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A STUDY OF SELECTING THE BEST COGENERATION SYSTEM BY FUZZY TOPSIS

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ABSTRACT
Cogeneration is a highly efficient process that transforms energy from one source into two energy products: electricity and heat. Cogeneration produces a given amount of electric power and process heat with 10% to 30% less fuel than it takes to produce the electricity and process heat separately. Because of important benefits it's started to gain importance in common applications such as pulp and paper, food manufacturing, petrochemicals, brewing, textiles in industrial sector such as hotels, hospitals, schools/universities, swimming complexes, large commercial developments, medium/high density residential in common commercial applications. Fuzzy set theory resembles human reasoning in its use of approximate information and uncertainty to generate decisions. Triangular fuzzy numbers are used to decide the priority of one decision variable over other. A TOPSIS solution is defined as the alternative which is simultaneously farthest from the negative-ideal and closest to the ideal alternative. In fuzzy TOPSIS, attribute values are represented by fuzzy numbers. The aim of this paper is to select the best cogeneration system in Çırağan Kempinski Hotel providing the most satisfaction. To improve the TOPSIS method and to facilitate to cogeneration system selection process, this paper discusses a fuzzy TOPSIS approach using triangular fuzzy numbers.
Keywords: *Cogeneration system, triangular fuzzy numbers, fuzzy TOPSIS.*

1. INTRODUCTION
Turkey located between Europe and Asia is geographically in the middle of the world, which means it is surrounded by the Middle East, Central Asia and Europe. Turkey's geographical location makes it a natural land bridge connecting Europe to Asia. This area is not only geographically, but also economically, very important. In other hands, Turkey has improved its economic situation in recent years, and this has caused more energy needs, which means more consumption. Multi-attribute decision making (MADM) refers to making decisions in the presence of multiple, usually conflicting, attributes. Multi-attribute decision-making (MADM) techniques have the advantage that they can assess a variety of options according to a variety of criteria that have different units [8]. By using four common methods of comparing alternative investments as criteria in a TOPSIS technique, Salehi (2009) [5] supported project selection decisions to obtain an aggregative assessment of criteria in their paper. Purpose of the study of Amiri et. al (2009) [4] was an investigation and explanation of effective factors on improving e-banking by using fuzzy TOPSIS in Parsian bank. Besides, in their study, Bazzazi et al.(2008)[6] introduced to select the suitable loading-haulage equipment in large open pit mines with combination of AHP, TOPSIS and fuzzy set theory techniques. In their article, Saghafian and Hejazi (2005)[2] proposed a modified Fuzzy Technique for Order Performance by Similarity to Ideal Solution (modified Fuzzy TOPSIS) for the Multi-criteria Decision Making (MCDM) problem when there was a group of decision makers. In the paper of Salehi and Moghaddam (2008)[5], by using a fuzzy TOPSIS technique they showed a new method for a project selection problem. In section

two, fuzzy TOPSIS methodology is mentioned. In Section three, fuzzy TOPSIS application is presented. We present an example for the model. This example is applied in Çırağan Kempinski Hotel in Istanbul in Turkey. Finally, concluding remarks are provided in Section four.

2. FUZZY TOPSIS METHODOLOGY

Fuzzy set theory introduced by Zadeh in 1965, represents uncertainty and vague data and characterized by a continuum of grades of membership, which assigns to each object a grade of membership ranging between 0 and 1. symbol, which placed below, represents a fuzzy set. A triangular fuzzy number (TFN) 'M' is shown in Fig. 1.

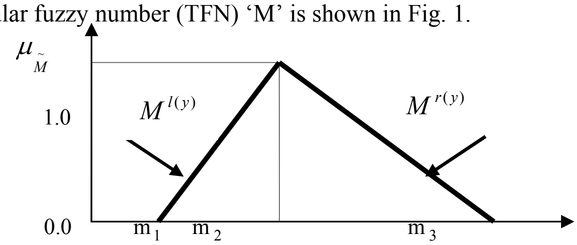

Figure 1. A triangular fuzzy number, M

Fuzzy set theory has been expanded and deepened a lot since its first appearance and has been applied in many areas [5].Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), one of the known classical MCDM methods, also was first developed by Hwang and Yoon (1981) [1]. It bases upon the concept that the chosen alternative should have the shortest distance from the Positive Ideal Solution (PIS), the solution that maximizes the benefit criteria and minimizes the cost criteria; and the farthest from the Negative Ideal Solution (NIS), the solution that maximizes the cost criteria and minimizes the benefit criteria. In classical MCMD methods, including classical TOPSIS, the ratings and the weights of the criteria are known precisely [2]. Considering the fuzziness in the decision data and group decision making process, linguistic variables are used to assess the weights of all criteria and the ratings of each alternative with respect to each criterion. It is often difficult for a decision-maker to assign a precise performance rating to an alternative for the attributes under consideration. The merit of using a fuzzy approach is to assign the relative importance of attributes using fuzzy numbers instead of precise numbers. The fuzzy TOPSIS procedure is then defined as follows:

Step 1: Choose the linguistic ratings $(\tilde{x}_{ij}, i = 1,2,..,m, j = 1,2,..,n)$ for alternatives with respect to criteria and the appropriate linguistic variables $(\tilde{w}_j, j = 1,2,...,n)$ for the weight of the criteria.

Step 2: Construct the weighted normalized fuzzy decision matrix. The weighted normalized value $\tilde{v}$ is calculated.

Step 3: Identify positive ideal (A^*) and negative ideal (A^-) solutions.

$A^* = (x_1^*,...........,x_j^*,...........,x_n^*)$ (1) $\qquad$ $A^- = (x_1^-,...........,x_j^-,...........,x_n^-)$ (2)

Step 4: Calculate separation measures. The distance of each alternative from (A^*) and (A^-) have to be calculated.

$d_i^* = \sum_{j=1}^{n} d(v_{ij}, v_j^*)$, j=1,2,…..,m (3) $\qquad$ $d_i^- = \sum_{j=1}^{n} d(v_{ij}, v_j^-)$, j=1,2,…..,m (4)

Step 5: Calculate similarities to ideal solution.

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \quad , \quad i=1,2,\ldots,m \qquad (5)$$

3. FUZZY TOPSIS APPROACH APPLICATION

One of the most prominent hotels (*Çırağan Kempinski Hotel*) in İstanbul in Turkey wants to select the most appropriate cogeneration system to meet of hotel' s energy and heat needs. These are cogeneration system with diesel motor (CDM), cogeneration system with gas turbine (CGT) and cogeneration system with steam turbine (CST). In this application sample, the goal is to select the best cogeneration system among the alternatives and for this goal multi attribute comparison using fuzzy TOPSIS of three cogeneration systems used. During the evaluation, five main criteria has been selected. Finally, the best cogeneration system among three alternative systems has been investigated. The hierarchy of the selection of best cogeneration system can be seen from Fig 2. The criterion are; Cost (C) = C1, Productivity (P) = C2, Environment (E) = C3, Transportation (T) = C4, Reliability (R) = C5

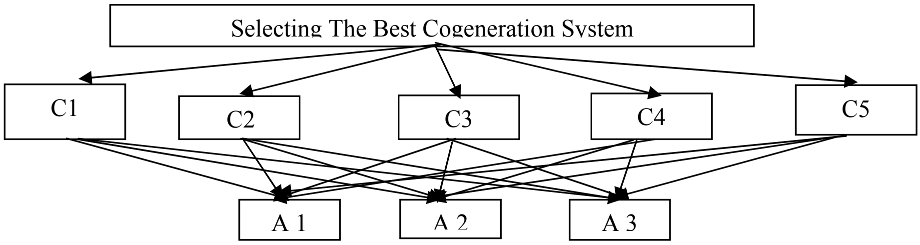

Figure 2. Hierarchy for the best cogeneration selection

The decision makers use the linguistic weighting variables to assess the importance of the criteria. They use the linguistic rating variables (shown in Table 2) to evaluate the rating of alternatives with respect to each criterion. The linguistic evaluations (shown in Tables 3 and 4) are converted into symmetric triangular fuzzy numbers in order to construct the fuzzy decision matrix. The (normalized) fuzzy decision matrix and the weighted normalized fuzzy decision matrix is constructed.

Table 1. Linguistic Variables for the Importance Weight of Each Criterion

(VL)	Very low	0,0	0.0	0.1
(L)	Low	0.0	0.1	0.3
(ML)	Medium low	0.1	0.3	0.5
(M)	Medium	0.3	0.5	0.7
(MH)	Medium high	0.5	0.7	0.9
(H)	High	0.7	0.9	1,0
(VH)	Very high	0.9	1.0	1,0

Table 2. Linguistic Variables For The Ratings

(VP)	Very poor	0	0	1
(P)	Poor	0	1	3
(MP)	Medium poor	1	3	5
(F)	Fair	3	5	7
(MG)	Medium good	5	7	9
(G)	Good	7	9	10
(VG)	Very good	9	10	10

Table 3. The Importance Weight of Each Criterion Given by Decision Makers for the Numerical Example

Criterion	Decision Maker 1	Decision Maker 2	Decision Maker 3	Decision Maker 4	Decision Maker 5
C1	H	VH	H	H	H
C2	VH	H	H	VH	H
C3	MH	H	M	M	M
C4	H	M	ML	M	M
C5	MH	H	MH	H	H

Table 4. Linguistic Variables for the Ratings Given by Decision Makers for the Numerical Example

Criterion	Alternatives	Decision Makers				
		DM1	DM2	DM3	DM4	DM5
C1	A1	G	MG	G	VG	VG
	A2	G	VG	VG	VG	VG
	A3	G	G	VG	G	VG
C2	A1	G	G	VG	MG	G
	A2	VG	G	VG	VG	VG
	A3	VG	G	G	VG	G
C3	A1	MG	F	MG	G	MG
	A2	VG	VG	VG	VG	VG
	A3	G	G	G	G	MG

C4	A1	MP	MG	MG	F	MG
	A2	VG	G	VG	VG	VG
	A3	F	F	MG	MG	MG
C5	A1	G	G	G	MG	G
	A2	G	G	VG	VG	VG
	A3	G	G	G	G	VG

Table 5. The Fuzzy Mean Numbers of the Alternatives

	C1	C2	C3	C4	C5
A1	7.4, 9, 9.8	7, 8.8, 9.8	5, 7, 8.8	3.8, 5.8, 7.8	6.6, 8.6, 9.8
A2	8.6, 9.8, 10	8.6, 9.8, 10	9, 10, 10	8.6, 9.8, 10	8.2, 9.6, 10
A3	7.8, 9.4, 10	7.8, 9.4, 10	6.6, 8.6, 10	4.2, 6.2, 8.2	7.4, 9.2, 10

Finally The closeness coefficient is calculated for each candidate. The results are:

Table 6. d_i^* and d_i^- values of the Alternatives.

Alternatives	d_i^*	d_i^-	CC_i
A1	2.14	2.25	0.54
A2	2.68	3.21	0.51
A3	2.47	2.19	0.47

According to the these closeness coefficients, the ranking order of the three candidates will be A2, A3 and A1, respectively. Obviously, the best selection is candidate A2 having a greater closeness coefficient.

4. CONCLUSION

Turkish economy is currently among the fastest growing economies in the OECD and this has caused more energy needs, which means more consumption. In this paper a fuzzy TOPSIS approach has been presented to select the most appropriate cogeneration system for one of the biggest hotel in Istanbul. Each factor affecting the supply of the product have been analyzed and discussed. According to the final score, CGT is the most appropriated supplier because it has the highest priority weight and CST is the second one.

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