integrated approach is based on House of Quality (HOQ) of QFD methodology, which is widely used as a strong tool in successful companies all around the world (Akao, 1990). QFD was originally developed and implemented in Japan at the Kobe Shipyards of Mitsubishi Heavy Industries in 1972 (Hauser & Clausing, 1988). It is a widely applied customer-driven design and manufacturing tool to translate customer requirements (WHATs) into appropriate product engineering characteristics (HOWs). QFD advantages include higher customer satisfaction, greater customer focus, shorter lead time, and knowledge preservation (Liu, 2009). A crucial and essential activity when using QFD is constructing HOQ, precisely. This includes determination of weights of customer requirements, relationship matrix between customer requirements and engineering characteristics, and correlation matrix among engineering characteristics (For HOQ modeling approaches, see Fig.1) (Akao, 1990; Chan & Wu, 2005; Fung et al., 2003; Vairaktarakis, 1999).

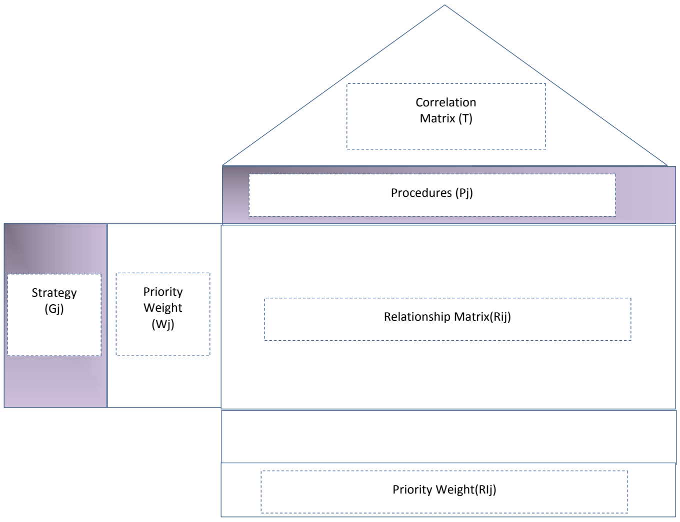


Fig. 1. House of Quaity

$$\mathrm{RIj} = \sum (\mathrm{W_i} \times \mathrm{R_{ij}}) \qquad \mathrm{i} = 1, \dots, \mathrm{n} \quad , \quad \mathrm{j} = 1, \dots, \mathrm{m} \tag{1}$$

$$\mathrm{RI}_j^* = \mathrm{RI_j} + \sum (\mathrm{TK_j} \times \mathrm{RK_j}) \qquad \mathrm{k} = \mathrm{j} \quad , \quad \mathrm{j} = 1, \dots, \mathrm{m} \tag{2}$$

2.2. Linaer goal programming (LGP)

A Goal Programming (GP) model is useful to deal with multi-criteria decision-making problems where, the goals cannot be optimized, simultaneously. GP helps decision-makers consider several objectives together to find a set of acceptable solutions and to obtain an optimal compromise. It was originally introduced by Charnes and Cooper (1957), and was further developed by Lee (1972), Ignizio (1985), Tamiz et al. (1998), and Chang (2007) purposed GP to minimize deviations in achievement of goals and their aspiration levels. Sharma et al. (1989) proposed a GP formulation for vendor selection to attain goals pertaining to price, quality and lead-time under demand and budget constraints. Buffa and Jackson (1983) also proposed GP to evaluate vendors by their price, quality and delivery. The structure of multiple-goal model is as follows,

$min\ Z = [W_1(d^-, d^+), W_2(d^-, d^+), \dots, W_k(d^-, d^+)]$

subject to

$$f_i\,(x) + di^- - di^+ = b_i, \tag{3}$$

$x,\ d_i^-,\ d_i^+$ *and* $d_i^- \times d_i^+ = 0,$

where Z is vector of weighted goals, x is vector of decision-making variables, d_i^- and d_i^+ are positive and negative deviations from i-th goal, respectively, and $W_k\ (d_i^-, d_i^+)$ is a linear function from positive and negative deviations by W elements of goals.

2.3. Fuzzy logic

Fuzzy set theory was developed to extract primary possible outcomes from information expressed in vague or imprecise terms (Tamiz, 1998). A fuzzy set is defined by a membership function, used to map an item onto an interval [0, 1] that can be associated with linguistic terms (Lee et al., 2008). A triangular fuzzy number (TFN), a special case of a trapezoidal fuzzy number, is a very popular tool in fuzzy applications. In classic set theory, each element of an X belongs to set A or not, while in fuzzy set theory, each element belongs to set A with a definite level of membership. Fuzzy set A in X is defined as:

$$A = \lfloor (X, \mu_A(X)) / \mu_A(X) \in [0,1] \rfloor \tag{4}$$

Usually, several shapes are considered for fuzzy numbers, such as, triangles or trapezoids. Triangular functions, express proximity to a real number and trapezoidal functions express a fuzzy distance. If $\tilde{A} = (a_1\,,\ b_1,\ c_1)$ and $\tilde{B} = (a_2\,,\ b_2,\ c_2)$ are two triangular fuzzy numbers, Algebraic mathematical operations on them are defined as follows,

$$\begin{aligned}
\tilde{A} + \tilde{B} &= (a_1 + a_2\ , b_1 + b_2,\ c_1 + c_2)\\
\tilde{A} - \tilde{B} &= (a_1 - c_2\ , b_1 - b_2,\ c_1 - a_2)\\
\tilde{A} \times \tilde{B} &= (a_1 \times a_2\ , b_1 \times b_2,\ c_1 \times c_2)
\end{aligned} \tag{5}$$

$$\frac{\tilde{A}}{\tilde{B}} = \left(\frac{a_1}{c_2}\ , \frac{b_1}{b_2}, \frac{c_1}{a_2}\right) \tag{6}$$

For instance, let U = *{VL; L;M;H;VH}* be a linguistic set used to express opinions on a group of attributes (VL = very low :(0, 1, 2), L = low :(2, 3, 4), M = medium :(4, 5, 6) , H = high :(6, 7,8), VH = very high :(8, 9, 10)). The linguistic variables of U, can be quantified using triangular fuzzy numbers as follows (Fig. 2):

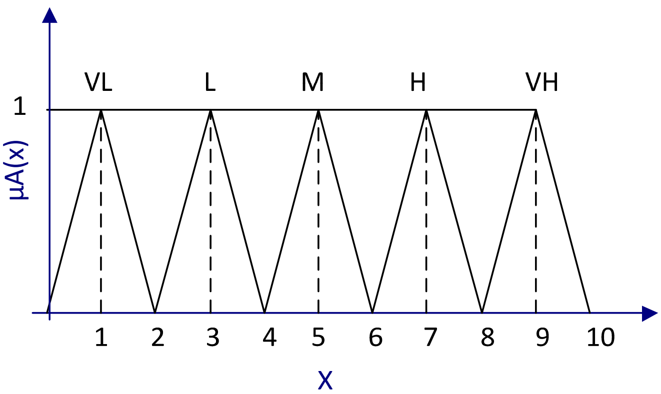


Fig. 2. Linguistic scale for relative importance

3. Case study: Ranking suppliers by FQFD and FLGP

First, an expert team was formed from 5 higher managers of PETROCHEMICAL Co. plus, the researcher to evaluate and select suppliers. If an organization needs the suppliers, experts indicate key purchases, supply requirements and determine supplier evaluation indices. Then, logistics department indicates potential suppliers. Then, brain storming is formed among experts and these criteria are compared in pairs. Then, weights of supplier selection criteria are calculated by goal programming technique. After identification of potential suppliers, situation of each supplier toward each index is determined by linguistic variables or consensus of experts. Finally, ranks of suppliers are determined by FQFD method. Data is analyzed so that primary data are gathered by questionnaires by the following steps.

3.1. Step 1:Qualitative requirements of product (What's)

A purchased product must have four features:

1. Product quality (B_1): Compatibility of product in production conditions and product performance
2. Production cost (B_2): Compatibility with future of product and accessible resources
3. Delivery performance (B_3): Ability of supplier to consider a predetermined delivery date
4. After-sell services (B_4)

3.2. Step 2: Technical and engineering requirements or recognition of supplier's evaluation criteria (How's)

Using general criteria in this problem provides comparison of goals for all suppliers. Therefore, after analysis of questionnaires and obtaining 47 criteria, expert team identifies necessary criteria to evaluate and select suppliers in a brainstorming session. These criteria are as follows,

1. Flexibility in condition of changing strategy and market (C_1)
2. Experience of supplier (C_2)
3. Financial stability (C_3)
4. Optimum feature (C_4): Previous performance of suppliers helps selection of them.
5. Quality system licenses (C_5)
6. Flexibility in response to customer requests (C_6)
7. Geographical location (C_7)

3.3. Step 3: Finding relation between customers' needs and technical definitions

Finding relation between customers' needs and technical definitions is very complex because each technical definition may influence on many customers' needs and vice versa. Views of each employee group about linguistic variables defined based on triangular fuzzy numbers are used to determine communications matrix for quality house. This is determined after brainstorming and is recorded in Table 2. Then, average of employees' views is recorded in the quality house. (Fig.3)

$$RATING = \{r_{ij}, where\ i = 1, \dots, k\ and\ j = 1, \dots, m\}$$
$$r_{ij} = \frac{1}{n} \times (r_{ij1} + \dots + r_{ijn}) \qquad (9)$$

where k = number of the ''WHATs'', m = number of the ''HOWs'' and n = number of the decision-makers (in our case, k = 4, m =7 and n =5). This time, the RATING is the matrix of the ''how''–''what'' correlation scores, whose r_{ij} elements represent an aggregate correlation score between the ith ''what'' and the jth ''how''. Here again, the r_{ij} elements are triangular fuzzy numbers defined by the triplets $r_{ij} = (r_{ij\alpha}, r_{ij\beta}, r_{ij\gamma})$.

Table 2
Relationship between product needs and technical definitions (criteria) up on views of experts

	C1					C2					C3					C4					C5					C6					C7				
	DM1	DM2	DM3	DM4	DM5	DM1	DM2	DM3	DM4	DM5	DM1	DM2	DM3	DM4	DM5	DM1	DM2	DM3	DM4	DM5	DM1	DM2	DM3	DM4	DM5	DM1	DM2	DM3	DM4	DM5	DM1	DM2	DM3	DM4	DM5
B1	VH	H	H	VH	H	VH	VH	VH	H	VH	L	VL	VL	L	VL	M	L	L	L	L	L	VL	VL	L	VL	H	H	H	H	H	L	L	L	L	L
B2	M	M	L	M	M	H	H	M	M	H	VH	VH	VH	H	VH	L	L	L	L	L	M	M	M	M	M	L	L	VL	L	L	M	M	H	M	M
B3	H	M	H	M	M	M	M	M	M	M	L	L	L	L	L	H	VH	VH	H	VH	L	L	L	L	L	VH	VH	VH	H	VH	H	H	H	H	H
B4	H	H	VH	H	H	VH	VH	VH	H	VH	M	L	L	M	L	H	VH	VH	VH	VH	L	L	L	L	L	M	VL	H	H	VL	L	VL	VL	L	VL

3.4. Step 4: Finding priority of requests and quality requirements (What's)

Usually, developmental analysis method is used to rank fuzzy numbers. In some cases, this method has unsuitable results, namely, many low importance factors may obtain zero weight. To remove this problem, GP method is used; this method has not weaknesses of developmental analysis method and has precise and dependable results. This is a linear GP where W_L, W_M, W_U and fuzzy weight of pair comparison matrix will be obtained by solving it (Tavakoli et al., 2013).

$$\min J = \sum_{i=1}^{n} (\varepsilon_i^+ + \varepsilon_i^- + \gamma_i^+ + \gamma_i^- + \delta_i) = e^T (E^+ + E^- + \Gamma^+ + \Gamma^- + \Delta)$$

subject to:

$$(A_L - I)W_U - (n-1)W_L - E^+ + E^- = 0$$
$$(A_U - I)W_L - (n-1)W_U - \Gamma^+ + \Gamma^- = 0$$
$$(A_M - nI)W_M - \Delta = 0$$

Limitation type 1: for deviation vectors from matrix compatibility condition

$$w_i^L + \sum_{j=1, j\neq i}^{n} w_j^U \geq 1, \quad i = 1,\ldots,n$$
$$w_i^U + \sum_{j=1, j\neq i}^{n} w_j^L \leq 1, \quad i = 1,\ldots,n$$
$$\sum_{i=1}^{n} w_i^M = 1 \tag{10}$$

Limitation type 2: for normality of fuzzy weight vectors

$$W_U - W_M \geq 0$$
$$W_M - W_L \geq 0$$
$$W_L, E^+, E^-, \Gamma^+, \Gamma^-, \Delta \geq 0$$

Limitation type 3: for relationship between lower and higher bounds of fuzzy weight vector

weights of criteria for selection of suppliers are determined by FLGP method and using pair comparison matrix of TABLE 3. Pair comparison matrix is as follows, obtained by consensus of experts.

Table 3
Pair comparison matrix up on triangular fuzzy numbers (Priority of criteria)

	C_1	C_2	C_3	C_4
C_1	(1,1,1)	(1.7,1.5,1.3)	(5,7,9)	(1,3,5)
C_2	(3,5,7)	(1,1,1)	(8,9,9)	(8,9,9)
C_3	(1.9,1.7,1.5)	(1.9,1.9,1.8)	(1,1,1)	(1.5,1.3,1)
C_4	(1.5,1.3,1)	(1.9,1.9,1.8)	(1,3,5)	(1,1,1)

Then, adjustment of non-fuzzy matrices for A_L, A_M, A_u:

$$A_L = \begin{bmatrix} 1.00 & 0.20 & 7.00 & 3.00 \\ 5.00 & 1.00 & 9.00 & 9.00 \\ 0.14 & 0.11 & 1.00 & 0.33 \\ 0.14 & 0.11 & 1.00 & 0.33 \\ 0.33 & 0.11 & 3.00 & 1.00 \end{bmatrix} \qquad A_M = \begin{bmatrix} 1.00 & 0.14 & 5.00 & 1.00 \\ 3.00 & 1.00 & 8.00 & 8.00 \\ 0.11 & 0.11 & 1.00 & 0.20 \\ 0.20 & 0.11 & 1.00 & 1.00 \end{bmatrix} \qquad A_M = \begin{bmatrix} 1.00 & 0.33 & 9.00 & 5.00 \\ 7.00 & 1.00 & 9.00 & 9.00 \\ 0.20 & 0.13 & 1.00 & 1.00 \\ 1.00 & 0.13 & 5.00 & 1.00 \end{bmatrix}$$

Weights of evaluation criteria for selection of suppliers are obtained by LGP. In consequence, linear GP models based on pair comparison matrix are formed. The results of optimal solutions are summarized in Table 4.

Therefore, as indicated in matrix of relative importance of evaluation and selection criteria of suppliers, product quality (C_2) has the highest importance and delivery performance (C_3) has the lowest importance. Applied to a triangular fuzzy number Wi = (W_i^L; W_i^M; W_i^U) the approach produces a score identified by this value and ranking is shown in Table 4.

$$W_i = \frac{W_i^l + [(W_i^U - W_i^L) + (W_i^M - W_i^l)]}{3} \tag{11}$$

Table 4

Fuzzy weights for evaluation and selection criteria of suppliers

Priority	Non fuzzy weight	(WL, WM, WU)	Fuzzy weight	Evaluation and Selection Criteria
1	0.18762	(0.198451,0.198451,0.218026)	W1	Production Cost (C1)
2	0.64492	(0.628170,0.683850,0.693751)	W2	Product Quality (C2)
4	0.03244	(0.015047,0.026371,0.027371)	W3	Deliver Performance (C3)
3	0.13503	(0.061853,0.091329,0.127433)	W4	Optimum Feature (C4)

3.5. Step 5: Development of technical and engineering requirements (prioritizing technical and engineering specifications of product):

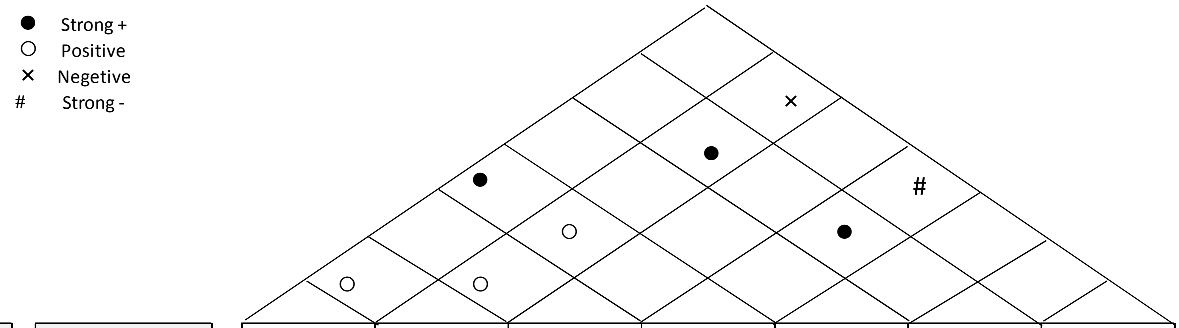
We can now complete the HOQ, calculating the weights of the ‘‘HOWs’’, averaging the aggregate weighted r_{ij} correlation scores with the aggregate weights of the ‘‘WHATs’’ W_i, according to the equation. The above relative and exact rates show cases that must be concentrated. The absolute and relative weights are as follows,

$$WEIGHT_{SHOW} = \{W_j \ , Where \ j = 1, \dots, m\} \tag{12}$$
$$W_j = \frac{1}{k} \times [(r_{j1} \times w_1) + \cdots + (r_{jk} \times w_k)]$$

where the usual conventions are assumed for k and m. Each W_j on the WEIGHTS HOW vector represents the weight of each supplier attribute. The W_j are, once again, triangular fuzzy numbers defined by means of the triplets $(W_{i\alpha}, W_{i\beta} \ , W_{I\gamma} \ )$. The fuzzy values for the weights of the ‘‘HOWs’’ are shown in the Fig. 3.

3.6. Step 6: *Development of mutual communications matrix among technical specifications of service product:*

Correlations among supplier assessment criteria (‘‘HOWs’’) are contained in the ‘‘roof’’ of HOQ (Fig. 3). This step in construction of HOQ enables the team members to keep track of pairs of ‘‘HOWs’’. This matrix contains positive and negative correlations between pairs of ‘‘HOWs’’ using, the same symbols as Hines et al (1998). The completed fuzzy-HOQ is illustrated below (Fig. 3).



How-What	Weight			C1			C2			C3			C4			C5			C6			C7		
				α	β	γ	α	β	γ	α	β	2	α	β	γ	α	β	γ	α	β	γ	α	β	γ
B1	0.198	0.198	0.218	6.8	7.8	8.8	7.6	8.6	9.6	0.8	1.8	2.8	2.4	3.4	4.4	0.8	1.8	2.8	6.0	7.0	8.0	2.0	3.6	5.6
B2	0.628	0.684	0.694	3.6	4.6	5.6	5.2	6.2	7.2	7.6	8.6	9.6	2.0	3.0	4.0	4.0	5.0	6.0	1.6	2.6	3.6	6.0	8.4	11.2
B3	0.015	0.026	0.026	4.8	5.8	6.8	4.0	5.0	6.0	2.0	3.0	4.0	7.2	8.2	9.2	2.0	3.0	4.0	7.6	8.6	9.6	10.8	14	17.6
B4	0.062	0.091	0.127	6.4	7.4	8.4	7.6	8.6	9.6	2.8	3.8	4.8	7.6	8.6	9.6	2.0	3.0	4.0	3.2	4.2	5.2	0.4	1.6	3.2

weight the How Matrix f	W1			W1			W2			W3			W5			W5			W6		
	α	β	γ	α	β	γ	α	β	2	α	β	γ	α	β	γ	α	β	γ	α	β	γ
	1.0	1.4	1.8	1.3	1.7	2.1	1.3	1.7	2.0	0.6	0.9	1.3	0.7	1.0	1.3	0.6	0.0	1.3	1.1	1.7	2.5
Normal Weight	0.161			0.198			0.190			0.110			0.120			0.112			0.208		
CR/SR Weight	0.08	0.15	0.27	0.11	0.18	0.32	0.10	0.18	0.30	0.05	0.10	0.20	0.06	0.11	0.20	0.05	0.10	0.19	0.09	0.19	0.37

Fig. 3. HOQ

3.7. Ranking Suppliers

In this study, 7 suppliers were selected by consensus of experts of PETROCHEMICAL Co. according to maximum purchase rates. This evaluation is shown in Table 5. Therefore, to evaluate and rank suppliers of PETROCHEMICAL Co. we have:

$$SUPPLIER\ RATING\ = \{SR_{hj}\ , Where\ \ h = 1, \dots, p\ \ ,\ \ j = 1, \dots, m\} \tag{13}$$
$$SR_{hj} = \frac{1}{n} \times [sr_{hj1} + \cdots + sr_{hjn}]$$

where, m is the number of attributes (‘‘HOWs’’), p is the number of suppliers, n is the number of decision-makers, and SR_{hj} is the (fuzzy) evaluation expressed by the n-th decision maker for the h-th supplier regarding to the j-th attribute. The SUPPLIER RATING matrix contains aggregate assessments SR_{hj} of the h-th supplier for the j-th attribute. The elements in this matrix are also triangular fuzzy numbers identified by triplets $SR_{hj} = (SR_{hja}; SR_{hjb}; SR_{hjg})$.

The last step, in this procedure involves calculating the FSI for each supplier; this index expresses the degree to which each supplier satisfies a given requirement. The FSI_h index is a triangular fuzzy number obtained from the previously calculated aggregate scores, multiplied by the weights for each assessment criterion. The equation is as follows,

$$FSI\ = \{FSI_h\ , Where\ \ h = 1, \dots, p\ \}$$
$$FSI_h = \frac{1}{m} \times [(SR_{h1} \times w_1) + \cdots + (SR_{hm} \times w_m)] \tag{14}$$

where, the previously adopted conventions apply for p and m.

Table 5
Evaluation of the suppliers

Supplier	C1					C2					C3					C4					C5					C6					C7				
	DM 1	DM 2	DM 3	DM 4	DM 5	DM 1	DM 2	DM 3	DM 4	DM 5	DM 1	DM 2	DM 3	DM 4	DM 5	DM 1	DM 2	DM 3	DM 4	DM 5	DM 1	DM 2	DM 3	DM 4	DM 5	DM 1	DM 2	DM 3	DM 4	DM 5	DM 1	DM 2	DM 3	DM 4	DM 5
1	H	M	H	M	M	VH	VH	H	H	VH	VL	L	L	M	L	H	VH	VH	VH	VH	M	M	M	M	M	H	H	VH	H	H	H	H	VH	H	H
2	VH	H	H	VH	H	VH	VH	VH	H	VH	L	VL	VL	L	VL	M	L	L	L	L	L	VL	VL	L	VL	H	H	H	H	H	L	L	L	L	L
3	M	M	L	M	M	H	H	M	M	H	VH	VH	VH	H	VH	L	L	L	L	L	M	M	M	M	M	L	L	VL	L	L	M	M	H	M	M
4	H	M	H	M	M	M	M	M	M	M	L	L	L	L	L	H	VH	VH	H	VH	L	L	L	L	L	VH	VH	VH	H	VH	H	H	H	H	H
5	H	H	VH	H	H	VH	VH	VH	H	VH	M	L	L	M	L	H	VH	VH	VH	VH	L	L	L	L	L	M	VL	H	H	VL	L	VL	VL	L	VL
6	H	H	H	H	H	H	H	M	H	H	L	L	L	M	L	M	M	M	M	M	L	L	VL	L	L	H	H	H	H	H	VL	VL	VL	L	VL
7	H	M	H	M	M	VH	VH	H	H	VH	VL	L	L	M	L	H	VH	VH	VH	VH	M	M	M	M	M	H	H	VH	H	H	H	H	VH	H	H

The FSI vector contains the FSIh indexes for each supplier, which are triangular fuzzy numbers as usual, defined by the triplets FSI_h =(FSI_{ha}; FSI_{hb}; FSI_{hg}), the components of which can be calculated as follows:

$$FSI_{hx} = \frac{1}{m}\sum_{j=1}^{m} SR_{hjx} . W_{j\alpha} \tag{15}$$

$$FSI_{h\beta} = \frac{1}{m}\sum_{j=1}^{m} SR_{hj\beta} . W_{j\beta} \tag{16}$$

$$FSI_{h\gamma} = \frac{1}{m}\sum_{j=1}^{m} SR_{hj\gamma} . W_{j\gamma} \tag{17}$$

Finally, for this case, the FSIh indexes are given in Table 6:

Table 6
Ranking suppliers

Supplier	α	β	γ	Score	Ranking
1	0.99	1.21	1.45	1.22	1
2	0.6	0.77	0.96	0.78	6
3	0.74	0.94	1.15	0.94	4
4	0.87	1.09	1.32	1.09	3
5	0.65	0.82	0.99	0.82	5
6	0.55	0.71	0.89	0.71	7
7	0.99	1.21	1.45	1.22	2

Applied to a triangular fuzzy number FN = ($FN_\alpha, FN_\beta, FN_\gamma$) , the Facchinetti et al. (1998) approach produces a score identified by this value.

$$\frac{FN_\alpha + 2\,FN_\beta + FN_\gamma}{4} \tag{18}$$

Using the fuzzy ranking principle, these fuzzy ratings produce the following ranking order for the suppliers:

Sup 1>Sup 7>Sup 4>Sup 3>Sup 5>Sup 2>Sup 6

where, “>” means ‘‘better than’’.

4. Conclusion

Supplier selection is one of the most important problems in each manufacturing company. In order to increase competitive advantages, companies must have an efficient supplier selection system (Sanayei, et al., 2008). In this paper, an integrated approach for supplier selection has been proposed. The study has explained two different methods, F-QFD and F-LGP, and then, the proposed combined approach were introduced. Alternative suppliers and the set of criteria have been determined according to the views of the decision making team, and the weights for the criteria in F-QDF method were assigned with regards to decision-making team’s experiences and conviction. The F-LGP approach endeavored to minimize the overall deviations in the objective function and F-QFD method has been used in order to rank the suppliers. The result in PETROCHEMICAL Co. shows, that this company must use the 7 obtained criteria to evaluate its suppliers, or at least it must prioritize these 7 criteria than the others. The second result is that PETROCHEMICAL Co. must use this priority to rank its suppliers. For example, if these 7 suppliers supply a common product, PETROCHEMICAL Co. must select the supplier with higher rank. The used models in this research are capable for decision-making of managers. However, regarding to the existing limitations in each model, we propose to use these model in combination, because by this method, limitation of a model will be covered by another. The proposals for future researchers are:

- Fulfillment of this research in other organizations and comparing the results
- Study of risk and its calculation in decision-making problems
- Repetition of this research by other new methods
- Briefing the goal of this research and concentration on the limited goals

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