Ranking the Suppliers using a Combined SWARA-FVIKOR Approach

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Abstract
People are evaluating suppliers due to their responsibility which requires the need of a structured process for supplier evaluation. In this paper we used a new model for weighting of criteria's and ranking the alternatives. This model is the combination of SWARA (Stepwise weight assessment ratio analysis) and FVIKOR (VlseKriter ijumskaOptimizacija I KompromisnoResenje) methods which evaluate the main criteria's based on evaluation of factors that have major impacts on quality of suppliers, and selects the best suppliers according to the criteria's.
SWARA method is used in determining the weights of the criteria by decision makers and then rankings of the suppliers were determined by Fuzzy VIKOR method. The proposed method in this study is used for ranking the three suppliers of ABZARSAZI in Iran by five indexes that have major impacts on it. For this purpose, in this paper, designed questionnaires are sent to 20 professional experts in different departments of ABZARSAZI COMPANY in Iran for evaluating the criteria's using SWARA. The result showed that Delivery is the most important criteria's. Such, the results of FVIKOR technique showed that supplier 1 is the best supplier. This proposed approach gives an evaluation method for all of the companies in order to help managers to identify the best suppliers.

Keywords: *Supply chain management (SCM), Suppliers, Ranking, SWARA, Fuzzy VIKOR, ABZARSAZI Company*

1. Introduction

In contemporary supply chain management, the performance of potential suppliers is evaluated against multiple criteria rather than considering a single factor[1].
Since managers typically rely on only a subset of information (e.g. heuristics), AHP helps managers make "more rational" decisions by structuring the decision as they see it and then fully considering all available information on the criteria and alternatives[2].
One of the main motivation factors for developing new supplier evaluation approaches is directly deduced from practical problems in supplier selection due to the fact that mostly used approaches are based on simple weighted scoring methods primarily relying on subjective judgments and opinions of supply professionals and other involved parties in the evaluation process[3].
Ref [4], in their paper, treat supplier selection as a group multiple criteria decision making (GMCDM) problem and obtain decision makers' opinions in the form of linguistic terms. Then, these linguistic terms are converted to trapezoidal fuzzy numbers. They extended the VIKOR method with a mechanism to extract and deploy objective weights based on Shannon entropy concept. The final result is obtained through next steps based on factors R, S and Q. A numerical example is proposed to illustrate an application of the proposed method.
Ref [5], utilizing a hybrid multi-criteria decision making (MCDM) model for selecting a supplier. First, eight evaluation criteria, including cost, quality, distance, delivery reliability, reputation, technology level, compatibility and development ability are identified. The Analytic Hierarchical Process (AHP) is initially used for calculating the weight of each criterion. The COPRAS of alternatives to Grey relations (COPRAS-G method) is adopted for ranking and selecting suppliers.
Ref [6], Applied the Fuzzy AHP and COPRAS to Solve the Supplier Selection Problems
The major purpose of this paper is ranking the suppliers of ABZARSAZI COMPANY by using a hybrid Fuzzy AHP and COPRAS approaches. Finally, results of this research, give an evaluation method for companies in order to help managers to identify and select the best suppliers.
Ref [7], In their paper proposed method employs Fuzzy Analytic Hierarchy Process (FAHP) for weighting of criteria, and Fuzzy Inference System (FIS). The FIS determines the effectiveness ratio for FAHP method and Fuzzy Technique for Order Performance by Similarity to Ideal Solution (FTOPSIS). The proposed method has been applied for supplier selection in a steel company to illustrate its applicability, flexibility and accuracy in different decision making situations.

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Ref [8], presents an integrated evaluation approach for decision support enabling effective supplier selection and ordering processes in textile industry. The integrated evaluation method in their study includes two phases that consist of fuzzy AHP and goal programming approaches Finally, a goal programming model is built using the goals about coefficients of suppliers, total ordering cost, number of wrong deliveries, total delivery cost under the constraints of required minimum and maximum number of orderings and acceptable quality cost levels of each supplier and demand constraint of the product.
Ref [9], by presenting a new hybrid method based on fuzzy Shannon's Entropy and fuzzy COPRAS, evaluate the CRM performance of Mellat Bank in Iran.
Ref [10], used a fuzzy compromise solution, called fuzzy VIKOR, to select suppliers. Moreover, the fuzzy logic and trapezoidal fuzzy numbers utilized to overcome ambiguity of evaluation process.
Ref [11], apply a new integrated method for supplier selection. In this paper, the weights of each criterion are calculated using Fuzzy AHP method. After that, Fuzzy VIKOR is utilized to rank the alternatives. Then they select the best supplier based on these results.
Ref [12], used the DANP (DEMATEL and ANP) model to determine both the importance of evaluation criteria in selecting suppliers and the causal relationships between them. Finally, the VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method was used to evaluate the environmental performances of suppliers and to obtain a solution under each evaluation criterion. Such, they presented a case example of an electronics company to demonstrate how to select green suppliers.
Ref [13], used a two-stage method for supplier selection. In the first stage, they used a new Data Envelopment Analysis (DEA) method based on network framework to determine the efficiency of the suppliers. This model considered 4 layers for supply chain of each supplier. At the end of this stage, the better suppliers have been selected for the second stage. In the second stage, after determining the efficient suppliers, they identified several criteria for agility in sanitation supply chain. Due to the uncertainty on the supplier's data, they used a fuzzy Delphi method and ideas of experts about those criteria have been finalized in 8 criteria. Next step was devoted to prioritization of 5 selected suppliers in sanitation industry based on the final criteria with fuzzy VIKOR.
Abzarsazi Industries in Iran, produces metal components that tries to improve its quality, safety and occupational hygiene performance constantly by establishing quality management systems, safety and occupational hygiene based on ISO9001:2008 and OHSAS18001:2007 for achieving its strategic aims. At present, having efficient human resource and equipped and advanced shop floors and also various processes of production such as machining, thermal operations, forging, founding, die making, etc. this industry is one of pioneer component maker companies in the country.
In this research, according to the literature review, first we identified the Supplier Selection Criteria in Iran and then we will rank the suppliers of ABZARSAZI Co. using a combined approach of SWARA and fuzzy VIKOR.
The rest of this paper is organized as follows: In Section 2 the evaluation criteria's of suppliers are Identified; Section3 gives a review of used technique (SWARA, FVIKOR); In Section 4, Data analysis is done, finally section 5 is the conclusion of this paper.

2. Identification of evaluation criteria's

The first step of evaluation is the identification of decision/evaluation criteria which potential supplier will be evaluated upon. The identification and analysis of criteria for selection and evaluation of vendors has been the focus of attention for many academicians and practitioners. In his seminal work, Ref [14] conducted a questionnaire survey mailed to about 300 commercial organizations, primarily manufacturing firms. The purchasing managers of these firms were asked to identify factors that were important for selecting suppliers. His findings were divided into two categories: vendor selection practices by firms and vendor selection practices by individuals. Table 1 summarizes his results pertaining to factors commonly used to rate potential suppliers by firms. It identifies quality, price, and delivery as the most critical factors in the supplier selection process.
Also based on the previous literatures, Criteria's of supplier selection is as Table 1:

Table 1 Criteria's of supplier selection

Criteria	Reference
Quality	[15]–[17]
Delivery	[15]–[17]
Service	[16], [18]
Technical Capability	[8], [14], [19]
Rejection rate	[19], [20]
Lead-time	[16], [21], [22]
Reaction to demand change	[16], [17]
Production capability	[14], [18], [21]
Price	[14], [16]
Up to Date	[17], [22]
Willingness and Attitude	[10], [17], [23]
Reputation	[18], [22]

Based on the literature on supplier evaluation and interviews with company managers, the evaluation criteria of this research are defined as Quality (C1), Price (C2), Delivery (C3), Service (C4) and Technical Capability (C5), also three suppliers have considered for evaluation.

This paper aimed to find out and rank the suppliers and present a suitable ranking for suppliers of ABZARSAZI COMPANY using a hybrid SWARA and Fuzzy VIKOR approaches.

3. A review of used techniques

3.1. The SWARA

In order to calculating of weight the criteria, SWARA technique is used. SWARA is one of the new methods of MCDM which was used in 2010 to develop analysis of the differences between the criteria. In SWARA, each expert ranks the criteria at first. The most important criterion is scored one and the least important one receives low score. Finally, the criteria are prioritized according to average values of the relative importance. In this method, the expert assesses the calculated weights. In addition, each expert specifies the importance of each criterion according to tacit knowledge, information and experience. Then according to the average value of the group's ranks obtained by experts, the weight of each criterion is determined [15]. Therefore, in this study, the interviews of 20 Iranian Industries experts were used. The weight of each criterion indicates its importance. Measuring of weight is an important topic in many issues of decision-making. SWARA is one of the weighting methods in which professionals play an important role in the calculation of their weight and final assessment. Figure 1 shows the technique executive steps [17-25].

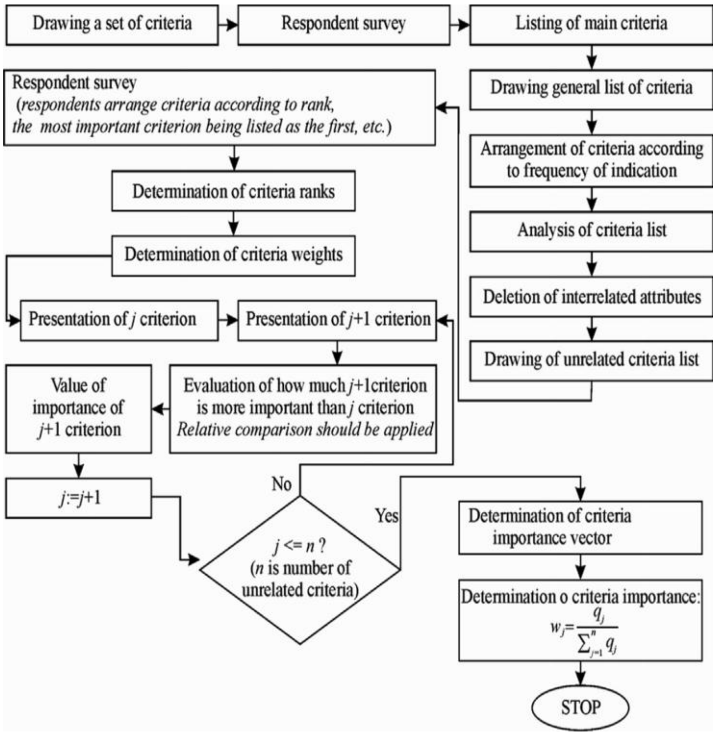

Figure 1 The technique executive steps [25-27]

3.2. The Fuzzy VIKOR

3.2.1. Introduction to VIKOR

The VIKOR method is a compromise MADM method, developed by [24] and [24], started from the form of LP-metric:

$$L_{p_i} = \left\{ \sum_{j=1}^{n} \left[\frac{w_j \left(F_j^* - F_{ij} \right)}{\left(F_j^* - F_j^- \right)} \right]^p \right\}^{\frac{1}{p}} \quad 1 \le p \le +\infty \,; i = 1, 2, ..., I. \tag{1}$$

The VIKOR method can provide a maximum ‘‘group utility’’ for the “majority” and a minimum of an individual regret for the ‘‘opponent’’ [28, 29].

3.2.2. Fuzzy VIKOR stepwise procedure

Step1. Construct Fuzzy Decision Matrix by consider to the scores of each supplier as fuzzy in each criteria as figure2:

Fuzzy DM	C_1	...	C_n
A_1	(l, m, u)	...	(l, m, u)
⋮	⋮		⋮
A_m			
W_j	(l, m, u)		(l, m, u)

Figure 2 fuzzy decision matrix

To convert the fuzzy linguistic variables to fuzzy number can use the table 2:

Table 2 Linguistic variables for paired comparison criteria

Equal important	1	1	1
Weakly more important	1	3	5
More important	3	5	7
Strongly more important	5	7	9
Absolutely more important	7	9	11

Step2. Determine the Best and Worst values in each column and finally subtract them as figure 3:

Fuzzy DM	C_1	...	C_n
A_1	(l, m, u)	...	(l, m, u)
⋮	⋮		⋮
A_m			
W_j	(l, m, u)		(l, m, u)
F^*			
F^-			
$F_j^* - F_j^-$			

Figure 3 The best and worst values in each column and subtract them

For all the attribute functions, the best value was F_j^* and the worst value was F_j^-, that is, for attribute j=1,…, n, it gets formulas (2) and (3):

$$F_j^* = \max F_{ij} \, , i = 1, 2, \ldots, m \qquad (2)$$

$$F_j^- = \min F_{ij} \, , i = 1, 2, \ldots, m \qquad (3)$$

$$F_j^* - F_j^- \qquad (4)$$

Where F_j^* the positive ideal solution for the jth criteria is, F_j^- is the negative ideal solution for the jth criteria. If one associates all F_j^*, one will have the optimal combination, which gets the highest scores, the same as F_j^-

Step3. Calculate Weighted Normalized Fuzzy Decision Matrix as figure 4 by formulas (6) and (7):

$$0 \le x_{ij}^N = \frac{F_j^* - x_{ij}}{F_j^* - F_j^-} \le 1 \qquad (6)$$

$$m_{ij} = x_{ij}^N \times W_j \qquad (7)$$

Weighted Normalized Fuzzy DM	C_1	...	C_n
A_1	$m_{11} = (l, m, u)$	...	$m_{1n} = ((l, m, u)$
⋮	⋮		⋮
A_m	$m_{m1} = (l, m, u)$		$m_{mn} = (l, m, u)$

Figure 4 Weighted Normalized Fuzzy DM

Step4. Compute the distance of alternatives to ideal solution (Calculating S, R) as figure 5:

This step is to calculate the distance from each alternative to the positive ideal solution and then get the sum to obtain the final value according to formulas (8) and (9).

$$S_i = \sum_{j=1}^{n} w_j \left(F_j^* - F_{ij}\right) / \left(F_j^* - F_j^-\right) \qquad (8)$$

$$R_i = \max_j \left[w_j \left(F_j^* - F_{ij}\right) / \left(F_j^* - F_j^-\right) \right] \qquad (9)$$

Where S_i represents the distance rate of the ith alternative to the positive ideal solution (best combination), R_i represents the distance rate of the ith alternative to the negative ideal solution (worst combination). The excellence ranking will be based on S_i values and the worst rankings will be based on R_i values. In other words, S_i , R_i indicate L_{1i} and L_{*i} of L_{p-} metric respectively.

Step5. Calculate (– ,+,"−" − "+") as below:

Negative $(-) = Max\ all\ of\ numbers\ in\ each\ column\ of\ S\ Matrix$

$Positive\ (+) = Min\ all\ of\ numbers\ in\ each\ column\ of\ S\ Matrix$

$$\text{Negative} - Positive = (-) - (+)$$

Step6. Calculate the Fuzzy VIKOR values Q_i for i=1, 2,…, m, which are defined as:

$$Q_i = v\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1-v)\left[\frac{R_i - R^*}{R^- - R^*}\right] \quad (10)$$

Where

$$S^- = \max_i S_i\ ,\ S^* = \min_i S_i\ ,\ R^- = \max_i R_i\ ,\ R^* = \min_i R_i$$

and v is the weight of the strategy of "the majority of criteria" (or "the maximum group utility"). $\left[(S - S^*)/(S^- - S^*)\right]$ Represents the distance rate from

The positive ideal solution of the its alternative'sachievements In other words, the majority agrees to use the rate of the it's. $\left[(R - R^*)/(R^- - R^*)\right]$ Represents the distance rate from the negative ideal solution of the it's alternative; this means the majority disagree with the rate of the it's alternative. Thus, when the v is Larger (> 0.5), the index of Q_i will tend to majority agreement; when

V is less (< 0.5), the index Q_i will indicate majority negative attitude; in general, v = 0.5, i.e. compromise attitude of evaluation experts.

Step7. Defuzzification and Ranking the alternatives by Q_i values

According to the Q_i values calculated by step6, it can rank the alternatives and to make suitable decision.

Weighted Normalized Fuzzy DM	C_1	…	C_n	$0 \le S_i$	$0 \le R_i \le 1$
A_1	$m_{11} = (l, m, u)$	…	$m_{1n} = ((l, m, u)$	$S_i = \sum_{j=1}^{n} m_{ij}$	$R_i = Max_{j=1}^{n}(m_{ij})$
⋮	⋮		⋮	⋮	⋮
A_m	$m_{m1} = (l, m, u)$		$m_{mn} = (l, m, u)$	$\sum m_{mj}$	$Max(m_{mj})$

Figure 5 Calculating S, R

4. Data analysis

In this section, first we calculate the weight of criteria's using 5 steps as following:

4.1. Calculating the weight of criteria with SWARA

After the literature review of research and interview with experts, 5 criteria in ABZARSAZI industry were identified as table 2:

Table 2 the Criteria

Symptom	Criteria
C1	Quality
C2	Price
C3	Delivery
C4	Service
C5	Technical Capability

Then, these CRITERIA were studied using SWARA technique. SWARA technique is based on expert's opinions, and it is a judgment method. In this research, we have used from 20 experts as table 3:

Table 3 Information of experts

Group	Classification	Number
Record of service	Manager	1
	Exploitation engineering	12
	Programming and control	7
Education level	Licentiate	6
	Master	10
	Doctoral	4
Sexuality	Male	15
	Female	5

For doing so, the opinions of 20 experts on criteria were identified and the criteria initial weight was extracted. In fact, the experts were asked to rank each criterion individually, and finally to calculate the relative importance of these criteria, count the number of priorities of each criterion according to experts' viewpoints. For example, the third criterion was placed eight times in rank one, five times in rank two, four times in rank three, and two times in rank 4 and one time in ranks 5. After prioritizing criteria by the experts, to calculate the weight of each criterion, the number of priorities for each criterion was multiplied by the difference score of the highest score and relevant score.

Table 4 summarizes final calculation of the weight and importance of each of the criteria using SWARA, so that criteria can be ranked according to the last column weights.

Table 4 The weight and importance of each of the Criteria

Criteria	Sj	Kj =Sj+1	Wj	Qj
C3	–	1	1	0.272
C5	0.16	1.16	0.86	0.237
C1	0.172	1.172	0.736	0.200
C4	0.2754	1.2754	0.577	0.157
C5	0.137	1.137	0.507	0.138

4.2. Ranking the Alternatives (Suppliers) with Fuzzy VIKOR

In order to select the best supplier of ABZARSAZI Company, VIKOR method was used. Each of the decision makers evaluated every supplier according to the five criteria.

Step1. Design fuzzy decision matrix by consider to the scores of each supplier as fuzzy in each criteria.

To convert the fuzzy linguistic variables to fuzzy number can use the table 5.

Table 5 Linguistic variables for paired comparison criteria

Equal important	1	1	1
Weakly more important	1	3	5
More important	3	5	7
Strongly more important	5	7	9
Absolutely more important	7	9	11

The final geometric fuzzy decision matrix to rank the three suppliers is as figure 6:

DM	C_1			C_2			C_3			C_4			C_5		
A_1	2	3	4	1	3	5	3	5	6	2	4	5	4	5	6
A_2	1	2	3	2	4	6	3	6	7	2	3	6	2	3	4
A_3	2	3	4	2	4	7	4	7	8	5	7	9	5	7	8
W_j	0.272	0.272	0.272	0.237	0.237	0.237	0.200	0.200	0.200	0.157	0.157	0.157	0.138	0.138	0.138

Figure 6 The final geometric fuzzy decision matrix

Which fuzzy weights are obtained from SWARA approach and consider as input to Fuzzy VIKOR method.

Step2. Determine the best and worst values in each column by use formula (2), (3) and subtract them by use formula (4) as table 6:

Table 6 The Best and worst values in each column

F*	2	3	4	2	4	7	4	7	8	5	7	9	5	7	8	
F−	1	2	3	1	3	5	3	5	6	2	3	5	2	3	4	
F*−F−	−1	1	3	−3	1	6	−2	2	5	0	4	7	1	4	6	Min = −3
(F*−F−)N	2.01	4.01	6.01	0.01	4.01	9.01	1.01	5.01	8.01	3.01	7.01	10.01	4.01	7.01	9.01	

Which for example $2.01 = (-1) + |-3| + 0.01$

Step3. Using formulas (6) and (7) for Calculating Weighted Normalized Fuzzy Decision Matrix as table 7 and finally table 8:

Table 7 Calculating Weighted Normalized Fuzzy Decision Matrix

NDM	C1			C2			C3		
A_1	−0.09	0.00	0.27	−0.08	0.06	139.80	−0.05	0.08	0.98
A_2	−0.04	0.07	0.40	−0.10	0.00	116.50	−0.07	0.04	0.98
A_3	−0.09	0.00	0.27	−0.13	0.00	116.50	−0.10	0.00	0.78

C4			C5			
0.00	0.07	0.37	−0.04	0.04	0.14	
−0.05	0.09	0.37	0.04	0.08	0.21	Min all of numbers = −0.21
−0.21	0.00	0.21	−0.11	0.00	0.11	

Table 8 Calculating Weighted Normalized Fuzzy Decision Matrix

NDM	C1			C2			C3		
A_1	0.13	0.21	0.48	0.14	0.27	140.01	0.16	0.29	1.19
A_2	0.17	0.28	0.61	0.11	0.21	116.71	0.14	0.25	1.19
A_3	0.13	0.21	0.48	0.08	0.21	116.71	0.12	0.21	1.00

C4			C5		
0.21	0.28	0.59	0.18	0.25	0.35
0.16	0.31	0.59	0.25	0.29	0.42
0.00	0.21	0.43	0.11	0.21	0.32

Step4. Compute the distance of alternatives to ideal solution (Calculating S, R) as figure 7:

S			R		
0.82	1.06	142.28	0.21	0.29	140.01
0.83	1.05	119.11	0.25	0.31	116.71
0.43	0.86	118.62	0.13	0.21	116.71
0.83	1.06	142.28	0.25	0.31	140.01
0.43	0.86	118.62	0.13	0.21	116.71
−117.79	0.21	141.84	−116.46	0.09	139.89
0.01	118.01	259.64	0.01	116.57	256.36

Figure 7 Calculated S, R

Which for example in S: $0.82 = 0.13 + 0.14 + 0.16 + 0.21 + 0.18$ and in R: $0.21 = Max(0.13,0.14,0.16,0.21,0.18)$

Step5. Calculate (− , +, "−" − "+") as figure 8:

Negative $(-) =$
$Max\ all\ of\ numbers\ in\ each\ column\ of\ S\ Matrix$

$Positive\ (+)$
$= Min\ all\ of\ numbers\ in\ each\ column\ of\ R\ Matrix$

$$\text{Negative} - Positive = (-) - (+)$$

	S			R			
	0.82	1.06	142.28	0.21	0.29	140.01	
	0.83	1.05	119.11	0.25	0.31	116.71	
	0.43	0.86	118.62	0.13	0.21	116.71	
−	0.83	1.06	142.28	0.25	0.31	140.01	
+	0.43	0.86	118.62	0.13	0.21	116.71	
− − +	−117.79	0.21	141.84	−116.46	0.09	139.89	**Min = −117.79**
− − + N	0.01	118.01	259.64	0.01	116.57	256.36	

Figure 8 Calculated S, R

Step6. Calculate the Fuzzy VIKOR values Q_i for i=1, 2,…, m, by formula 10 as figure 9:

In this paper we suppose v = 0.5

Table 7 Calculating Final Weighted Normalized Fuzzy Decision Matrix

Q		
−0.454	0.001	14086.583
−0.454	0.001	11763.587
−0.455	0.000	11738.758

Figure 9 Fuzzy VIKOR values Qi

Which for example: $-0.454 = 0.5 \times \left(\frac{1.01-130.39}{285.20}\right) + (1-0.5) \times \left(\frac{0.25-128.41}{282.01}\right)$

Step7. Defuzzification and Ranking the alternatives by Q_i values

According to the Q_i values calculated by step6, the final ranking of suppliers is as figure 10:

Defuzzification	Rank
2347.689	1
1960.463	2
1956.384	3

Figure 10 the final ranking of suppliers

Which for example: $2580.536 = \frac{(-0.454)+(4\times 0.001)+(15483.668)}{6}$

5. Conclusion

Evaluation and selection of the right business partner/supplier is very important for companies to create and increase competitive advantages. The supplier selection problem is of vital importance for operation of every firm because the solution of this problem can directly and substantially affect costs and quality. Indeed, for many organizations effective supplier evaluation and purchasing processes are critical success factors. This paper demonstrates the structured approach of SWARA and Fuzzy VIKOR which can be used as a tool in supplier evaluation to identify best-in-class suppliers and build a ranking out of the defined criterion's weight and the degree of performance.

Using SWARA technique, the weight of criteria's was calculated. Then using Fuzzy VIKOR, an initial assessment of the selecting of best supplier has been conducted. The analysis compared three alternative supplier based on five weighted decision criteria. Based on the judgment of decision makers as ranking the suppliers is compiled (figure 10): priority1= A_1, priority2= A_2, priority3=A_3. Therefore, the best supplier is A_1. Different from other studies in the literature, in this paper SWARA and Fuzzy VIKOR methods used together.

The results of research show that Delivery (C3) is the most important of criteria's for supplier's selection and such the supplier1 is the best suppliers of Abzarsazi Co.

- This proposed decision making model can be used in other areas of managerial decision making such as project selection, location selection and technology selection in supply chain.
- Other categorizing approaches would be used for classifying items and suppliers and develop the model depend upon it.
- Other categorizing approaches would be used for classifying items and suppliers and identify important, strategic, value added and relevant to organizations criteria and develop model based on them.
- Classification the criteria were introduced for supplier selection and present a comprehensive index for evaluating with classification technique.

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