An Integrated MCDM for a Medical Company Selection in Health Sector

Seyma Emec (Corresponding author)
Industrial Engineering Department, Ataturk University, Erzurum, Turkey
E-mail: seyma.yayla@atauni.edu.tr

Betul Turanoglu
Industrial Engineering Department, Ataturk University, Erzurum, Turkey

Sinan Oztas
Industrial Engineering Department, Ataturk University, Erzurum, Turkey

Gokay Akkaya
Industrial Engineering Department, Ataturk University, Erzurum, Turkey

Abstract
The correct choice of the devices used in the health sector is great importance for reduction of the workforce, improving quality and saving time. Therefore, selection of medical company that devices will be provided is an important decision problem. In this study, AHP and fuzzy VIKOR methods were utilized for selection of DNA-RNA-protein isolation device which will be used in a laboratory that conducts scientific research in the Atatürk University Faculty of Medicine. As a result of surveys conducted by responsible experts for the medical selection, 7 criteria were determined and pairwise comparison matrix has been established. Then, weights of criteria determined by AHP and 4 different alternatives were listed by fuzzy VIKOR. To the best of the authors' knowledge, there is no study on the selection of suppliers in the field of health in the literature. It is aimed to contribute to the literature in this respect.

Keywords: Medical Company Selection, AHP, Fuzzy VIKOR

DOI: 10.7176/JSTR/5-4-09

1. Introduction

Medical device sector is an essential part of health industry along with pharmaceutical industry. Due to improving medicine technology, medical device industry –just as pharmaceutical industry- had an ever increasing use, and this had showed up as health expenses increasing in the whole world. The whole world is taking measures in order to decrease health expenses. Thus, in this study it was intended to select the medical company which is the most qualified one and which is the most appropriate in respect of cost for the procurement of medical devices.

Ataturk University, Medical Faculty, Department of Pharmacology was established in 1966 by the Internal Diseases Specialist Dr. Hasan GACAR. At the Department of Medical Pharmacology, they carry out the scientific studies along with 16 doctoral students and 14 postgraduate students. In the studies performed at the department, it was intended to make medication researches for diseases whose treatment is not available, to perform experiments searching the mechanism of action of available medications, to make researches on the basic pharmacology and clinical pharmacology of recent medications, and to announce these studies to world through scientific magazines.

One of the significant operations performed at the laboratories of department of pharmacology is the isolation of DNA-RNA-Protein. This operation is normally being performed manually, and an operation on 12 samples is taking about 2.5-3 hours. Despite that, complete pure result cannot be obtained. There are devices in the market which perform this operation in a much shorter time. The employees of the laboratory are considering to procure these devices for the operation in subject. They had encountered the selection of medical company from which the device will be procured as a decision problem, and we suggested an integrated AHP (Analytical Hierarchy Process) and Fuzzy VIKOR (VIsekriterijumska optimizacija i KOmpromisno Resenje) method for the solution of that problem.

1.1 Literature Survey

Multi-criteria decision making (MCDM) methods deal with problems of compromise selection of the best solutions from the set of available alternatives according to objectives. Usually neither of the alternatives satisfies all the objectives, therefore satisfactory decision is made instead of optimal one. The literature search is shown in three parts: Studies on sustainable supplier selection (Table 1), on green supplier selection (Table 2) and on supplier selection (Table 3) and studies using MCDM methods.

Table 1. Studies on sustainable supplier selection

Author/s and Year of Publication	Application Areas	Application Location	MCDM Methods
Liu et al.,2019	A watch manufacturing company	-	Combining the IVIUL (interval-valued intuitionistic uncertain linguistic)-BWM (Best-Worst Method) with the IVIUL-AQM (alternative queuing method)
Yu et al., 2019	a home appliances manufacturer	China	TOPSIS (Technique For Order Preference By Similarity To An Ideal Solution) and IVPFS (interval-valued Pythagorean fuzzy set)
Xu et al.2019	A long-term partner for company	-	IT2FSs (interval type-2 fuzzysets) AHP Sort II Model
Rashidi and Cullinane 2019	set of logistics service providers	Sweden	Fuzzy DEA (Data Envelopment Analysis) and Fuzzy TOPSIS
Pishchulov et al.2019	medium-sized company in the wood construction industry	Switzerland	Voting AHP
Abdel-Baset et al. 2019	A large importing company	Egypt	Neutrosophic ANP (Analytic Network Process) And VIKOR
Costa et al. 2018	a manufacturing industry	India	ELECTRE (elimination and et choice translating reality) TRI- nC method
KhanMohammadi et al. 2018	in the petrochemical industry	-	Graph theory and matrix approach (GTMA)
Ghoushchi et al. 2018	A chemical industry company	Qazvin	on goal programming (GP) - DEA
Azimifard et al. 2018	A steel industry	Iran	AHP and TOPSIS

Table 2. Studies on green supplier selection

Author/s and Year of Publication	Application Areas	Application Location	MCDM Methods
Chen et al. 2019	The panel manufacture	-	Fuzzy six sigma quality indices
Haghighi et al. 2019	The food sector.	Iranian	IT2FSs
Yucesan et al. 2019	An injection molding facility	Turkey	IT2F TOPSIS
Liu et al. 2019	A manufacturing enterprises	-	The hesitant fuzzy prioritized weighted average (HFPWA)
Darminto et al. 2018	One of the industries in the diesel engine exporting company	Indonesia	Fuzzy Analytical Network Process (FANP)
Jiang et al. 2018	An automotive industry	Taiwan	GREY DEMATEL (Decision making trial and evaluation laboratory)-BASED ANP (GDANP)
Quan et al. 2018	A real estate company	China.	a modified MULTIMOORA (Multi-Objective Optimization by Ratio Analysis plus the Full Multiplicative From)

Table 3. Studies on supplier selection

Author/s and Year of Publication	Application Areas	Application Location	MCDM Methods
Hajek and Froelich	A supplier selection task	-	IVIFCM-TOPSIS
Huang et al. 2019	A manufacturing company	-	MS-DIFDT (A multi-scale IF decision table)
Çalı and Balaman et al. 2019	In automotive sector	-	IFS ELECTRE AND VIKOR
Fu 2019	The best catering selection for ABC airline	-	AHP-ARAS (Additive Ratio Assessment)- MCGH Multi-choice goal programming
Wang and Chen 2019	The existing literature problem	-	A partial-consensus posterior-aggregation FAHP (PCPA-FAHP) approach
Suraraksa and Shin 2019	İn automotive industry	Thailand	AHP
Alkahtani et al. 2019	X company produces chemicals	-	Fuzzy TOPSIS and Fuzzy AHP
Stević et al. 2019	A company for the production of plastic bags	-	Fuzzy AHPa nd Fuzzy EDAS ((Evaluation based on Distance from Average Solution)
Phumchusri et al. 2019	A raw material suppliers	Thailand	AHP
Kumar et. al. 2018	A leavy locomotive firm	Indian	TOPSIS and AHP
Wang et al. 2018	In the food processing industry	Vietnam.	A hybrid FAHP and GDEA model green data envelopment analysis
Wang et al. 2018	In the Gas and Oil Industry	Vietnam.	Hybrid SCOR Metrics, AHP, and TOPSIS
Chen et al. 2018	A food industry	China	A hybrid model that combines total interpretive structural modeling (TISM) and FANP
Liao et al. 2018	An aircraft manufacturer	-	A new hesitant fuzzy linguistic ORESTE (Organization, Rangement Et Synthese De Donnes Relationnelles)
Diouf and Kwak 2018	A printing industry	Korea	Fuzzy AHP, DEA, and Managerial Analysis
Abdel-Basset et al. 2018	A distribution company	Turkey	Neutrosophic DEMATEL
Wang and Tsai 2018	A solar Panel Supplier Selection	Taiwanese	FAHP and DEA
Büyüközkan, AND Göçek 2018	Digital Supply Chain	Turkey	IVIF AHP and IVIF ARAS
Joshi and Kumar 2018	An automobile manufacturer	-	An extended VIKOR method
Grandhi and Wibowo 2018	most suitable solar energy supplier	India	Fuzzy MCDM
Abdel-Basset et al. 2018	food industry	Egypt	A Hybrid Neutrosophic Group ANP-TOPSIS

ISSN 2422-8702 (Online), **DOI:** 10.7176/JSTR/5-4-09
Vol.5, No.4, 2019

To the best of the authors' knowledge, there is no study on the selection of suppliers in the field of health in the literature. It is aimed to contribute to the literature in this respect.

2. Methodology

2.1 *Analytical Hierarchy Process (AHP)*

AHP was first developed by Saaty in 1971 and is available in many studies in the literature. Saaty proposed the scale of significance given by Table 4, which includes decision numbers from 1 to 9 (Subramanian ve Ramanathan, 2012). When determining factor weights with AHP method, the steps to be followed are as follows: (Emeç and Akkaya, 2018; Akkaya *et al*. 2015):

Table 4. Linguistic and Corresponding Numeric AHP

AHP lingustic scale	AHP numeric scale
1	Equally important
3	Moderately more important
5	Strongly more important
7	Demonstrated more important
9	Extremely more important
2,4,6,8	Compromises or between scales

Step1: Using the scale values given in Table 1, a pairwise comparison of the factors is made and pairwise comparison matrices as in Equation 1 are generated.

$$D = \begin{bmatrix} 1 & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & 1 \end{bmatrix} \quad (1)$$

where $a_{ij} = \frac{1}{a_{ji}}$, $a_{ij} > 0$

Step 2: The generated comparison matrix is normalized. For this, column totals are taken, and each value is divided by its column sum. In this way, normalized decision matrix is obtained.

$$a_{i1} = \frac{a_{i1}}{\sum_{i=1}^{m} a_{i1}} \quad i = 1;2,..,m \quad (2)$$

Step 3: Line averages are taken to calculate factor weights.

$$w_i = \frac{\sum_{j=1}^{n} a_{ij,}}{n} \, i = 1,2..,m \;\; j = 1,2,..,n \quad (3)$$

2.2 Fuzzy VIKOR Technique

Fuzzy VIKOR technique is applying fuzzy logic to VIKOR technique. Method offers rational and systematic process for the best and compromise solution by handling linguistic expressions. In this process, implemented steps are as follows (Emeç and Akkaya, 2018):

Stage 1: Firstly, n decison makers, m alternatives and k criteria are determined to solve the problems.

Stage 2: Alternatives and criteria are evaluated by experts using the linguistic variables given in Table 5. Linguistic variables are used to determine the weight of criteria and evaluate the alternatives. However, stochastic AHP are used when determining criteria weight in the study.

Table 5. Linguistic Variables Used in Fuzzy VIKOR

Linguistic Variables	Triangular Fuzzy Numbers
Very poor	(0, 0, 1)
Poor	(0, 1, 3)
Moderately poor	(1, 3, 5)
Moderate	(3, 5, 7)
Moderately good	(5, 7, 9)
Good	(7, 9, 10)
Very good	(9, 10, 10)

Stage 3: Evaluation of decision makers are combined and integrated fuzzy weight of each criterion is calculated with the aid of Eq. (4).

$$\breve{w}_j = \frac{1}{n}\left[\sum_{e=1}^{n} \breve{w}_j^{\,e}\right] \quad j = 1,2,\dots,k \tag{4}$$

Importance weight of ith alternative according to jth criteria is calculated with the aid of Eq. (5).

$$\breve{x}_{ij} = \frac{1}{n}\left[\sum_{e=1}^{n} \breve{x}_{ij}^{\,e}\right] \quad i = 1,2,\dots,m \tag{5}$$

Stage 4: Fuzzy decision matrix is created.

$$\breve{D} = \begin{bmatrix} \breve{x}_{11} & \cdots & \breve{x}_{1k} \\ \vdots & \ddots & \vdots \\ \breve{x}_{m1} & \cdots & \breve{x}_{mk} \end{bmatrix} \quad i = 1,2,\dots,m \; j = 1,2,\dots,k \tag{6}$$

$$\breve{W} = [\breve{w}_1; \breve{w}_2; \dots; \breve{w}_k],\ j = 1,2,\dots,k \tag{7}$$

Where $\breve{x}_{ij}$ is the degree of Ai alternative according to Cj criteria, $\breve{w}_{ij}$ is importance weight of jth criteria

Stage 5: Fuzzy best $(\breve{f}_j^*)$ and worst $(\breve{f}_j^-)$ values are determined.

$$(\breve{f}_j^*) = \max_i \breve{x}_{ij},\ (\breve{f}_j^-) = \min_i \breve{x}_{ij} \tag{8}$$

Stage 6: $\breve{S}_i$ and $\breve{R}_i$ values are calculated.

$$\breve{S}_i = \sum_{j=1}^{k} \breve{w}_j (\breve{f}_j^* - \breve{x}_{ij}) / (\breve{f}_j^* - \breve{f}_j^-) \tag{9}$$

$$\breve{R}_1 = \max_j \left[\sum_{j=1}^{k} \widetilde{w}_j (\breve{f}_j^* - \widetilde{x}_{ij}) / (\breve{f}_j^* - \breve{f}_j^-)\right] \quad (10)$$

$\breve{S}_1$ is total of criteria value distance to fuzzy best value. $\breve{R}_1$ is the maximum distance of alternatives Ai to the fuzzy worst value according to jth criteria. In other words, $\breve{S}_1$ and $\breve{R}_1$ values represent moderate and the worst scores of Ai alternatives.

Stage 7: $\breve{S}^*, \breve{S}^-, \breve{R}^*, \breve{R}^-$ and $\widetilde{Q}_1$ values are calculated.

$$\breve{S}^* = \min_i \breve{S}_1 , \ \breve{S}^- = \max_i \breve{S}_1 \quad (11)$$

$$\breve{R}^* = \min_i \breve{R}_1 , \ \breve{R}^- = \max_i \breve{R}_1 \quad (12)$$

$$\widetilde{Q}_1 = \frac{v(\breve{S}_1 - \breve{S}^*)}{(\breve{S}^- - \breve{S}^*)} + \frac{(1-v)(\breve{R}_1 - \breve{R}^*)}{(\breve{R}^- - \breve{R}^*)} \quad (13)$$

where $\breve{S}^*$ represents maximum benefit of the group and $\breve{R}^*$ represents minimum regret of opposite view. $\widetilde{Q}_1$ index is calculated together with the assesment group of benefits and minimum regret. v value represents weight of strategy which ensures maximum group benefit. Compromise can be provided with "majority vote" (v >0.5), "compromise" (v=0.5) or "rejection" (v <0.5).

Stage 8: Q_i index is obtained by defuzzification using Eq. 14. There are different defuzzification methods in literature. BNP (Best Non Fuzzy Performance Value) proposed by Hsiesh et all., 2004 is used for defuzzification in this study. In the equation; u_i is the upper value of triangular fuzzy number, m_i is the median value of triangular fuzzy number and l_i is the lower value of triangular fuzzy number.

$$BNP=[(u_i- l_i)+(m_i- l_i)]/3+ l_i \quad \forall_i \quad (14)$$

Q_i indexes are arranged in increasing order. Alternative which have lowest Q_i value is the best alternative.

Stage 9: In this stage, compromise solution is determined. If following two conditions are satisfied, obtained solution by using Q_i index is compromise solution ($a^{ı}$)

Condition 1: acceptable advantage: with condition 1, it is established that there is a clear difference between the best and closest options.

$$Q(a^{ıı})-Q(a^{ı})\geq DQ \quad (15)$$

In the equation a value is an alternative in the second when ordered Q_i values.

$$DQ=1/(m-1) \quad (\text{eğer } m\leq 4 \text{ ise } DQ=0.25) \quad (16)$$

Condition 2: acceptable stability: a alternative must also be the best alternative when ordered based on S and/or R values. If $Q(a^{(m)})-Q(a^{ı})<DQ$, condition 1 is not satisfied, $a^{(m)}$) and $a^{ı}$ are the same compromise solutions. Because of similar compromise solution ($a^{ı}$, $a^{ıı}$,..., $a^{(m)}$), $a^{ı}$ does not have comparative advantage. If condition 2 is not satisfied, decision making is not stable although a has a comparative advantage. Therefore compromise solution of $a^{ı}$ and $a^{ıı}$ is similar.

Stage 10: Finally, the best alternative is selected. Alternative which has minimum Q value is the best solution.

ISSN 2422-8702 (Online), DOI: 10.7176/JSTR/5-4-09
Vol.5, No.4, 2019

3. Application

This study benefited from the AHP and Fuzzy VIKOR methods for the selection of DNA-RNA-Protein isolation device to be used at laboratories where scientific researches of Ataturk University Medical Faculty are being carried out. As the result of questionnaires applied on specialists being responsible for the selection of medicals, 7 criteria (brand, cost, quality, time, technical service, customer representative, diversity) were determined and brief description of criteria of the implementation is shown Figure 1 and 4 alternative (A, B, C, D) medical companies were selected for evaluation by the fuzzy VIKOR method.

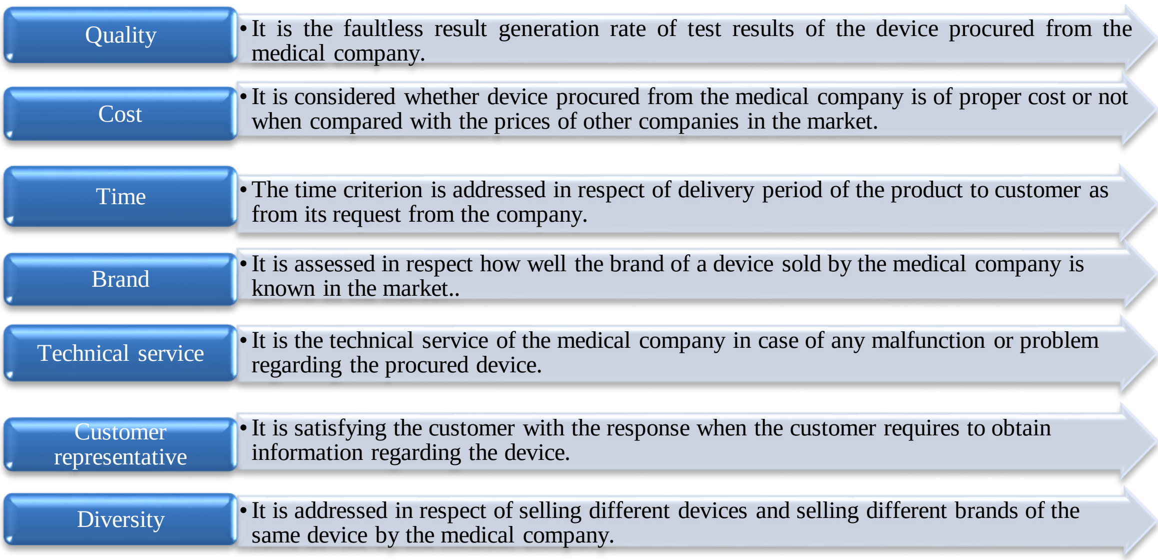

Figure 1. The Description of Criteria of the Implementation

The decision hierarchy of the selection of medical company is shown in Figure 2. Then these criteria and alternatives were evaluated by the purchasing officer and the PCM was formed. By using the data in the formed matrix, the importance degrees of criteria were calculated by the AHP method. And then, the assessment of the alternatives was performed by an individual who is specialized in the field and who is responsible for the selection of medical company, and linguistic variables were used in the assessment.

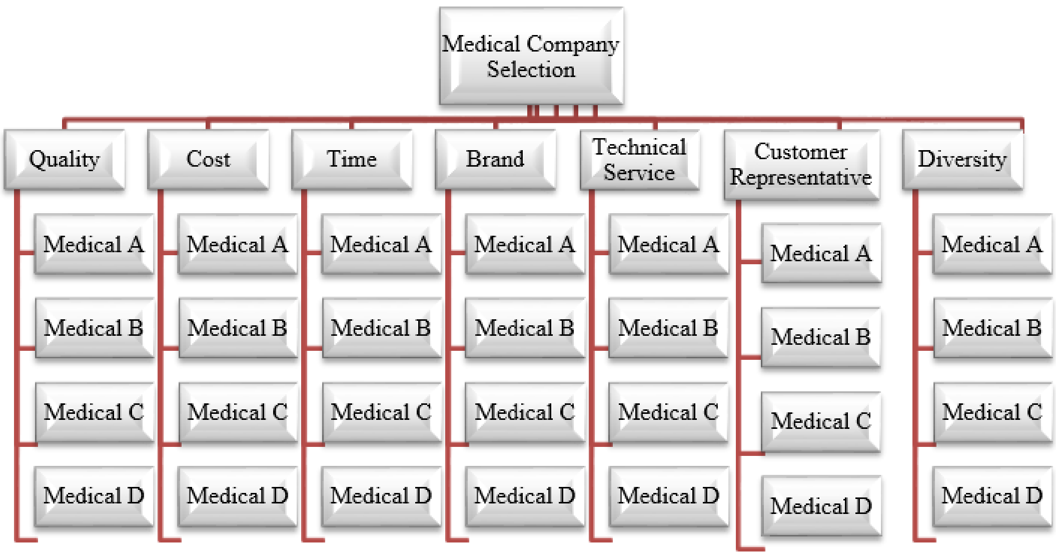

Figure 2. Decision Hierarchy for Medical Company Selection

The pairwise comparison matrix was created by using Table 4. The criteria weights were found by AHP method as 0.09 (brand), 0.08 (cost), 0.17 (quality), 0.09 (time), 0.29 (technical service), 0.16 (customer representative) and 0.10 (diversity). Subsequently, alternatives were evaluated by using Table 5 and fuzzy decision matrix was formed as in Table 6.

ISSN 2422-8702 (Online), **DOI:** 10.7176/JSTR/5-4-09
Vol.5, No.4, 2019

Table 6. The Fuzzy Decision Matrix

Criteria / Alternatives	Brand	Cost	Quality	Time	Technical Service	Customer Representative	Diversity
Medical A	(5,7,9)	(7,9,10)	(9,10,10)	(7,9,10)	(5,7,9)	(5,7,9)	(5,7,9)
Medical B	(7,9,10)	(5,7,9)	(7,9,10)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)
Medical C	(3,5,7)	(7,9,10)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(3,5,7)
Medical D	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(3,5,7)	(3,5,7)	(3,5,7)

The best and worst fuzzy values were determined using equality 8. Fuzzy best and fuzzy worst values for the criteria are shown in Table 7. Then, the fuzzy $\breve{S}_1$and $\breve{R}_1$ values were determined using equalities 9 and 10 in Table 8.

Table 7. The Fuzzy Best Value and The Fuzzy Worst Values

Criteria	$(\breve{f}_j^*)$	$(\breve{f}_j^-)$
Brand	(7,9,10)	(3,5,7)
Cost	(7,9,10)	(5,7,9)
Quality	(9,10,10)	(5,7,9)
Time	(7,9,10)	(5,7,9)
Technical Service	(5,7,9)	(3,5,7)
Customer Representative	(5,7,9)	(3,5,7)
Diversity	(5,7,9)	(3,5,7)

Table 8. $\breve{S}_1$and $\breve{R}_1$ Values

Alternatives	$\breve{S}_1$	$\breve{R}_1$
Medical A	(0.045,0.045,0.030)	(0.045,0.045,0.030)
Medical B	(0.255,0.227,0.170)	(0.090, 0.090,0.090)
Medical C	(0.450,0.450,0.450)	(0.170,0.170,0.170)
Medical D	(0.935,0.935,0.935)	(0.290,0.290,0.290)

Fuzzy maximum and minimum $\breve{S}_1$ and $\breve{R}_1$ values ($\breve{S}^*, \breve{S}^-, \breve{R}^*, \breve{R}^-$ values) were calculated with the help of the equalities 11 and 12 and these values are shown in Table 9.

Table 9. $\breve{S}^*, \breve{S}^-, \breve{R}^*, \breve{R}^-$ values

	l	m	u
$\breve{S}^*$	0.045	0.045	0.030
$\breve{S}^-$	0.935	0.935	0.935
$\breve{R}^*$	0.045	0.045	0.030
$\breve{R}^-$	0.290	0.290	0.290

Finally, the fuzzy $\breve{Q}_1$ index were found using equality 13 and fuzzy values are converted to crisp values using equation 14. Alternatives are ranked according to the crisp values of S_i, R_i and Q_i. Alternative Ranking is shown in Table 10. The results of the calculation showed that Medical A which is in the first rank in the alternative ranking was the best alternative.

Table 10. Alternative Ranking

	$\tilde{Q}_1$	Q_i		S_i		R_i	
		index	ranking	index	ranking	index	ranking
Medical A	(0,0,0)	0	1	0,04	1	0,04	1
Medical B	(0.210,0,222, 0.308)	0,247	2	0,22	2	0,09	2
Medical C	(0.483,0.483,0.501)	0,489	3	0,45	3	0,17	3
Medical D	(1,1,1)	1	4	0,94	4	0,29	4

Condition 1: Acceptable advantage: According to equalities 15 and 16, because of Q($a^{(u)}$)-Q($a^{\prime}$)=0,247-0=0,25≥0,25, Q($a^{(uu)}$)-Q($a^{\prime}$)=0,489-0≥0,25 and Q($a^{(uu)}$)-Q($a^{\prime}$)=1-0≥0,25, condition 1 is satisfied.

Condition 2: Acceptable stability: An alternative must also be the best alternative when ordered based on S and/or R values. If Q($a^{(m)}$)-Q($a^{\prime}$)<D Q , if condition 1 is not satisfied, $a^{(m)}$ and $a^{\prime}$ are the same compromise solutions. Because of similar compromise solution ($a^{\prime}$, a^{u},…, ^{m}), $a^{\prime}$ does not have a comparative advantage. If condition 2 is not satisfied, decision making is not stable although has a comparative advantage. Therefore compromise solution of $a^{\prime}$ and a^{u} is similar. Looking at table 10, Medical A has been the best alternative all ranked according to index. Hence condition 2 is satisfied.

4. Conclusion

In this study, it was benefited from the AHP and Fuzzy VIKOR methods for the selection of DNA-RNA-Protein isolation device to be used at laboratories where scientific researches of Ataturk University Medical Faculty are being carried out. For the problem of selection being addressed in this study, AHP and fuzzy VIKOR approaches among multi criteria decision making techniques- were used together and an assessment was made. The criteria affecting the selection of medical company were determined as quality, cost, time, brand, technical service, customer representative and diversity in the direction of the opinions of decision makers. These criteria were weighted by AHP, and the assessment of alternatives was performed by using the fuzzy VIKOR approach. When the results were examined, it was observed that Medical A was the best alternative**.** Medical B, Medical C and Medical D are followed, respectively. In the following studies, different multi criteria decision making methods can be used individually or together, and the results can be compared and, the proposed method can be applied to different problems. For different regions, the medical company specific problem can be addressed by increasing the number of alternatives and criteria.

References

1. Liu, H. C., Quan, M. Y., Li, Z., & Wang, Z. L. A new integrated MCDM model for sustainable supplier selection under interval-valued intuitionistic uncertain linguistic environment. Information Sciences. 2019.

2. Yu, C., Shao, Y., Wang, K., & Zhang, L. A group decision making sustainable supplier selection approach using extended TOPSIS under interval-valued Pythagorean fuzzy environment. Expert Systems with Applications, 121, 1-17, 2019.

3. Xu, Z., Qin, J., Liu, J., & Martínez, L. Sustainable supplier selection based on AHPSort II in interval type-2 fuzzy environment. Information Sciences, 483, 273-293, 2019.

4. Rashidi, K., & Cullinane, K. A comparison of fuzzy DEA and fuzzy TOPSIS in sustainable supplier selection: Implications for sourcing strategy. Expert Systems with Applications, 121, 266-281, 2019.

	

5. Pishchulov, G., Trautrims, A., Chesney, T., Gold, S., & Schwab, L. The Voting Analytic Hierarchy Process Revisited: A Revised Method with Application to Sustainable Supplier Selection. International Journal of Production Economics, 2019.

6. Abdel-Baset, M., Chang, V., Gamal, A., & Smarandache, F. An integrated neutrosophic ANP and VIKOR method for achieving sustainable supplier selection: A case study in importing field. Computers in Industry, 106, 94-110, 2019.

7. Costa, A. S., Govindan, K., & Figueira, J. R., Supplier classification in emerging economies using the ELECTRE TRI-nC method: A case study considering sustainability aspects. Journal of Cleaner Production, 201, 925-947, 2018.

8. KhanMohammadi, E., Talaie, H., Safari, H., & Salehzadeh, R., Supplier evaluation and selection for sustainable supply chain management under uncertainty conditions. International Journal of Sustainable Engineering, 1-15, 2018.

9. Ghoushchi, S. J., Milan, M. D., & Rezaee, M. J. Evaluation and selection of sustainable suppliers in supply chain using new GP-DEA model with imprecise data. Journal of Industrial Engineering International, 1-13, 2018.

10. Azimifard, A., Moosavirad, S. H., & Ariafar, S. Selecting sustainable supplier countries for Iran's steel industry at three levels by using AHP and TOPSIS methods. Resources Policy, 57, 30-44, 2018.

11. Chen, K. S., Wang, C. H., & Tan, K. H. Developing a Fuzzy Green Supplier Selection Model Using Six Sigma Quality Indices. International Journal of Production Economics, 2019.

12. Haghighi, M. H., Mousavi, S. M., & Mohagheghi, V. A new soft computing model based on linear assignment and linear programming technique for multidimensional analysis of preference with interval type-2 fuzzy sets. Applied Soft Computing, 2019.

13. Yucesan, M., Mete, S., Serin, F., Celik, E., & Gul, M. An Integrated Best-Worst and Interval Type-2 Fuzzy TOPSIS Methodology for Green Supplier Selection. Mathematics, 7(2), 182, 2019.

14. Liu, Y., Jin, L., & Zhu, F. A Multi-Criteria Group Decision Making Model for Green Supplier Selection under the Ordered Weighted Hesitant Fuzzy Environment. Symmetry, 11(1), 17, 2019.

15. Darminto, P., Erpita, R., & Trio, B. P. U. Implementation of Green Procurement in Supplier Selection of PT Kubota Indonesia with Fuzzy Analytical Network Process Approach (FANP). In E3S Web of Conferences (Vol. 73, p. 09021). EDP Sciences , 2018.

16. Jiang, P., Hu, Y. C., Yen, G. F., & Tsao, S. J. Green supplier selection for sustainable development of the automotive industry using grey decision-making. Sustainable Development, 26(6), 890-903, 2018.

17. Quan, M. Y., Wang, Z. L., Liu, H. C., & Shi, H. A hybrid MCDM approach for large group green supplier selection with uncertain linguistic information. IEEE Access, 6, 50372-50383, 2018.

18. Hajek, P., & Froelich, W. Integrating TOPSIS with Interval-Valued Intuitionistic Fuzzy Cognitive Maps for Effective Group Decision Making. Information Sciences, 2019.

19. Huang, B., Li, H., Feng, G., & Zhou, X. Dominance-based rough sets in multi-scale intuitionistic fuzzy decision tables. Applied Mathematics and Computation, 348, 487-512, 2019.

20. Çalı, S., & Balaman, Ş. Y. A novel outranking based multi criteria group decision making methodology integrating ELECTRE and VIKOR under intuitionistic fuzzy environment. Expert Systems with Applications, 119, 36-50, 2019.

21. Fu, Y. K. An integrated approach to catering supplier selection using AHP-ARAS-MCGP methodology. Journal of Air Transport Management, 75, 164-169, 2019.

22. Wang, Y. C., & Chen, T. C. T. A Partial-Consensus Posterior-Aggregation FAHP Method—Supplier Selection Problem as an Example. Mathematics, 7(2), 179, 2019.

23. Suraraksa, J., & Shin, K. S. Comparative Analysis of Factors for Supplier Selection and Monitoring: The Case of the Automotive Industry in Thailand. Sustainability, 11(4), 981, 2019.

24. Alkahtani, M., Al-Ahmari, A., Kaid, H., & Sonboa, M. Comparison and evaluation of multi-criteria supplier selection approaches: A case study. Advances in Mechanical Engineering, 11(2), 1687814018822926, 2019.

25. Stević, Ž., Vasiljević, M., Puška, A., Tanackov, I., Junevičius, R., & Vesković, S. Evaluation of suppliers under uncertainty: a multiphase approach based on fuzzy AHP and fuzzy EDAS. Transport, 34(1), 52-66 2019.

26. Phumchusri, N., Tangsiriwattana, S., & Luangiarmekorn, P. Supplier Selection Method: A Case-study on a Car Seat Manufacturer in Thailand. In 2018 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM) (pp. 46-50). IEEE, 2018.

27. Kumar, R., Padhi, S. S., & Sarkar, A. Supplier Selection of an Indian Heavy Locomotive Manufacturer: An Integrated Approach using Taguchi Loss Function, TOPSIS, and AHP. IIMB Management Review, 2018.

28. Wang, C. N., Nguyen, V. T., Thai, H. T. N., Tran, N. N., & Tran, T. L. A. Sustainable Supplier Selection Process in Edible Oil Production by a Hybrid Fuzzy Analytical Hierarchy Process and Green Data Envelopment Analysis for the SMEs Food Processing Industry. Mathematics, 6(12), 302, 2018.

29. Wang, C. N., Huang, Y. F., Cheng, I., & Nguyen, V. A Multi-Criteria Decision-Making (MCDM) Approach Using Hybrid SCOR Metrics, AHP, and TOPSIS for Supplier Evaluation and Selection in the Gas and Oil Industry. Processes, 6(12), 252, 2018.

30. Chen, Y., Wang, S., Yao, J., Li, Y., & Yang, S. Socially responsible supplier selection and sustainable supply chain development: A combined approach of total interpretive structural modeling and fuzzy analytic network process. Business Strategy and the Environment, 27(8), 1708-1719, 2018.

31. Liao, H., Wu, X., Liang, X., Xu, J., & Herrera, F. (2018). A New Hesitant Fuzzy Linguistic ORESTE Method for Hybrid Multicriteria Decision Making. IEEE Transactions on Fuzzy Systems, 26(6), 3793-3807 , 2018.

32. Diouf, M., & Kwak, C. Fuzzy AHP, DEA, and Managerial Analysis for Supplier Selection and Development; From the Perspective of Open Innovation. Sustainability, 10(10), 3779 , 2018.

33. ABDEL-BASSET, Mohamed, et al. A hybrid approach of neutrosophic sets and DEMATEL method for developing supplier selection criteria. Design Automation for Embedded Systems, 2018, 1-22.

34. Wang, T. C., & Tsai, S. Y. Solar panel supplier selection for the photovoltaic system design by using fuzzy multi-criteria decision making (MCDM) approaches. Energies, 11(8), 1989, 2018.

35. Büyüközkan, G., & Göçer, F. An extension of ARAS methodology under interval valued intuitionistic fuzzy environment for digital supply chain. Applied Soft Computing, 69, 634-654, 2018.

ISSN 2422-8702 (Online), **DOI:** 10.7176/JSTR/5-4-09
Vol.5, No.4, 2019

36. Joshi, R., & Kumar, S. An intuitionistic fuzzy information measure of order-$$(\alpha,\beta) $$ with a new approach in supplier selection problems using an extended VIKOR method. Journal of Applied Mathematics and Computing, 1-24, 2018.

37. Grandhi, S., & Wibowo, S. Application of fuzzy MCDM approach for evaluating and selecting solar energy suppliers. In 2017 13th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD) (pp. 1396-1401). IEEE, 2018.

38. Abdel-Basset, M., Mohamed, M., & Smarandache, F. A hybrid neutrosophic group ANP-TOPSIS framework for supplier selection problems. Symmetry, 10(6), 226, 2018.

39. Subramanian, N., & Ramanathan, R. (2012). A review of applications of Analytic Hierarchy Process in operations management. International Journal of Production Economics, 138(2), 215-241.

40. Emeç, Ş., & Akkaya, G. Stochastic AHP and fuzzy VIKOR approach for warehouse location selection problem. Journal of Enterprise Information Management, 31(6), 950-962, 2018.

41. Akkaya, G., Turanoğlu, B., & Öztaş, S. An integrated fuzzy AHP and fuzzy MOORA approach to the problem of industrial engineering sector choosing. Expert Systems with Applications, 42(24), 9565-9573, 2015.

42. Emeç, Ş.,&Akkaya, G. Sağlık Sektöründe Zihinsel İş Yükü Değerlendirilmesi ve Bir Uygulama. Ergonomics, 1(3), 156-162, 2018.