USE OF FUZZY TOPSIS MODEL FOR EVALUATING COOLING TOWERS

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ABSTRACT:

Present paper applies **F**uzzy **TOPSIS M**odel for identification of indicators regarding to cooling towers and assigning weight to indicators and prioritizing **C**ooling **T**owers distributed questionnaires among 37 expert and specialist in **B**esat **E**lectricity **P**roduction **C**ompany in Tehran – Iran.

The current research concluded to this result that in most of the existing studies on decision making issue , the issue is supposed in an environment of definitive data but in some cases it seen that determination of exact values for the criteria is difficult and the value should be considered as Fuzzy Values.

KEY WORDS:

Fuzzy **TOPSIS** (**T**echnique for **O**rder **P**reference by **S**imilarity to **I**deal **S**ituation) **M**odel, **C**ooling **T**ower, **T**echnology **S**election, **D**ecision **M**aking.

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INTRODUCTION

Technology selection is concerned with choosing the best technology from a number of available options. The criteria for a 'best' technology may differ depending on the specific requirements of a company. (Shehabuddeen et al, 2006) technology selection process as 'identification and selection of new or additional technologies which the firm seeks to master'.(Garegory,1995) technology selection involves 'gathering information from various sources about the alternatives, and the evaluation of alternatives against each other or some set of criteria'.(Lamb and Gregory,1997) Technology selection and justification involve decision makings that are critical to the profitability and growth of a company in the increasing competitive global scenario.(Chan et al, 2000) One of the technologies regarding the industry is cooling tower which has many applications in industries. Role of cooling towers for chemicals producing units is like role of radiator in an automobile. As cutting off flow of cooling water in automobile and radiator break down causes irreparable damages to engine and other parts of automobile, in industry too, cutting off cooling water even for a short time involves huge damages as consequence so that operators in case of cooling water cut-off for any reason often consider it a saving action to put the system out of service in spite heavy costs of production halt. This strong dependence of production on cooling towers function indicates their special economic importance. On the other side, limitation of water sources and necessity of their use make the towers' economic role more obvious and on the other side, incorrect selection of this technology may in addition to loss of water sources, bring irremediable damages to the country's industry. Hence, selection of this technology is of very high importance. This paper, using Fuzzy TOPSIS Model tries to evaluate and prioritize cooling towers.

LITERATURE REVIEW

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Some mathematical programming approaches have been used for technology selection in the past. Hsu et al. (2010) provided a systematic approach towards the technology selection in which two phase procedures were proposed. The first stage utilized fuzzy Delphi method to obtain two the critical factors of the regenerative technologies by interviewing the experts. In the second stage, fuzzy AHP was applied to find the importance degree of each criterion as the measurable indices of the regenerative technologies. They considered eight kinds of regenerative technologies which have already been widely used, and established a ranking model that provides decision markers to assessing the prior order of regenerative technologies. To select the best technologies in the existence of both cardinal and ordinal data Faerzipoor Saen(2006) proposed an innovative approach, which is based on Imprecise date envelopment analysis (IDEA). Lee and Hwang (2010) proposed to use AHP as a tool for prioritizing the strategically promising nuclear technologies for commercial export from Korea. Jaganathan et al (2007) proposed an integrated Fuzzy AHP based approach to facilitate the selection and evaluation of new manufacturing technologies in the presence of intangible attributes and uncertainty. However, AHP as two main weaknesses First subjectivity of AHP is a weakness. Second AHP could not include interrelationship within the criteria in the model this paper, using Fuzzy TOPSIS Model tries to evaluate and prioritize cooling towers.

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FUZZY TOPSIS METHOD

The TOPSIS is widely used for tackling ranking problems in real situations. This method is often criticized for its inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of the decision-makers perception to crisp values. In the traditional formulation of the TOPSIS, personal judgments are represented with crisp values. However, in many practical cases the human preference model is uncertain and decision makers might be reluctant or unable to assign crisp values to the comparison judgments (Chan & Kumar, 2007; Shyur & Shih, 2006). Having to use crisp values is one of the problematic points in the crisp evaluation process. One reason is that decision-makers usually feel more confident to give interval judgments rather than expressing their judgments in the form of single numeric values. As some criteria are difficult to measure by crisp values, they are usually neglected during the evaluation. Another reason is mathematical models that are

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based on crisp value. These methods cannot deal with decision-makers' ambiguities, uncertainties and vagueness which cannot be handled by crisp values. The use of Fuzzy set theory (Zadeh, 1965) allows the decision-makers to incorporate unquantifiable information, incomplete information; non-obtainable information and partially ignorant facts into decision model (Kulak, Durmusoglu, & Kahraman, 2005). As a result, Fuzzy TOPSIS and its extensions are developed to solve ranking and justification problems (Büyükzkan, Feyzioglu, & Nebol, 2008; Chen & Tsao, 2007; Kahraman, Büyükzkan, & Ates, 2007; Onüt & Soner, 2007; Wang & Elhag, 2006; Yong, 2006). This study uses triangular Fuzzy number for Fuzzy TOPSIS. The reason for using a triangular Fuzzy number is that it is intuitively easy for the decision-makers to use and calculate. In addition, modeling using triangular Fuzzy numbers has proven to be an effective way for formulating decision problems where the information available is subjective and imprecise (Chang, Chung, & Wang, 2007; Chang & Yeh, 2002; Kahraman, Beskese, & Ruan, 2004; Zimmerman, 1996). In practical applications, the triangular form of the membership function is used most often for representing Fuzzy numbers (Xu & Chen, 2007).

NEED FOR A TECHNOLOGY SELECTION METHOD

Technology based businesses rely on renewal of existing technological resources and exploitation of new technologies to remain competitive and to sustain growth (McNamara and Baden-Fuller, 1999). These firms engage in various technology management practices, and deploy technology strategies and planning in order to meet these needs. This is becoming more difficult due to increasing complexity of technologies, convergence of technologies, abundance of technological options, higher cost of technological development, and rapid diffusion of technologies (see Lei, 2000; Steensma and Fairbank, 1999; Berry and Taggart, 1994). The dispersion of technology sources across organizations, geographical locations and countries, and the resulting obscurity, makes the task of accessing suitable technologies and selection of the most suitable option more difficult (Cantwell, 1992). Greenberg and Cazoneri (1995) and Hackett and Gregory (1990), report that projects to incorporate new technology, in a majority of companies, are failing or are not fulfilling expectations. Nabseth and Ray (1974) in their study of the European and USA machine tool companies found that similar problems still remain although several investigations have been undertaken to study these

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issues. As Huang and Mak (1999) explain in their study of 100 British manufacturing companies, the failure of a chosen technology often results from poor management and preparation of the change process. Some of the causes have been attributed to the inability to consider the wider relationship of technology to the business and organizational context and include these issues in the technology investment considerations (Schroder and Sohal, 1999). This finding is echoed by Efstathiades et al. (2000) who assert the need for careful assessment of potential problems before introducing a technology into an organization.

RESEARCH PURPOSES

I. Identification of indicators regarding cooling towers
II. Assigning weight to indicators and prioritizing cooling towers

RESEARCH METHODOLOGY

This research in terms of purpose is of applied type and the research execution method is of descriptive and survey type. The research's statistical society includes two parts: the first part is for identification of cooling towers' indicators including experts and specialists of cooling towers of Besat Electricity Production Company. Given that the statistical society was a limited society, 32 specialists were selected and the questionnaire was distributed among them. The second part regards weight assignment and prioritization of cooling towers' various options in which 5 connoisseurs were questioned.

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DATA COLLECTING TOOL

In this paper, to collect information with regard to the research's theoretical bases and literature, index cards and tables have been used. To gather the data from the 3 used questionnaires (first questionnaire for identification of indices, the two other questionnaires for weight assignment to the indices and prioritization of cooling towers) the validity of which has been confirmed by professors and its stability using Cronbach Alpha was found to be 75% and hence confirmed.

DATA ANALYSIS METHOD

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After data collection for all the alternatives , given the determined indicators, it was found that this issue in the field of decision making with multi indices and from among various models existing in the area of decision making with multi-indices, TOPSIS method due to its advantages relative to other method has been selected for weight assignment and prioritization.

Step1: formation of Fuzzy Decision Making Matrix in which m alternatives by n indices are assessed. A Fuzzy multi-indicator decision making matrix is defined as follows.

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{matrix} C_1 & C_2 & \cdots & C_n \end{matrix} \\ \begin{bmatrix} \tilde{X}_{11} & \tilde{X}_{12} & \cdots & \tilde{X}_{1n} \\ \tilde{X}_{21} & \tilde{X}_{22} & \cdots & \tilde{X}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{X}_{m1} & \tilde{X}_{m2} & \cdots & \tilde{X}_{mn} \end{bmatrix} \end{array}, i = 1,2,...,m,\ j = 1,2,...,n \quad (1)$$

In which, $A_1, A_2,..., A_m$ represent alternatives, $C_1, C_2,..., C_n$ represent indices, and $\tilde{x}_{ij}$ denotes Fuzzy value of the option i in terms of the index j . Verbal variables and Fuzzy numbers equivalent to each verbal variable used in this study are presented in table (1).

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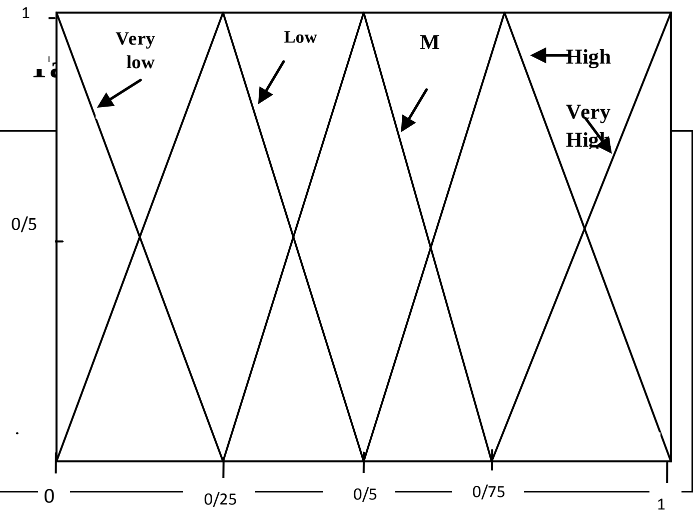
Social Capital	Verbal Variables	Fuzzy Numbers Equivalent
sc_1	Very low	(0 0 0/25)
sc_2	Low	(0 0/25



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		0/5)	
sc_3	Medium	(0/25 0/5 0/75)	
sc_4	High	(0/5 0/75 1)	
sc_5	Very High	(0/75 1 1)	

Step 2: Make normalize matrix decision making matrix as relation (2) which takes place by means of relations (3) and (4). Relation (3) is used for scale less making of indices with positive aspect and relation (4) for scale less making indices with negative aspect.

.

(2) $$\tilde{R} = [\tilde{r}_{ij}]_{m \times n}, i = 1,2,\ldots,m, \; j = 1,2,\ldots,n$$

(3) $$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+} \right), c_j^+ = \max c_{ij}$$

(4) $$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \right), a_j^- = \min a_{ij}$$

Step 3: calculation and make harmonic normalize matrix as relation (5) using relation (6).

(5) $$\tilde{V} = [\tilde{v}_{ij}]_{m \times n}, i = 1,2,\ldots,m, \; j = 1,2,\ldots n$$

(6) $$\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \tilde{w}_j$$

At this stage, we need to evaluate indices' weights. To calculate indices' weight in this research the suggested method by Wang and Chang (1995) has been used. For this purpose, five connoisseurs have been asked to determine indices' importance with verbal variables. To determine importance of the constituents and the respective weights, the respective verbal variables and Fuzzy numbers suggested by Wang and Chang (1995) have been used. Table 2

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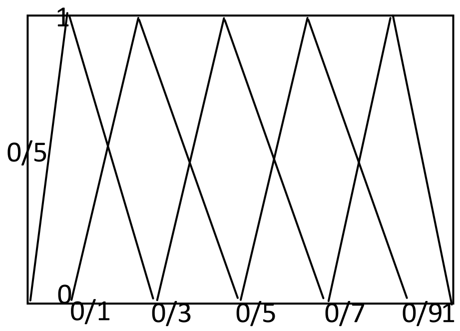
shows verbal variables and Fuzzy numbers. This method has been used by Wang and Chang (1995) and Chen (2000), Wang and Elhag (2007) to determine the indices' weights.

Table(2)

Verbal Variables	**Fuzzy Number**
Very low	(0 0/1 0/3)
Low	(0/1 0/3 0/5)
Medium	(0/3 0/5 0/7)
High	(0/5 0/7 0/9)
Very High	(0/7 0/9 1)



Source: (Wang & Chang, 1995, ; 2007,)

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Step 4: determining positive and negative ideal for each index using relations (7) and (8).

(7) $$\tilde{v}_j^{+} = \{(\max \tilde{v}_{ij} | j \in J) i = 1, \ldots, m\}$$

(8) $$\tilde{v}_j^{-} = \{(\min \tilde{v}_{ij} | j \in J) i = 1, \ldots, m\}$$

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$\tilde{V}_{ij}^{+}$ And $\tilde{V}_{ij}^{-}$ takes place in three stages and using the following relations. Obviously, if at both stages the greatest and smallest Fuzzy numbers are found, there will be no need for other stages.

Stage 4.1: at this stage, using relation (9) we rank Fuzzy numbers in order to find its greatest and smallest quantity.

(9) $$S(\tilde{A},0) = \frac{a+2b+c}{4}$$

Stage 4.2: if at stage one there are numbers which are placed in one group, or in other words, using relation (9) we cannot determine their smallness or greatness relative to each other, we take their tide into consideration and using Fuzzy numbers' tide we rank them.

(10) $$\mathrm{mod}\, e(\tilde{A})$$

Stage 4.3: at third stage, if there are still numbers which are placed in one group, for their ranking we consider Fuzzy numbers' Domain.

(11) $$(\tilde{A})$$

Stage 5: distance of each alternative is found through positive and negative ideal solution. This is done using relations (12) and (13).

(12) $$d_i^{+} = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^{+}), i = 1,2,\ldots,m. j = 1,2,\ldots,n$$

(13) $$d_i^{-} = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^{-}), i = 1,2,\ldots,m. j = 1,2,\ldots,n$$

In which $d(\tilde{v}_{ij}, \tilde{v}_{ij}^{\mp})$ by taking $\tilde{A}_1 = (a_1, b_1, c_1)$ and $\tilde{A}_2 = (a_2, b_2, c_2)$ into account as two triangular Fuzzy numbers it calculated as relation (14). .

(14) $$d(\tilde{A}_1, \tilde{A}_2) = \sqrt{\frac{1}{3}\left[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2\right]}$$

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Step 6: calculation of relative closeness of each alternative to ideal solution which is done using relation (15)

(15) $$cc_i = \frac{d_i^-}{d_i^+ + d_i^-}, i = 1,2,\ldots,m$$

Step 7: alternatives ranking; at which the existing alternatives from the hypothetic problem are ranked in ascending order starting from the most important.

RESULTS

The questionnaire which had been provided to the statistical society (32 persons) was analyzed and 8 indicators were selected for cooling towers evaluation. Next, 5 connoisseurs were asked to assign weight to the indices the results of which are presented in the table below:

Table1: Weights Indices

Indices	Weights indices
Volume & Girth (C1)	(0/16,0/34,0/54)
Strength (C2)	(0/26,0/46,0/66)
Water consumption(C3)	(0/46,0/66,0/84)
Services(C4)	(0/34,0/54,0/74)
Control Tower(C5)	(0/26,0/46,0/66)
Price tower(C6)	(0/46,0/66,0/84)
Water evaporation rate(C7)	(0/34,0/54,0/74)
Pond capacity(C8)	(0/18,0/38,0/58)

Given identification of the identified indices and weigh of each index, now using Fuzzy TOPSIS method which has been explained in data analysis method we prioritize the options. The following results indicate relative closeness of each option to the ideal solution.

Table2: Closeness of Alternative to the Ideal Solution

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Alternatives	Closeness of Alternative to Ideal Solution(cc)
Tower with mechanical tension(A1)	0/3187
Tower with normal tension(A2)	0/3681
Tower with a blower fan(A3)	0/6549
Tower with a suction fan(A4)	0/7245
Tower with normal tension(A5)	0/5499
Tower with a Traction stokehole(A6)	0/5012

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RANKING OF ALTERNATIVES

Table3: Ranking Based on the Preferred Alternatives

Rank	Relative Closeness to the Ideal Solution	Alternatives
1	0/7245	(A4)
2	0/6549	(A3)
3	0/5499	(A5)
4	0/5012	(A6)
5	0/3681	(A2)
6	0/3187	(A1)

Check rank the cooling tower can be seen Tower with a suction fan(A4) rated first and Tower with a blower fan(A3), Tower with normal tension(A5), Tower with a Traction

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stokehole(A6), Tower with normal tension(A2), Tower with mechanical tension(A1) were next to the stars.

CONCLUSION

In this paper, evaluation of level and prioritization of cooling towers technology based on the specified indices by experts using ranking method based on similarity with ideal answer Fuzzy TOPSIS was investigated. In most of the existing studies on decision making issue, the issue is supposed in an environment of definitive data but in some cases, it is seen that determination of exact values for the criteria is difficult and the values should be considered as Fuzzy values. In this paper, we have investigated the existing options in Fuzzy environment and based on the Theory of Fuzzy Sets and then based on TOPSIS method approach which is a simple method and quickly specifies the required answer, we calculated the closest option to the ideal solution.

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