Presenting a Pattern for Assessing the Suppliers by Combining Group AHP Approach & the TOPSIS Technique

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Abstract- **Decision making has been described as one of the principles of management and considering the importance of supply chain in any organization, the necessity of optimized organizational management and pursuance of a desirable decision making pattern, decision making therefore has an important role in improvement of any organization. Operations research techniques are suitable tools for decision making processes. In this paper, we intend to present a reliable and applied pattern for assessment of our organization's indices and selecting suitable suppliers for raw materials by combining group AHP approach and the TOPSIS technique. The case study of the present research is Mazandaran wood & paper industries (MWPI), which is the largest producer of paper in the Middle East and uses a continuous production line for producing its products. Many types of raw materials play critical roles in its processes and the above mentioned company always has to make logical decisions and select suitable suppliers.**

Keywords- Supplier Chain; Management; AHP; TOPSIS

I. INTRODUCTION

In today's competitive market, producers are not only concerned with improving local conditions, but selecting the best markets (considering the phenomenon of globalization) and therefore selecting the best suppliers is in the top of their agendas [11]. Changing production methods and passing through traditional methods and using the newest procedures and also rapid and continuous environmental changes, have made co-operation between suppliers and manufacturing companies closer than ever before and purchasing management has transformed into strategic supply management [20]. Considering the fact that about %55 of the supplier's incomes are consumed for goods and services, "purchasing" is therefore a potential section for costs savings [16]. Organizations must have an efficient and powerful supply chain to provide systems requirements regarding the needed items, according to their production programs or preventive and emergency repairs in due course [1]. Since the quality and flexibility of the presented productions and services are affected to a great extent by the items that are received from manufactures [15], therefore the process of source searching & selecting suitable suppliers are potential aspects for improving the above mentioned organization's products [8].

On the other hand, decision making is one of the elements of management and using suitable methods plays an important role in the success of any organization [12]. Operation research is a scientific approach which searches for managerial problem solving methods and its goal is to help managers for better decision making and it emphasizes a group of mathematical methods [3]. One of the common and operational methods of operation research includes analytical hierarchy process (AHP)[1]. The output of this analysis includes a group of ranks, such that the required co-ordinations are provided by the most suitable means [2]. In fact, this method is used to solve the problems in which one option must be selected among the available limited ones and it has a very high efficiency [14]. If we have the weights of indices, the technique for order-preference by similarity to ideal solution (TOPSIS)[2] has a high potential for the process of the desirable option [2].

In this paper, we have tried to present a reliable and applied pattern for assessing the organization's indices and selecting suitable suppliers of raw materials by using a combined method of group AHP approach & TOPSIS technique. The case study of the present research is Mazandaran wood & paper industries (MWPI), which is the largest producer of paper in the Middle East and uses a continuous production line for producing its products. Many types of raw materials play a role in its processes and the above mentioned company always has to make logical decisions and select suitable suppliers.

II. LITERATURE REVIEW

The problem of selecting suitable suppliers has been emphasized by the researchers since 1960s [20]. In the researches performed, the researchers have either determined indices for assessing the suppliers or presented a pattern for assessments and ultimately selecting the required suppliers. In a few researches, both cases have been reviewed and the researchers have

[1]. Includes a method for decision making considering the simultaneous and mutual effects of parameters by the aid of pair comparison matrices which ultimately specifies the weight value of each option [18]
[2]. TOPSIS is one of the decision making methods which is very effective for selection of one option among several options and in addition to considering the least possible positive distance, it considers the farthest possible negative distance as well [2].

introduced an applied pattern for using, identifying and domestication of indices [16]. The first study was performed by Dickson regarding the suppliers in 1966. He prepared a summarized list including 50 different factors expressed by some authors [6] & ultimately 23 distinct indices were presented for decision making in relation to the suppliers [11]. His studies were continued by individuals such as Dempsey [5] and Weber. Each of them used their own views for specifying indices for assessment of suppliers. Among these, Hamphreys has reviewed the environment factors which are effective in selection of suppliers [9]. And Merli assessed the suppliers from the aspect of expenses that they impose on organizations [4].

In our country (Iran), some actions were taken by some people such as Ghodsypour and first, some indices were presented for assessing the suppliers [7]. In continuation, a pattern was also introduced for assessing the suppliers in 2006 [16]. Reviewing the subject of assessing suppliers was gradually started in theses and researchers such as Taimouri [17] and Karbasian [10] have reviewed the subject of suppliers considering supply chain. Riazi by considering organization's strategy [13], Sohanian in car manufacturing industry [16] and Yazdani in an industry with continuous production line [20] assessed the suppliers and determined the values and weights of indices related to it.

III. RESEARCH METHOD

The method that is used in the present research is a Multiple Criteria Decision Making (MCDM)[3] method. In this research, first we reviewed and domesticated the indices of assessing the suppliers resulting from the previous researches, while consulting with the related experts and specialists of MWPI in this regard. Consequently, among the 29 initial collected indices, 10 indices were selected and described, such as to include the main and domesticated indices of this industry for assessing the raw materials suppliers including the following items:

1- Quality of the goods (raw materials);

2- Suitable prices of the goods and their competitive capabilities in competitive markets;

3- After-sales services and the guarantee and commitments regarding the sold goods;

4- Past records (credibility of supplier for the organization) and trusting the supplier for on-time delivery;

5- Supplier's financial condition;

6- Physical proximity, shipment commitments and means of delivering the supplier's good;

7- Capability of packing the consignments;

8- Technical knowledge, the utilized technology, design capabilities of the product and flexibility of productions;

9- Public affairs and communications;

10- Observing safety and sanitation principles by suppliers.

To determine the weight and value of each domesticated indices, the group AHP approach was used for decision making. This device is a measurement theory that deals with assessable and intangible indices [19]. This hierarchical analysis is based on three principles [18]:

1- Establishing a structure and a ranked model for the problem which in fact decomposed complicated problems into simpler ones.

2- Determining the preferences through pair comparisons, which is usually done by pair comparison matrixes for assessment.

3- Establishing a logical compatibility for measurements which at the end of matrix calculations, the incompatibility rate of decision maker's minds decisions are calculated and desirable compatibility will be in a condition less than 0.1.

In this research, in order to use the group AHP method, first a questionnaire was prepared in which a 10×10 matrix had been requested from the addressed people to do a pair comparison for indices and a 9 optional spectrum, more important than infinity = 9 to infinitely unimportant = 1/9 based on the preferred value table. The questionnaire was distributed among top managers and the related experts who are involved in the supplier's activities. So that according to their opinions, the domesticated indices of supplier's assessment are analyzed in the above mentioned industry in order to determine the weight and value of each index by the organization. Since the result was presented in the form of several pair matrixes, a geometrical average was calculated for each of the matrix's elements & the results are in presented in the table no. 1.

This Matrix was normalized based on the below formula. The total value of each column was calculated and each of the Matrix's numbers was divided by total value of the same column. The mathematical average of each line was measured which shows the value of the desired value or weight of the related index (Eq. 1).

$$W_i = \sum (X_i / Sum) / n \quad (1)$$

[3]. In these decision making methods, it is possible to use several criteria for decision making instead of using one criterion for optimal assessment [2].

Based on the above mentioned, for example, we can calculate the weight of quality index as follows:

W_1 = (1 / 2.86 + 4.53 / 7.56 + 4.88 / 12.13 + 5.02 / 18.1 + 4.74 / 18.69 + 4.64 / 20.06 + 5.08 / 18.22 + 5.1 / 21.3 + 5.28 / 25.21 + 4.07 / 18.77) / 10 = (0.349 + 0.6 + 0.402 + 0.277 + 0.254 + 0.231 + 0.279 + 0.239 + 0.209 + 0.217) / 10

$$W_1 = 0.31$$

TABLE 1 GEOMETRICAL AVERAGE MATRIX FOR PAIR COMPARISON OF INDICES

Indices	Quality of goods	Price of goods	After Sale Services	Supplier's Reputation & Credibility	Supplier's Financial Condition	Physical Proximity	Supplier's Packing Capability	Technical Knowledge Flexibility	Supplier's Communications	Observing Safety Matters
Quality of goods	1	4.53	4.88	5.02	4.74	4.64	5.08	5.10	5.28	4.07
Price of goods	0.22	1	3.74	5.11	4.69	4.80	3.56	3.87	4.00	3.07
After Sale Services	0.20	0.26	1	3.44	3.76	2.99	2.48	2.84	3.44	1.89
Supplier's Reputation & Credibility	0.20	0.19	0.29	1	2.06	1.83	1.26	1.66	2.48	1.70
Supplier's Financial Condition	0.21	0.21	0.26	0.47	1	1.93	1.96	2.26	2.14	1.72
Physical Proximity	0.21	0.21	0.39	0.54	0.51	1	1.29	1.55	1.79	1.22
Supplier's Packing Capability	0.20	0.32	0.40	0.79	0.51	0.86	1	1.80	2.14	1.71
Technical Knowledge Flexibility	0.19	0.26	0.35	0.74	0.44	0.64	0.55	1	1.92	1.42
Supplier's Communications	0.19	0.25	0.29	0.40	0.40	0.56	0.46	0.52	1	0.98
Observing Safety Matters	0.24	0.32	0.53	0.59	0.58	0.82	0.58	0.70	1.01	1
Total	**2.86**	**7.56**	**12.13**	**18.10**	**18.69**	**20.06**	**18.22**	**21.30**	**25.21**	**18.77**

The result of normalization shows the weight of each index as follows in table no. 2.

TABLE 2 ASSESSMENT INDICES FOR SUPPLIERS AND AVERAGE WEIGHT OF EACH ONE

Index	**Weight**	
Quality of goods	W_1	0.31
Price of goods	W_2	0.20
After Sale Services	W_3	0.12
Supplier's Reputation & Credibility	W_4	0.07
Supplier's Financial Condition	W_5	0.07
Physical Proximity	W_6	0.05
Supplier's Packing Capability	W_7	0.06
Technical Knowledge Flexibility	W_8	0.05
Supplier's Communications	W_9	0.03
Observing Safety Matters	W_{10}	0.04
Total		1

It is worth mentioning that calculating the incompatibility rate of indices pair comparisons based on the above mentioned group AHP, shows a desirable compatibility (IR = 0.056 < 0.1) in the comparisons and reliability of the results[4].

The above mentioned indices were classified into 5 main below indices after elimination of 6 indices with minor importance:

1- The quality of goods supplied by the suppliers: 0.31

2- Prices of the produced goods: 0.2

3- Goods after sales services & guarantees: 0.12

4- Suppliers reputation, credibility & capability for goods on-time supply: 0.07

5- Supplier's financial conditions: 0.07

6- Other: 0.23

[4]. Inconsistency Ratio: Includes a criterion for assessing the inconsistency ratio and logical stabilities between the pair comparisons performed on the parameters which must be less than 0.1 and the description and proof of its calculations are out of the scope of the present article [17].

In one practical instance, based on the requirements and by using TOPSIS, we tried to specify and select the anti-bacterial substance according to the coordinated indices and ultimately to choose a suitable supplier for this substance. By using this method, we considered one of the options distance from the ideal point, in addition to its distance from the negative ideal point [2]. For this substance (micro organism control) which is one of the main substances for paper production process, there were 4 different suppliers and sources including:

1- Farin Kimia Co.

2- Nalco Co. (Italy)

3- Buckman Co.

4- PMW Co.

By collecting the information and documents of the suppliers considering selected indices such as price, quality parameters and their past records in presenting after-sales services, each of the suppliers was assessed after consulting with the related experts and specialists considering each individual index. To do this process, a questionnaire was submitted to the managers and the decision makers were asked to assess each supplier considering the five selected indices, by specifying a numerical value for them including: Average = 1, Good = 2, Relatively Good = 3 & Very Good = 4. The results are indicated in the table no. 3:

TABLE 3 RESULTS OF SUPPLIER'S ASSESSMENT PERFORMED BY THE DECISION MAKERS

Result of Assessment		**Suppliers**		**Indices**	
Value	**Relative**				
4	Very Good	A_1	Farin Kimia	I_1	**Quality**
3	Relatively Good	A_2	Nalco		
1	Average	A_3	Buckman		
2	Good	A_4	PWM		
4	Very Good	A_1	Farin Kimia	I_2	**Price**
2	Good	A_2	Nalco		
1	Average	A_3	Buckman		
3	Relatively Good	A_4	PWM		
3	Relatively Good	A_1	Farin Kimia	I_3	**After Sales Services**
1	Average	A_2	Nalco		
4	Very Good	A_3	Buckman		
3	Relatively Good	A_4	PWM		
4	Very Good	A_1	Farin Kimia	I_4	**Credibility & on-time Supply**
1	Average	A_2	Nalco		
4	Very Good	A_3	Buckman		
4	Very Good	A_4	PWM		
4	Very Good	A_1	Farin Kimia	I_5	**Financial Condition**
4	Very Good	A_2	Nalco		
4	Very Good	A_3	Buckman		
4	Very Good	A_4	PWM		

Based on TOPSIS, first the below table was created for the decision matrix (table no. 4).

TABLE 4 MATRIX OF INITIAL DECISION

	Quality	**Price**	**Services**	**On-time Delivery**	**Financial Condition**
A_1	4	4	3	4	4
A_2	3	2	1	1	4
A_3	1	1	4	4	4
A_4	2	3	3	4	4

The below equation (No. 2) was used for normalization of the above decision matrix.

$$n_{ij} = r_{ij} / \sqrt{\sum r_{ij}^2} \quad (2)$$

For instance, the previous matrix component (Quality, A_1) which was equal to 4, is calculated as follows (for normalization):

$$n_{11} = r_{11} / \sqrt{\sum r_{ij}^2} = 4 / \sqrt{\sum (4)^2 + (3)^2 + (1)^2 + (2)^2} = 4 / \sqrt{30} = 4 / 5.48$$

$$n_{11} = 0.73$$

Other components of the matrix are also calculated according and the final normalized matrix which is presented in the table no. 5.

TABLE 5 NORMALIZED DECISION MATRIX

	Quality	Price	Services	On-time Delivery	Financial Condition
A_1	0.73	0.73	0.51	0.57	0.50
A_2	0.55	0.37	0.17	0.14	0.50
A_3	0.18	0.18	0.68	0.57	0.50
A_4	0.37	0.55	0.51	0.57	0.50

In the next stage, if the above matrix is called N_d, the normalized matrix can be coordinated according to the below equation (No. 3):

$$V = N_d \,.\, W \tag{3}$$

The vector of W is the result of indices assessments based on AHP and for instance, for the component (Quality, A_1), the calculation are continued as follows:

$$V = N_d \,.\, W \longrightarrow V_{11} = 0.73 \times 0.31 \longrightarrow V_{11} = 0.2264$$

As a result, the coordinated matrix of decision will be in the following form (table no. 6).

TABLE 6 NON-SCALED NORMALIZED DECISION MATRIX

	Quality	Price	Services	On-time Delivery	Financial Condition
A_1	0.2264	0.1461	0.0609	0.0400	0.0350
A_2	0.1698	0.0730	0.0203	0.0100	0.0350
A_3	0.0566	0.0365	0.0811	0.0400	0.0350
A_4	0.1132	0.1095	0.0609	0.0400	0.0350

To determine the ideal and negative ideal options, we can use Eqs. 4 and 5.

$$\text{Ideal option:} \quad \{ (\max V_{ij} / j \in J) , (\min V_{ij} / j \in J') / i = 1 , 2 , \dots m \} \tag{4}$$

$$\text{Negative ideal option:} \quad \{ (\min V_{ij} / j \in J) , (\max V_{ij} / j \in J') / i = 1 , 2 , \dots m \} \tag{5}$$

According to the available non-scaled matrix, the values for ideal and negative ideal options were specified as follows:

$$V^+_j = \{ 0.2264 , 0.1461 , 0.0811 , 0.04 , 0.035 , 0.115 \}$$

$$V^-_j = \{ 0.0566 , 0.0365 , 0.0203 , 0.01 , 0.035 , 0.115 \}$$

In the next step, the distance of suppliers in each index of positive and negative ideal types was obtained by the below equations (Eqs. 6 & 7):

$$\text{Distance of option from ideal:} \quad d_{i+} = \{ \sum (V_{ij} - V^+_j)^2 \}^{0.5} , i = 1 , 2 , \dots m \tag{6}$$

$$\text{Distance of option from negative ideal:} \quad d_{i-} = \{ \sum (V_{ij} - V^-_j)^2 \}^{0.5} , i = 1 , 2 , \dots m \tag{7}$$

For example, based on the above mentioned equation, we can calculate "d_{1+}" as follows:

$$\text{Distance of the first option from ideal:} \quad d_{1+} = \{ \sum (V_{1j} - V^+_j)^2 \}^{0.5}$$

$$d_{1+} = \{ 0 + 0 + (0.0609 - 0.0811)^2 + 0 + 0 \}^{0.5} = \{ (- 0.0203)^2 \}^{0.5} = 0.0203$$

According to the other options of the problem, the distance from the ideal point was calculated and the results are presented in table no. 7.

TABLE 7 DISTANCE OF OPTIONS FROM IDEAL

Option	Distance
d_{1+}	0.0203
d_{2+}	0.1146
d_{3+}	0.2021
d_{4+}	0.1207

The above table shows that the first option has the least distance from the ideal point. Similarly, we can calculate "d_{1-}" as follows:

$$\text{Distance of the first option from negative ideal:} \quad d_{1-} = \{ \sum (V_{1j} - V^-_j)^2 \}^{0.5}$$

$d_{1-} = \{(0.226 - 0.056)^2 + (0.1461 - 0.0365)^2 + (0.0609 - 0.0203)^2 + (0.04 - 0.1)^2 + 0\}^{0.5} = 0.2083$

By continuing the calculations, the distance from the negative ideal point is calculated for each option and the results are as follows in table no. 8.

TABLE 8 DISTANCE OF OPTIONS FROM NEGATIVE IDEAL

Option	Distance
$\mathbf{d_{1+}}$	0.2083
$\mathbf{d_{2+}}$	0.1189
$\mathbf{d_{3+}}$	0.0678
$\mathbf{d_{4+}}$	0.1053

The calculations show that the first option has the farthest distance from the negative ideal, too. In the next step, proximity coefficient is calculated for each supplier using the below equation (Eq. 8). The most desirable option is the supplier who has the most amount of fraction:

$$cl_{i+} = d_{i-} / (d_{i+} + d_{i-}) \quad (8)$$

Based on the above equation, the value of "cl_{1+}" can be calculated by the below equation.

$$cl_{1+} = d_{1-} / (d_{1+} + d_{1-}) = 0.2083 / (0.0203 + 0.2083) = 0.2083 / 0.2286 = 0.91$$

In table no. 9, all the values for ideal and negative ideal distance and also the proximity coefficient have been calculated and presented:

TABLE 9 PROXIMITY COEFFICIENT CALCULATED FOR EACH SUPPLIER

	d+	**d-**	**Sum of distances**	cl
$\mathbf{A_1}$	0.0203	0.2083	0.2286	0.91
$\mathbf{A_2}$	0.1146	0.1189	0.2336	0.51
$\mathbf{A_3}$	0.2021	0.0678	0.2699	0.25
$\mathbf{A_4}$	0.1207	0.1053	0.2259	0.47

Based on TOPSIS, the calculated proximity coefficient is arranged in the descending order and the supplier who has the highest proximity coefficient will be selected as the best choice.

$$0 =< cl_i =< 1 \rightarrow \begin{cases} cl_i = 0 & In\ the\ worst\ point \\ cl_i = 1 & In\ the\ worst\ point \end{cases}$$

Proximity coefficients are between zero & unity and the proximity coefficient is most desirable when its value is closest to one and will be the best option for decision making. It has the least distance from ideal & the most distance from the negative ideal. The descending order of suppliers will have the below form (table no. 10) after assessment based on the organizations desired indices.

TABLE 10 THE DESCENDING ORDER OF OPTIONS BASED ON THE CALCULATED PROXIMITY COEFFICIENT

Option		**cl**
Farin Kimia	$\mathbf{A_1}$	**0.91**
Nalco	$\mathbf{A_2}$	0.51
Buckman	$\mathbf{A_4}$	0.47
PWM	$\mathbf{A_3}$	0.25

IV. RESEARCH FINDINGS

By utilization of multiple criteria decision making methods such as group AHP with the aid of pair comparison matrix, the weight and the value of supplier's main assessment indices were determined (such as quality, price, services, on-time delivery and their financial conditions, based on the industry's expert's opinions). The results of matrix calculations based on this method showed the highest weight for the supplier's good's quality index and the lowest one for the supplier's public relations with the customers. These coordinated indices were used for assessing the suppliers of different raw materials.

As an example, with the aid of interviews and by completing the documents, the suppliers of different anti bacteria substances, which are among the important substances of complicated and continuous process of paper manufacturing, were assessed and ranked. Considering table no. 10, the option A_1 (Farin Kimia Co.), A_2 (Nalco co.), A_4 (PWM) and A_3 (Buckman) were selected in respective priority for supplying anti bacteria substances. The process of ranking and selecting the suppliers for MWPI can be shown as follows.

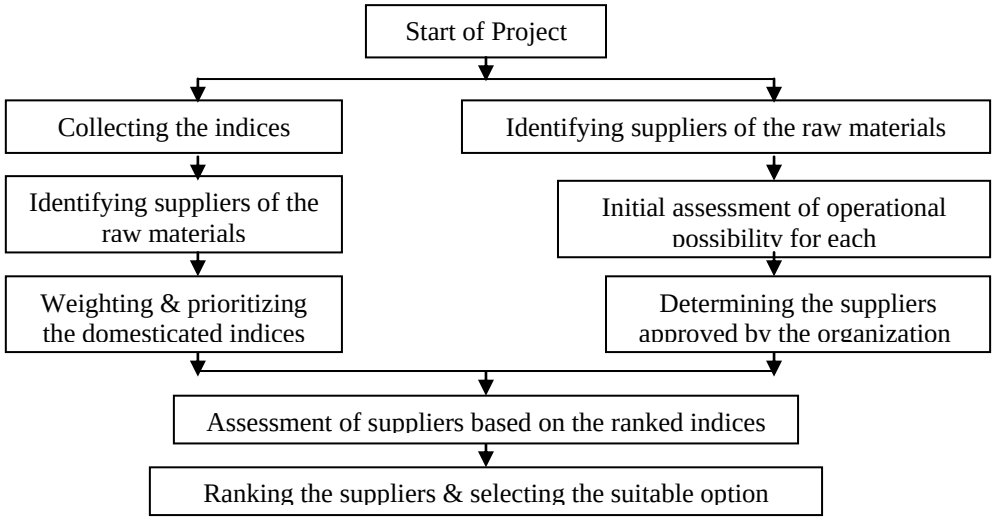

Fig. 1 The process of ranking and selecting the suppliers

At the final stage, the organization recognized that the assessment pattern is usable and as a result the necessary arrangements were made for purchasing the required substances.

V. CONCLUSIONS

As usual, the researches regarding suppliers and their assessment have been performed in two areas. The researchers have identified and assessed the related indices, such as researches performed by Dikson [6] and Weber [4] or they have presented an approach for assessment of the suppliers among which we can mention Sohanian's research [16]. The research done in MWPI has resulted in presenting an applicable pattern for selecting suitable suppliers for each substance, while identifying the effective indices.

The above mentioned research and the results obtained which are also applicable in the real world, indicate that the presented pattern which is a combination of group AHP approach and the TOPSIS method in the decision making process, is extendable to other substances for the purpose of assessing the suppliers of the under study company. In this research, we can evaluate the suppliers in each index by TOPSIS and the coordinated indices which results from group AHP approach for all those cases which need decision making & selecting the best suitable options among various suppliers of this substance. By TOPSIS, we can assess all of the related suppliers in each index and ultimately it is possible to rank & select them based on the specific needs. These two tools have the desirable combination of supplying the organization's requirements and accessing a suitable pattern for decision making regarding suppliers of raw materials.

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