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COMBINING ANALYTICAL HIERARCHY PROCESS AND TOPSIS APPROACHES FOR SUPPLIER SELECTION IN A CABLE COMPANY

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KEYWORDS

Supplier selection, multi criteria decision making, analytical hierarchy process (AHP), TOPSIS method, cable sector.

ABSTRACT

In the competitive business environment of the 21st century, organizations must reply quickly and precisely to customer demands. The choice of suppliers and their performance assessment are becoming major challenges that face supply chain managers or directors. Evaluating suppliers and selecting one of them are complicated tasks due to the fact that various criteria or objectives must be considered in the decision making process. Also in many real world cases the criteria are not equally important for the purchase managers. In this study, we proposed a supplier selection analysis model considering both Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. Subjective and objective opinions of purchase managers/experts turn into quantitative form with AHP. TOPSIS technique is used for calculating the supplier's ratings.
The aim of this paper is to determine the appropriate supplier providing the most customer satisfaction for the criteria identified in the supply chain. In this paper, data taken from a well-known cable manufacturing company in Turkey is used to illustrate the supplier selection procedure. Due to the fact that main raw material used in all cables, the company strongly focuses on supply of the Electrolytic Copper Cathode. The company detects eight different criteria for procurement of the Electrolytic Copper Cathode. These are origin, quality, availability, cost, delivery requirements, cost of conveyance, reliability of supplier and quality certificates. There are four firms providing the Electrolytic Copper Cathode for the company.

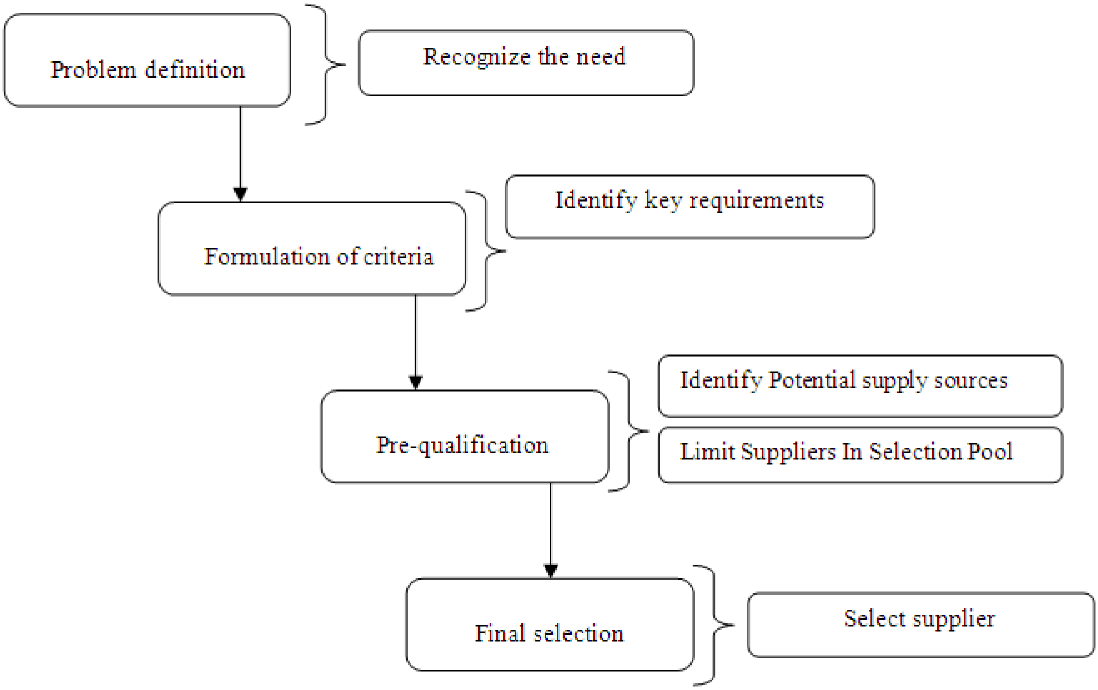
1. INTRODUCTION

In recent years, firms have been focused their attention on supply chain functions. Supplier selection is one of the most important functions in supply chain management due to the fact that it affects the quality of last product and total performance of the company. Also, it provides companies with opportunities to reduce cost. The supplier selection process requires evaluating various criteria and different supplier features. This process can be considered as a multi-criteria decision making problem (MCDM) that includes both quantitative and qualitative factors. Therefore, firms should take in the consideration all the criteria impact the production process when evaluating the suppliers.

Fundamentally, there are two types of supplier selection. In the first type, one supplier can provide all of the buyer requirements which is called single sourcing. The buyer makes one decision in this type; which supplier is the best. In the other type, one supplier cannot provide total needs of the buyer. In this case, buyer has to divide order quantities among several suppliers. This type of supplier selection is called as multiple sourcing. The buyer should answer two types of questions in multiple sourcing: which supplier is the best and how much should I purchase from every supplier (Shahroudi and Rouydel, 2012). In this study, single sourcing is used.

Decision method in supplier selection is usually consisting of four steps. First step is problem definition, second step is formulation of criteria, third step is pre-qualification and the last step is final selection. Decision process and activities in steps are shown in Figure 1.

Figure 1: Supplier Selection Process



The first step, “Problem Definition”, concerns decision makings which should identify the strategy of purchases e.g. the duration of new selection. There are two activities in the second step: identifying the key criteria and determining the sourcing strategy. Pre-qualification, the third step is the process of identifying potential supply source and gathering a limited pool of suppliers. The last step in the supplier selection process is final selection. In this step, firstly selection method is determined and then, best supplier is selected. While qualitative tools are used in the first two steps, quantitative tools are used in last two steps.

The aim of this paper is to determine the appropriate supplier providing the most customer satisfaction for the criteria identified in the supply chain. In this paper, data taken from a well-known cable manufacturing company in Turkey is used to illustrate the supplier selection procedure. We proposed a supplier selection analysis model considering both AHP and TOPSIS method. Subjective and objective opinions of purchase managers/experts turn into quantitative form with Analytic Hierarchy Process. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) technique is used for calculating the supplier's ratings.

The study is composed of seven sections. The second section provides an overview of existing methods and studies. The third section shows the structure of the problem in the cable company. The next section describes the proposed approach and gives information about AHP and TOPSIS. In section five, an empirical study is illustrated in the cable production industry. Results of the study are presented in section six. Finally, concluding remarks and discussions follow.

Multi-criteria decision making technique called AHP is applied to determine the relative weights of the evaluation criteria. AHP approach achieves pairwise comparisons among factors or criteria in order to prioritize them using the eigenvalue calculation. AHP model was represented in a questionnaire to survey experts' opinions. The relative weight of each factor in the model was calculated.

2. LITERATURE REVIEW

Decision making for supplier selection is complex process due to the fact that various criteria must be considered in this process. Researchers have been focus on the analysis of selection criteria and supplier performance measurement since 1960s. Dickson (1966) studied the importance of supplier evaluation and selection criteriafor purchasing managers and offered 23 supplier criteria that managers consider in such an evaluation, including quality, delivery, price, performance history and others. Weber, Current, and Benton (1991) suggested a number of selection criteria to measure supplier performance, such as price, delivery, quality, productive capability, location, technical capability, management organization, reputation, industry position, financial stability, performance history, and maintainability. Mazurak, Rao, and Scotton (1985) applied a linear weighting model that includes quality, delivery, net price and financial position as selection criteria. Ellram (1990) proposes three principal criteria: 1) financial statement of the supplier 2) organizational culture of the supplier 3) technological state of the supplier. Barbarosoglu and Yazgac (1997) determined three different primary criteria:1) the performance of the supplier, 2) the technical capabilities and financial situation of the supplier, and 3) the quality system of the supplier.

Various methods have been suggested for supplier selection problem. All the methods can be classified in four different categories: MCDM is the first category which contains Analytic Hierarchy Process (AHP), Analytical Network Process (ANP) and TOPSIS methods. Yahya and Kingsman (1999) used Saaty'sAHP method to identify priority in selecting suppliers. The researchers applied vendor rating in supplier selection and in deciding how to distribute business, as well as in determining where development effort is applied. Chan (2003) developed an interactive selection model with AHP to facilitate decision makers in selecting suppliers. Liu and Hai (2005) studied on supplier selection problem by combining a collaborative purchasing program and a new approach, based on the use of Saaty's (1980) AHP method. Chan et al. (2007) suggested an AHP-based decision making approach to solve the supplier selection problem. All suppliers were evaluated based on 14 criteria. Hou and Su (2007) developed an AHP-based decision support system for the supplier selection problem in a mass customization environment. Sarkis and Talluri (2002) appliedANP method to appraise and select the best supplier with regard to organizational factors and strategic performance metrics, which consist of seven evaluating criteria.Bayazit (2006) proposed an ANP model to evaluate supplier selection process as a framework for managers. Gencer and Gurpınar (2007) proposed an ANP based model for an electronic company for supplier evaluation and selection with respect to various assessment criteria. Jadidi et al. (2010) asserted aTOPSIS based model for multi criteria supplier selection problem. Vimal et al. (2012) used TOPSIS method to develop a useful approach for a manufacturing company for selecting the convenient supplier.

The second category is mathematical programming methods. Data envelopment analysis (DEA) and linear programming methods can be included in this category. Talluri and Sarkis (2002) applied DEA to measure the performance of suppliers. Garfamy (2006) suggested a DEA model to evaluate the overall performances of suppliers based on total cost of ownership. Wu et al. (2007) presented a so-called augmented imprecise DEA for supplier selection. Talluri and Narasimhan (2003) improved a max-min method basedon linearprogramming to maximize and minimize the performance of a supplier against the best target measures set by the buyer. Ng(2008) developed a weighted linear programming method for the supplier selection problem, with an objective of maximizing the supplier score.

Artificial Intelligence methods, third category, contain Genetic algorithm, artificial neural network (ANN) and data mining methods. Ding et al. (2005) presented a GA based optimization methodology for supplier selection. The presented method provided possible configurations of the potential suppliers, including transportation modes. LiaoandRittscher (2007) formulated a multi-objective programming model for supplierevaluating under probabilistic demand circumstances. The GA is employed to solve the supplierselection and supply quantity allocation in this study. Wei et al. (1997) suggested an artificial neural network model for the supplier selection.In this study, the performance history, quality history, geography and price of a supplier were selected as determinant factors effecting the supplier selection. Lee and Ou-Yang (2009) offered aneural network-based model to forecast supplier's bid price in order to shorten the lead time in supplierselection.

The last category is integrated approaches. There are so many studies about integrated methods for supplier selection problem in the literature. Some studies are provided below. Guang et al. (2010) proposed an approach for the supplier selection problem in nuclear power plant supply chain systems utilizing AHP and improved technique for order preference by similarity to ideal solution (TOPSIS). Shahroudi et al. (2011) suggested an integrated model for supplier’s selection and order allocation in an automotive company. The research was performed in two sections. In first section, they used AHP-TOPSIS in order to select the best suppliers. In the second section, multi-objective linear programming model were used for order allocation to every selected suppliers in first section. Fazlollahtabar et al. (2011) proposed an integrated approach of AHP-TOPSIS, and multi-objective nonlinear programming to consider both tangible and intangible factors in choosing the best suppliers. The priorities are calculated for each supplier by use of AHP. TOPSIS is applied to rank the suppliers. Xu and Lin (2010) two-phase data mining methodology for strategic supplier selection. In-depth combined pattern mining is considered first to find the first-level or direct strategic suppliers. Then extend the whole supplier network, with the help of value network, graph theory and evaluation criteria, the strategic supplier network satisfied the needs of supply network is generated. After that, by using strategic supplier network, companies can select the most suitable suppliers.Bhutia and Phipon (2012) developed a methodology to evaluate suppliers in supply chain cycle based on AHP and TOPSIS. They have calculated the weights for each criterion based on AHPand then inputted these weights to the TOPSIS method to rank suppliers.

Demirtas and Ustun (2008) developed an integrated ANP andmulti-objective mixed integer linear programming approach to selectthe best set of suppliers, and to determine the optimal orderallocation.Shahroudi and Rouydel (2012) proposed an integrated approach of ANP- TOPSIS in choosing the best suppliers and defined the optimum quantities order among selected suppliers by using Multi-Objective Linear Programming. Kahraman et al. (2003) applied a fuzzy AHP to select the best supplier in a Turkish white good manufacturing company. Chan and Kumar (2007) also used fuzzy AHP for supplier selection as the case with Kahraman et al. (2003). In the approach, triangular fuzzy numbers and fuzzy synthetic extent analysis method were used to represent decision makers' comparison judgment and decide the final priority of different criteria.

Ramanathan (2007) suggested that DEA could be used to evaluate the performance of suppliers using both quantitative and qualitative information obtained from the total cost of ownership and AHP. Sevkli et al. (2007) applied an integrated AHP–DEA approach for supplier selection. AHP was used for the local weights and DEA was used to calculate the efficiency scores of all suppliers.Lau et al. (2006) developed an integrated ANN and GA approach for supplier selection. ANN was responsible for benchmarking the potential suppliers with respect to four evaluating factors. After that, GA was deployed to determine the best combination of suppliers. The four evaluating criteria were used again in the fitness function of GA.

The aim of this study is to propose a multi-criteria decision-making approach to evaluate the experts' preference orders, to examine experts' perceptions of supplier selection. The purposes of this study were to use Saaty's analytic hierarchy process (AHP) to investigate the factors that experts consider when choosing supplier, and to derive the relative weight of each factor.

3. SUPPLIER EVALUATION IN A CABLE COMPANY

An application is performed in a manufacturing company which is the most modern cable factory in Turkey. The factory has been established in 1989 with the %100 of national capital. With the understanding of quality and vision of chasing the development of market; the firm has been producing insulated medium voltage cables from 3,6/6 KV up to 20,3/35 KV and 154 KV high voltage cables.With modern IT structure and automation technology, the firm has 18.000 tons of colored and natural PVC granulate production, 24.000 tons of 8 mm copper wire production and 4.000 tons ofXLPE material usage capacity annually.

The firm which has the finest cable factory ornamented with the modern machine park and the test laboratories gives service with its copper wire drawing machine, cable extrusion lines, PVC granulate production, automatic coiling and packaging lines on international quality basis.The company aims to get standard of quality management systems and owns to certificates of TSE-ISO EN 9000 quality secure systems and TSE-ISO EN 14000 environment management systems.

Due to the fact that main raw material used in all cables, the company strongly focuses on supply of the Electrolytic Copper Cathode. The company considers eight criteriaduring purchasing of the Electrolytic Copper Cathode. These are origin, quality, availability, cost, delivery requirements, cost of conveyance, reliability of supplier and quality certificates. All of the criteria are detected by purchasing department which is consist of four personnel: purchasing manager and three purchasing specialist. There are four candidate suppliers for providing the Electrolytic Copper Cathode to the firm.

The Electrolytic Copper Cathode is analyzed by the Quality Control Laboratory. In this process, the quality laboratory gives points to the raw material based on convenience of the quality specifications determined by international institutions.Availability points are determined by the purchasing department according to the length of the supply process. The cost values are given as American dollar per 1000 kg. The cost of conveyance values are given as Turkish Lira per vehicle. The points of delivery requirement are identified by purchasing department according to the previous delivery times of suppliers. Reliability of suppliers points are defined with regard to fulfillments of commitments.

There are three important quality certificates for the firm in the supplier selection process. These are ISO 9000 Quality System Certificate, ISO 14001 Environmental Management System Certificate and OHSAS 18001 Occupational Health and Safety Certificate. The firm gives points to every supplier according to the weight determined by the purchasing department. As a result of the binary comparison made by purchasing specialist, weights were found 60, 30, 10respectively. However, the candidate supplier must have ISO 9000 Quality SystemCertificate beside other certificates. If the suppliers have more than one certificate, the total points is calculated by adding the weights. These values are determined as the input of TOPSIS method.

4. PROPOSED METHODOLOGY

The questionnaire conducted between the dates 1-7 March 2013 is answered by 4experts. Data were collected from the expertsin their offices.They are asked to compare the criteria at a given level on a pair-wise basis to identify their relative precedence. AHP is an effective decision making method especially when subjectivity exists and it is very suitable to solve problems where the decision criteria can be organized in a hierarchical way into sub-criteria. The findings of previous studies about factors influencing experts' choice of supplier were first identified by literature review. Experts expressed or defined a ranking for the attributes in terms of importance/weights. Each experts is asked to fill ''checked mark'' in the 9-point scale evaluation table. The AHP allows group decision making. One of the main advantages of the AHP method is the simple structure.

4.1. Using AHP to analyze priorities

AHP was developed in the 1970s by Thomas Saaty is a multi-criteria decision making (MCDM) methodology. It has been used extensively for analyzing complex decisions. The approach can be used to help decision-makers for prioritizing alternatives and determining the optimal alternative using pair-wise comparison judgments (Liberatore and, Nydick, 1997, p. 595;Yoo and Choi p. 137, 2006).Weighting the criteria by multiple experts avoids the bias decision making and provides impartiality (Dagdeviren, 2009).

The AHP is a selection process that consists of following steps (Saaty, 1990, 2008; Saaty and Vargas, 2001):

1. Define the problem and determine the criteria. Factors and related sub factors must be correlated

(Lee, 2012).

2. Structure the decision hierarchy taking into account the goal of the decision.

3. Construct a set of all judgments in a square comparison matrix in which the set of elements is compared with itself (size nxn) by using the fundamental scale of pair-wise comparison shown in

Table 1 assign the reciprocal value in the corresponding position in the matrix. Total number of comparison is n.(n-1)/2 (Lee, 2012).

Table 1: The fundamental scale of pair-wise comparison for AHP

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities have equal contribute to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another.
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong on demonstrated importance	An activity is favored very strongly over another
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically

4. Use overall or global priorities obtained from weighted values for weighting process. For synthesis of priorities obtain the principal right eigenvector and largest eigenvalue.

Matrix $A=(a_{ij})$ is said to be consistent if $a_{ij}.a_{jk}=a_{ik}$ and its principal eigenvalue (λ_{max}) is equal to n.

The general eigenvalue formulation is:

$$Aw = \begin{bmatrix} 1 & w_1/w_2 & . & w_1/w_n \\ w_2/w_1 & 1 & . & w_2/w_n \\ . & . & . & . \\ w_n/w_1 & w_n/w_2 & . & 1 \end{bmatrix} \begin{bmatrix} w_1 \\ . \\ . \\ w_n \end{bmatrix} = nw \quad (1)$$

$$a_{ij} = w_i / w_j, \qquad i, j = 1,2,....n \quad (2)$$

$$Aw = \lambda_{max} w \quad (3)$$

For measure consistency index (CI) adopt the value:

$$CI = (\lambda_{max} - n)/(n-1) . \quad (4)$$

Accept the estimate of w if the consistency ratio (CR) of CI that random matrix is significant small. If CR value is too high, then it means that experts' answers are not consistent (Lee, 2012;Saaty, 1980). Acceptable values of CR must be less than 0.1 (Saaty, 1990). The CR is obtained by comparing the CI with an average random consistency index (RI).

$$CR = \frac{CI}{RI} \quad (5)$$

The following gives the average RI:.

Table 2: Average RI values

n	1	2	3	4	5	6	7	8	9	10
Random Consistency Index(RI)	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1,49

Briefly, maximized eigenvalue, CI and CR are found to obtain the weights of each criteria (Lee, 2012). Experts are asked to compare the criteria on a pair-wise basis to determine their relative importance. AHP was used in order to determine which supplier selection attributes are important and precedence order of eight criteria, i.e., origin of raw material, quality, availability, cost, delivery requirements, cost of conveyance, quality certificates and reliability of the suppliers.

4.2. Using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to rank the alternatives

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was first presented by Yoon (1980) and Hwang and Yoon (1981), for solving multiple criteria decision making (MCDM) problems based upon the concept that the chosen alternative should have the shortest Euclidian distance from the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS). For instance, PIS maximizes the benefit and minimizes the cost, whereas the NIS maximizes the cost and minimizes the benefit. It assumes that each criterion require to be maximized or minimized. TOPSIS is a simple and useful technique for ranking a number of possible alternatives according to closeness to the ideal solution. Expanded developments of TOPSIS were done by Chen and Hwang in 1992, Lai, Liu and Hwang (1994). This MCDM technique is widely used in many fields, including financial performance evaluation, supplier selection, tourism destination evaluation, location selection, company evaluation, selecting the most suitable machine, ranking the carrier alternatives (Behzadian, 2012). One of the advantages of TOPSIS is that pair-wise comparisons are avoided. TOPSIS is conducted as follows (Tsaur, 2011).

Step 1.Establish a decision matrix for the ranking. TOPSIS uses all outcomes (x_{ij}) in a decision matrix to develop a compromise rank. The viable alternatives of the decision process are A_1, A_2, ..., A_n. The structure of the decision matrix denoted by $X = (x_{ij})_{n\times m}$ can be expressed as follows:

$$X = \begin{array}{c} \quad m \quad Criteria \\ \begin{array}{cccccc} C_1 & C_2 & \cdots & C_j & \cdots & C_m \end{array} \\ \left[\begin{array}{cccccc} x_{11} & x_{12} & \cdots & x_{1j} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2j} & \cdots & x_{2m} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ x_{i1} & x_{i2} & \cdots & x_{ij} & \cdots & x_{im} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \\ x_{n1} & x_{n2} & \cdots & x_{nj} & \cdots & x_{nm} \end{array}\right] \end{array} \left.\begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_n \end{array}\right\} n \quad Alternatives \tag{6}$$

x_{ij} is the outcome of i[th] alternative with respect to j[th] criteria. $W = (w_1, w_2, \ldots, w_j, \ldots, w_m)$ is the relative weight vector about the criteria, and w_j represents the weight of the j[th] attribute and $\sum_{j=1}^{m} w_j = 1$.

Step 2.Normalize the decision matrix using the following equation:

$$r_{ij} = \frac{w_{ij}}{\sqrt{\sum_{k=1}^{n} w_{ij}^2}} \text{ i=1,2,3,…,n j=1,2,3,…,m} \tag{7}$$

Step 3.Weighted normalized decision matrix is calculated by multiplying the normalized decision matrix by its associated weights as:

$$v_{ij} = w_j r_{ij} \text{ i=1,2,3,…,n j=1,2,3,…,m} \tag{8}$$

Step 4.Identify the positive ideal solution (PIS) and negative ideal solution (NIS), respectively, as follows:

$$PIS = A^* = \left\{v_1^*, v_2^*, \ldots, v_m^*\right\} = \left\{\left(\max_i v_{ij} \mid j \in \Omega_b\right), \left(\min_i v_{ij} \mid j \in \Omega_c\right)\right\} \tag{9}$$

$$NIS = A^- = \left\{v_1^-, v_2^-, \ldots, v_m^-\right\} = \left\{\left(\min_i v_{ij} \mid j \in \Omega_b\right), \left(\max_i v_{ij} \mid j \in \Omega_c\right)\right\} \tag{10}$$

Ω_b is associated with benefit criteria, and Ω_c is associated with cost criteria.

Step 5.Determine the Euclidean distance (separation measures) of each alternatives from the ideal and negative-ideal solution as below respectively:

$$d_i^* = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^*\right)^2} \text{ , i=1,2,3,...,n} \tag{11}$$

$$d_i^- = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^-\right)^2} \text{ , i=1,2,3,...,n} \tag{12}$$

Step 6. Calculate the relative closeness of the i[th] alternative to ideal solution using the following equation:

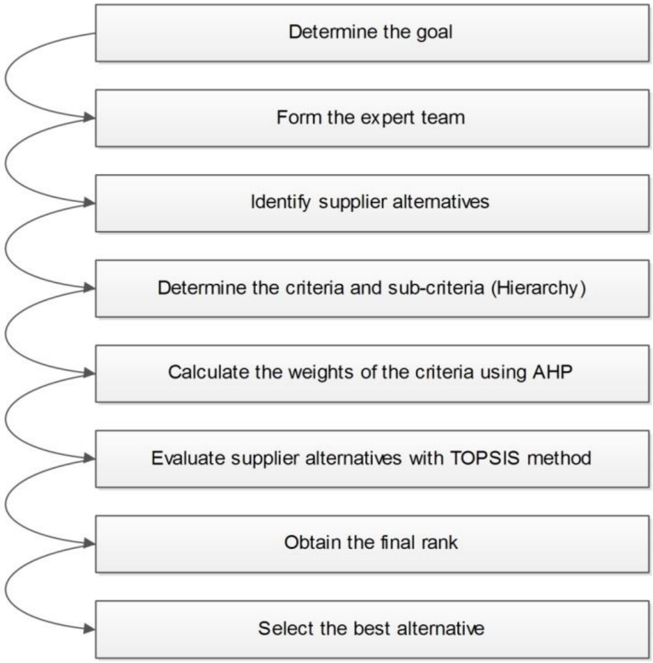
$$RC_i = \frac{d_i^-}{d_i^* + d_i^-} \quad , \quad \text{i=1,2,3,...,n} \tag{13}$$

$$RC_i \in [0,1]$$

Step 7.By comparing RC_i values, the ranking of alternatives are determined. The higher the closeness means the better the rank. Ranked the alternatives starting from the value that closest to 1 and in decreasing order.

4.3. Combining AHP and TOPSIS to determine the rank of alternatives

Figure 2: Steps of proposed method



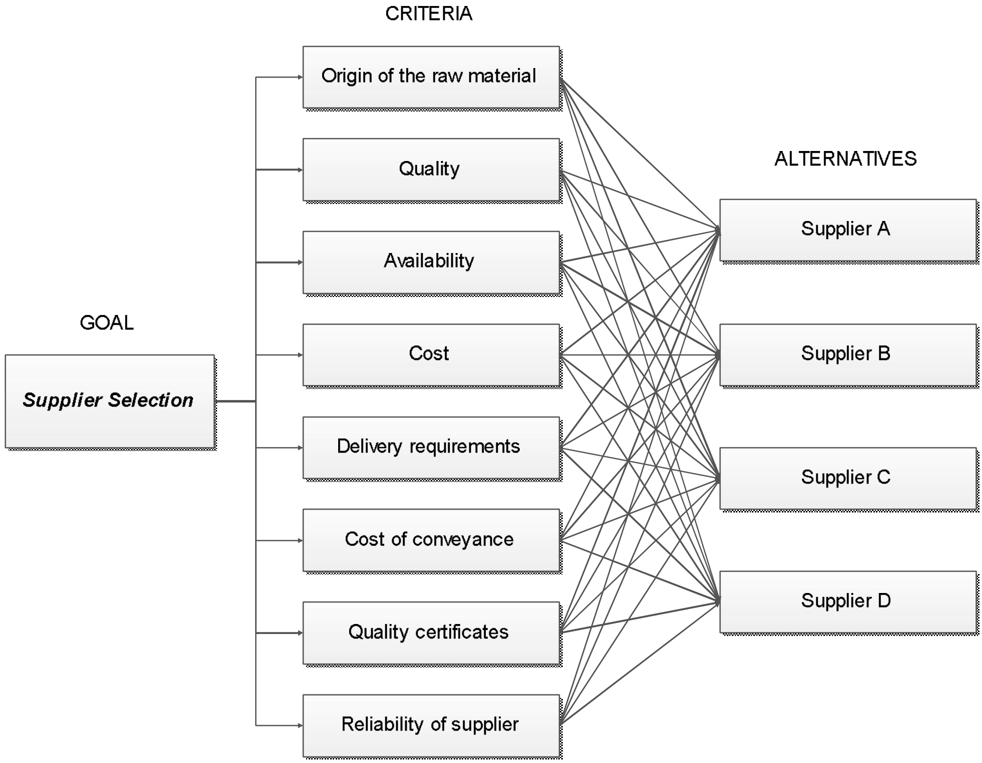
In analyzing the data, Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methodologies are used for the outranking of supplier alternatives. Fig. 2 shows the steps of the proposed method.

5. SOLVING ILLUSTRATIVE PROBLEM

To apply proposed method a real world supplier selection problem was solved. In this supplier selection problem there are 8 criteria and 4 alternatives. The hierarchical structure to select the best supplier is shown in Fig 3.The firm prefers the Electrolytic Copper Cathode originating from America, Europe and Asia. An interview was performed with the purchasing department in order to identify weight coefficients regarding origin of the Electrolytic Copper Cathode. As a result of the binary comparison made by specialist, weights were found as follows: America (0.249), Europe (0.087) and Asia (0.039). These values are determined as the input of TOPSIS method.

Criteria to be considered in the selection of supplier are determined by literature review and experts in the cable firm. Past experience and the back-ground of the experts are utilized in the determination of the criteria and 8 important criteria to be used for supplier selection are established. These 8 criteria are as follows: Origin of Raw Material (C1), Quality (C2), Availability (C3), Cost (C4), Delivery Requirements (C5), Cost of Conveyance (C6), Quality Certificates (C7)and Reliability of Supplier (C8).

Figure 3: Hierarchical Structure for Supplier Selection



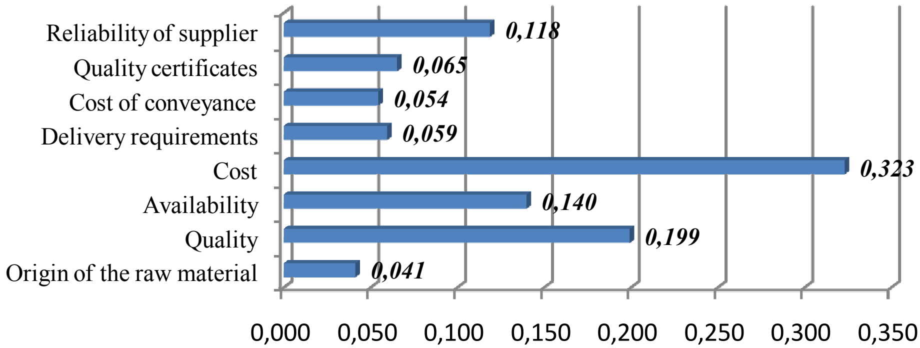
As a result, only these 8 criteria were used in evaluation and decision hierarchy is established accordingly. Decision hierarchy structured with the determined alternative supplier and criteria is provided in Fig. 3.There are three levels in the decision hierarchy structured for supplier selection problem. The overall goal of the decision process is ‘‘the selection of the optimal supplier” in the first level of the hierarchy. The criteria are on the second level and alternative suppliers are on the third level of the hierarchy.After forming the decision hierarchy for the problem, the weights of the criteria to be used in evaluation process are calculated by using AHP method. In this phase, the experts in the expert team are given the task of forming individual pairwise comparison matrix by using the Saaty’s 1-9 scale.

Table 3: The pairwise comparison matrix for criteria

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1,00	0,27	0,22	0,13	0,56	0,71	0,67	0,45
C2	3,71	1,00	1,39	0,58	3,36	3,31	4,36	2,00
C3	4,56	0,72	1,00	0,45	1,73	2,21	2,82	1,00
C4	7,97	1,73	2,24	1,00	5,03	5,89	5,14	3,13
C5	1,78	0,30	0,58	0,20	1,00	1,15	0,51	0,40
C6	1,41	0,30	0,45	0,17	0,87	1,00	0,80	0,40
C7	1,50	0,23	0,35	0,19	1,97	1,26	1,00	0,51
C8	2,21	0,50	1,00	0,32	2,51	2,51	1,97	1,00

Geometric means of experts' choice values are calculated to form the pairwise comparison matrix on which there is aagreement (Table 4). The results obtained from the calculations based on the pairwise comparison matrix provided in Table 3, are presented in Table 4.

Figure 4: Resulting weights of criteria obtained with AHP



The C4 (cost), C2 (quality) and C3 (availability) are determined as the three most important criteria in the supplier selection process by AHP. Consistency ratios of the experts' pairwise comparison matrixes are calculated as 0.074 (expert 1), 0.077 (expert2), 0.096 (expert 3) and 0.083 (expert 4). They all are less than 0.1. So the weights are shown to be consistent and they are used in the selection process. The most important criterion is "cost" (0.323) and the least important criterion is "origin of the raw material" (0.041).

Table 4: Results obtained by AHP

	Expert 1	Expert 2	Expert 3	Expert 4	Geometric Mean
Criteria	**Weights (w)**	**Weights (w)**	**Weights (w)**	**Weights (w)**	**Weights (w)**
Origin of the raw material	0.054	0.037	0.025	0.052	***0.041***
Quality	0.121	0.254	0.302	0.122	***0.199***
Availability	0.168	0.114	0.071	0.242	***0.140***
Cost	0.372	0.234	0.284	0.302	***0.323***
Delivery requirements	0.029	0.081	0.089	0.047	***0.059***
Cost of conveyance	0.105	0.079	0.020	0.052	***0.054***
Quality certificates	0.045	0.049	0.107	0.076	***0.065***
Reliability of supplier	0.105	0.152	0.101	0.106	***0.118***
λ_{max}	8.726	8.762	8.949	8.817	8.142
CI	0.104	0.109	0.136	0.117	0.020
RI	1.410	1.410	1.410	1.410	1.410
CR <0,1	***0.074***	***0.077***	***0.096***	***0.083***	

Finally, TOPSIS method is applied to rank the alternative suppliers. The priority weights of alternative suppliers with respect to criteria, calculated by AHP and shown in Table 4, can be used as input ofTOPSIS (Table 5). The weighted normalized decision matrixcan be seen from Table 6.

Table 5: Input values of the TOPSIS analysis

Weight	***0,041***	***0,199***	***0,140***	***0,323***	***0,059***	***0,054***	***0,065***	***0,118***
	Origin of the raw material	Quality	Availability	Cost	Delivery requirements	Cost of conveyance	Quality certificates	Reliability of supplier
Supplier A	0,249	40	80	7450	85	500	90	90
Supplier B	0,249	25	60	7400	75	430	100	60
Supplier C	0,039	15	70	7550	80	400	90	85
Supplier D	0,087	10	80	7430	90	400	60	100

Table 6: Weighted evaluation for the supplier selection

	Origin of the raw material	Quality	Availability	Cost	Delivery requirements	Cost of conveyance	Quality certificates	Reliability of supplier
Supplier A	0.028	0.158	0.077	0.161	0.030	0.031	0.034	0.063
Supplier B	0.028	0.099	0.057	0.160	0.027	0.027	0.038	0.042
Supplier C	0.004	0.059	0.067	0.163	0.029	0.025	0.034	0.059
Supplier D	0.010	0.039	0.077	0.161	0.032	0.025	0.023	0.070
	+	+	+	-	+	-	+	+
A^*	0.028	0.158	0.077	0.160	0.032	0.025	0.038	0.070
A^-	0.004	0.039	0.057	0.163	0.027	0.031	0.023	0.042

By using TOPSIS method, the ranking of alternative suppliers are calculated. Table 7 shows the evaluation results and final ranking of alternative suppliers.

Table 7: TOPSIS results

Alternatives	d_i^*	d_i^-	RC_i
Supplier A	0.010	0.124	0.924
Supplier B	0.068	0.066	0.490
Supplier C	0.103	0.031	0.231
Supplier D	0.121	0.035	0.226

Depends on theRCj values, the ranking of the alternatives from top to bottom order are supplier A, supplier B, supplier C and supplier D. Proposed model results show that supplier A is the best alternative with RC value of 0.924.

Table 8: Weighted and unweighted rankings

Rank	Weighted RC_i	Weighted Ranking	UnweightedRC_i	Unweighted Ranking
1	0.924	Supplier A	0.858	Supplier A
2	0.490	Supplier B	0.626	Supplier B
3	0.231	Supplier C	0.302	Supplier D
4	0.226	Supplier D	0.269	Supplier C

6. CONCLUSION

Supplier selection decision becomes more important strategic decision in complex and competitive business life. Choosing the suitable supplier involves the evaluation of subjective and objective factors;the decision criteria in Cable Company case are origin of raw material, quality, availability, cost, delivery requirements, and cost of conveyance, quality certificates and reliability of the suppliers. The results show that cost, quality and availability are most important criteria for the company to evaluate suppliers.Supplier A has the highest priority weight.Another important finding is that the proposed model is more reflecting the relation of how the selection criteria affect the selected suppliers and at the same time what is more important for the suppliers among the selection criteria.Using multi criteria decision techniques such as AHP and TOPSIS methods provides a useful approach for Cable Company for selecting the best supplier.This supplier evaluation framework will give direction and help the cable company in establishing a process for supplier selection. Main purpose of this paper is to combine AHP and TOPSIS methods to select suitable supplier for the Cable Company from available alternative suppliers. The weights of criteria (input of TOPSIS) are important. It is shown that final TOPSIS ranking can by criteria weights.

Supplier selection for a Cable Company involves multiple criteria decision making. The TOPSIS is a successful MCDM method for ranking the alternatives. AHP-TOPSIS framework was proposed for evaluating and ranking of supplier alternatives. In next studies analytic network process (ANP) may be used to structure network and identifydependence among criteria. The proposed methodology can also be applied to any other selection problem involving multiple and conflicting criteria. Selection of the suppliers can also be done using other MCDM techniques including MOORA, PROMETHEE, VIKOR etc. for comparing the results.

REFERENCES

Barbarosoglu, G., and Yazgac, T. (1997), An application of the analytic hierarchy process to the supplier selection proble, Production and Inventory Management Journal, 38(1), 14–21.

Bayazit, O., (2006), Use of analytic network process in vendor selection decisions, Benchmarking: An International Journal 13 (5), 566–579.

Benton, W.C., 1991, Quantity discount decisions under conditions of multiple items, multiple suppliers and resource limitations, International Journal of Production Research 29 (10), 1953-1961.

Behzadian, M., Otaghsara, S.K., Yazdani, M., Ignatius, J., 2012.A state-of the-art survey of TOPSIS applications. Expert Systems with Applications 39 (2012) 13051–13069

BhutiaP.W., and Phipon R. (2012), Application of AHP and TOPSIS method for supplier selection problem, IOSR Journal of Engineering 2(10), 43-50.

Chan, F.T.S.,(2003), Interactive selection model for supplier selection process: An analytical hierarchy process approach, International Journal Production Research 41 (15), 3549–3579.

Chan, F.T.S., and Kumar, N., (2007), Global supplier development considering risk factors using fuzzy extended AHP-based approach,OMEGA – International Journal of Management Science 35 (4), 417–431.

Chan, F.T.S., Chan, H.K., Ip, R.W.L., Lau, H.C.W., (2007), A decision support system for supplier selection in the airline industry, Proceedings of the Institution of Mechanical Engineers Part B – Journal of Engineering Manufacture 221 (4), 741–758.

Chen, S. J.,and Hwang, C. L. (1992). Fuzzy multiple attribute decision making: Methods and applications. Berlin: Springer- Verlag

Dagdeviren, M., Yavuz, S., Kilinc, N., 2009. Weapon selection using the AHP and TOPSIS methods under fuzzy environment, Expert Systems with Applications, 36, 8143-8151

Demirtas, E.A., andÜstün, Ö., (2008), An integrated multi-objective decision making process for supplier selection and order allocation, OMEGA – International Journal of Management Science 36 (1), 76–90.

Dickson, G. W. (1966), An analysis of supplier selection system and decision, Journal of Purchasing, 2(1), 5–17.

Ding, H., Benyoucef, L., Xie, X., (2005), A simulation optimization methodology for supplier selection problem, International Journal Computer Integrated Manufacturing, 18 (2–3), 210–224.

Ellram, L. M. (1990), The supplier selection decision in strategic partnerships. Journal of Purchasing and Materials Management, 26(4), 8–14.

Fazlollahtabar, H., Mahdavi, I., TalebiAshoori, M., Kaviani, S., Mahdavi-Amiri, N. (2011), A multi-objective decision-making process of supplier selection and order allocation for multi-period scheduling in an electronic market, International Journal of Advanced Manufacturing Technology, 52, 1039–1052.

Garfamy, R.M., (2006), A data envelopment analysis approach based on total cost of ownership for supplier selection, Journal of Enterprise Information Management, 19 (6), 662–678.

Gencer, C., and Gürpinar, D., (2007), Analytic network process in supplier selection: A case study in an electronic firm, Applied Mathematical Modeling, 31 (11), 2475–2486.

GUANG Y., WEN-JIE H., LIN-LI L., (2010), USING AHP AND TOPSIS APPROACHES IN NUCLEAR POWER PLANT EQUIPMENT SUPPLIER SELECTION, VOL.410-420, PP.761-764.

Hou, J., and Su, D., (2007), EJB–MVC oriented supplier selection system for mass customization, Journal of Manufacturing Technology Management, 18 (1), 54–71.

Hwang, C.L., and Yoon, K. (1981). Multiple attribute decision making: Method and application. New York: Spring-verlag.

Jadidi, O., Firouzi, F., Bagliery, E., (2010),TOPSIS Method for Supplier Selection Problem, World Academy of Science, Engineering and Technology 47, 956-958

Kahraman, C., Cebeci, U., Ulukan, Z., (2003), Multi-criteria supplier selection using fuzzy AHP, Logistics Information Management, 16 (6), 382–394.

Lai, Y.J., Liu, T.Y., Hwang, C.L. (1994). TOPSIS for MODM. European Journal of Operational Research, 76, 486-500

Lau, H.C.W., Lee, C.K.M., Ho, G.T.S., Pun, K.F., Choy, K.L., (2006), A performance benchmarking system to support supplier selection. International Journal of Business Performance Managemen,t 8 (2–3), 132–151.

Lee, C. C., and Ou-Yang, C. (2009), A neural networks approach for forecasting the supplier's bid prices in supplier selection negotiation process, Expert Systems With Applications, 36(2), p. 2961-2970.

Lee, S., Kim, W., Kim, Y.M., Oh, K.J., 2012.Using AHP to determine intangible priority factors for technology transfer adoption. Expert Systems with Applications, 39, 6388-6395.

Liao, Z., and Rittscher, J., (2007), A multi-objective supplier selection model under stochastic demand conditions, International Journal of Production Economics, 105 (1), 150–159.

Liberatore, M.J., and Nydick, R.L., (1997). Group Decision Making In Higher Education Using The Analytic Hierarchy Process, Research In Higher Education, Vol. 38, No. 5

Liu, F.H.F., and Hai, H.L., (2005), The voting analytic hierarchy process method for selecting supplier, International Journal of Production Economics 97 (3), 308–317.

Mazurak, R. E., Rao, S. R., Scotton, D. W. (1985), Spreadsheet software application in purchasing. Journal of Purchasing and Materials Management, 21, 8–16.

Ng, W.L., (2008), An efficient and simple model for multiple criteria supplier selection problem, European Journal of Operational Research, 186 (3), 1059–1067.

Ramanathan, R., (2007), Supplier selection problem: Integrating DEA with the approaches of total cost of ownership and AHP, Supply Chain Management: An International Journal, 12 (4), 258–261.

Saaty, T.L.,1980. The analytic hierarchy process. New York: McGraw-Hill.

Saaty, T.L., (1990). How To Make Decision: The Analytic Hierarchy Process, European Journal of Operational Research,North_Holland, 48, 9-26.

Saaty, T. L., and Vargas Luis L., (2001). Models, Methods, Conceptsand Applications of The Analytic Hierarchy Process. International Series in Operations Research and Management Science, Kluwer Academic Publishers.

Saaty, T. L.,(2008). Decision Making With The Analytic Hierarchy Process. Int. J. Services Sciences, 1 (1), 83.

Sarkis, J., Talluri, S., 2002. A model for strategic supplier selection. Journal of Supply Chain Management 38 (1), 18–28.

Sevkli, M., Koh, S.C.L., Zaim, S., Demirbag, M., Tatoglu, E., (2007), An application of data envelopment analytic hierarchy process for supplier selection: A case of BEKO in Turkey, International Journal of Production Research, 45 (9),1973–2003.

Shahroudi, K., Rouydel H., Assimi, S., Eyvazi, H., R. (2011), Supplier selection and order allocation a main factor in supply chain, 3rd International Conference on Advanced Management Science, IACSIT Press, Singapore.

Shahroudi, K. and Rouydel, H. (2012), Using a multi-criteria decision making approach (ANP-TOPSIS) to evaluate suppliers in Iran's auto industry, International Journal of Applied Operational Research, 2(2), 37-48.

Talluri, S., and Sarkis, J., (2002), A model for performance monitoring of suppliers, International Journal of Production Research, 40 (16), 4257–4269.

Talluri, S., and Narasimhan, R., (2003),Vendor evaluation with performance variability: A max–min approach, European Journal of Operational Research 146 (3), 543–552.

Tsaur, R.C., 2011. Decision risk analysis for an interval TOPSIS method. Applied Mathematics and Computation 218 (2011) 4295–4304

Weber, C. A., Current, J. R., Benton, W. C. (1991), Vendor selection criteria and methods, European Journal of Operational Research, 50(1), 2–18.

Wei, S., Zhang, J., Li, Z. (1997), A Supplier Selecting System Using A Neural Network, IEEE International Conference on Intelligent Processing Systems, pp. 468-471, ISBN: 0- 7803-4253-4, Beijing China, October 28-31.

Wu, T., Shunk, D., Blackhurst, J., Appalla, R., (2007), AIDEA: A methodology for supplier evaluation and selection in a supplier-based manufacturing International Journal of Manufacturing Technology and Management, 11 (2), 174–192.

Xu X., and Lin J. (2010), Strategic Supplier Network for Supplier Selection, Journal of Computers, 5(6), 975-986.

Yahya, S. and B. Kingsman (1999), Vendor rating for an entrepreneur development programme: a case study using the analytic hierarchy process method, Journal of the Operational Research Society, 50, 916-930.

Vimal J., Chaturverdi V., DubeyA.K, (2012),Application of topsis method for supplier selection in manufacturing industry, IJREAS, 2(5), 25-35.

Yang, G., Jie, H.,W.,Lei, Li, L. (2.010), Using AHP and TOPSIS Approaches in Nuclear Power Plant Equipment Supplier Selection, Key engineering Materials, Vols. 414-420

Yoo, K.E.,and Choi, Y.C.,(2006). Analytic Hierarchy Process Approach For Identifying Relative Importance Of Factors To Improve Passenger Security Checks At Airports, Journal of Air Transport Management 12, 135–142

Yoon, K. (1980). Systems selection by multiple attributes decision making . PhD Dissertation, Kansas State University, Manhattan, Kansas