A FUZZY MULTI CRITERIA DECISION MAKING FOR SELECTION OF MAINTENANCE ALTERNATIVES IN CONSTRUCTION COMPANY

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ABSTRACT

This paper present a fuzzy approach based on multi criteria decision making(MCDM) methodology for selective the optimal maintenance alternatives and it evaluate different type of maintenance strategies such as preventive maintenance, break down maintenance, corrective maintenance, predictive maintenance and condition based maintenance of different type of equipments. This methodology is applied for a construction company to solve the problem of maintenance alternatives.

Keywords:*, Fuzzy Sets, Maintenance alternative, Rank*

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1 .INTRODUCTION

Selection of maintenance alternatives is a crucial problem. It is difficult to quantify the qualitative factor in numerical terms. This factor can be expressed in linguistic terms and then translated to mathematical measures. In present work maintenance of diesel generator in bridge & roof company is studied. For diesel generator five maintenance alternatives policies are considered as preventive maintenance, break down maintenance, corrective maintenance, predictive maintenance and condition based maintenance. The methodology involves ranking of equipments fuzzy multiple criteria decision making method, ranking and evaluation of maintenance alternatives.

2. LITERATURE REVIEW

Lin & Chen (2004) developed a fuzzy linguistic approach for bid decision making process. The effective maintenance co ntributes to maximizing process profitability in term of reducing operating and manufacturing cost. Fuzzy set theory (Zadeh1965) provides a useful tool to deal with decision in which the phenomena are imprecise & vague. Li.et. (2005) propose a multi layer fuzzy pattern recognition method for selection of contractor. Dubois, D. and Prade,H. (1980) ,Possibility theory an approach to computerized processing of uncertainty .When a problem involves number of experts, criteria, unsound information & risk stands. (Hipel1993). Ng(1996)studied different decision support system for constructor contractor prequalification and developed a cased-based reasoning approach to prequalify contractors. D.Singh et.al. (2005) propose a fuzzy decision frame work for alternatives selection. Hanna and Russell(1997) develop neural network contractor prequalification model to solve CCPQ problem. Chan.F.T.S..,Lau,H.C.W.,Ip,R.W.L.,chan,H.K.,Kong,S., (2005) a case study of implementation of total productive maintenance. Yaveli (2007) a fuzzy frame work for selection of contractors at the stages of pre qualification where four approaches namely, Fuzzy Number Recognition method , Fuzzy Topsis method, Fuzzy number weight centre method & Simple defuzzification methods are used. Pratesh jayaswal, M.K. Trivedi and Arun Nagar(2011)developed maintenance alternative in manufacturing plant.

The methodology is adopted in this study is of D.Singh and Robert.L.K.Tiong(2005) and Pratesh jayaswal, M.K. Trivedi and Arun Nagar(2011) In the present study, the attributes & criteria are changed to fit in the model with minor modification in the selection of suitable maintenance alternative for the equipment in the construction company.

3. FUZZY SETS AND THEORY :

Membership's function of an element represents a degree to which the elements belong to a set.Ai be a fuzzy number such that ∀Ai ε R (set of real number) and considered in the form of

$$A\ i = (a, b, c, d);$$

$$i = 1 \ldots.m$$

Where a < b < c < d is the scale of preference to be used by the experts & M is the fuzzy numbers to be used the analysis .The memberships function for triangular and trapezoidal fuzzy number is shown as

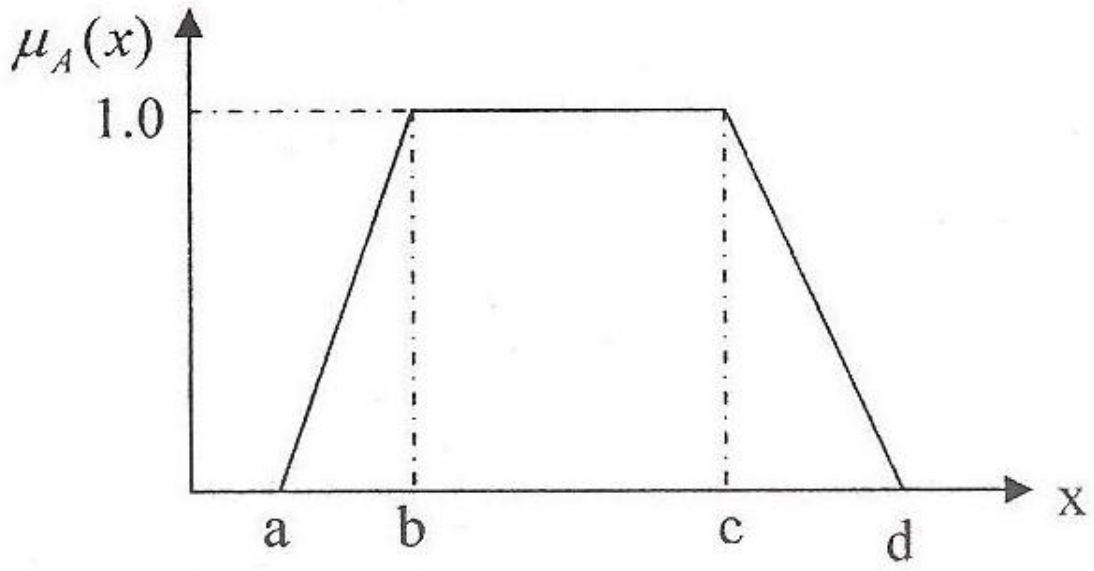


Fig-1 Trapezoidal membership function

$$\mu_A(x) = \begin{cases} \dfrac{(x-a)}{(b-a)} & a \le x \le b \\ 1 & b \le x \le c \\ \dfrac{(x-d)}{(c-d)} & c \le x \le d \\ 0 & \text{Otherwise} \end{cases}$$

OPERATIONS ON FUZZY NUMBERS:

Let A & B be the two fuzzy numbers parameterized by A= (a_1, b_1, c_1, d_1& B= (a_2, b_2, c_2, d_2) respectively. Then the operations [+,-, ×, ÷] of trapezoidal fuzzy number can be expressed as (Kaufmann & gupta1991).

$A \oplus B = (a_1, b_1, c_1, d_1) \oplus (a_2, b_2, c_2, d_2) = (a_1 + a_2, b_1 + b_2, c_1 + c_2, d_1 + d_2)$

$A \ominus B = (a_1, b_1, c_1, d_1) \ominus (a_2, b_2, c_2, d_2) = (a_1 - d_2, b_1 - c_2, c_1 - b_2, d_1 - a_2)$

$A \otimes B = (a_1, b_1, c_1, d_1) \otimes (a_2, b_2, c_2, d_2) = (a_1 \times a_2, b_1 \times b_2, c_1 \times c_2, d_1 \times d_2)$

$A \oslash B = (a_1, b_1, c_1, d_1) / (a_2, b_2, c_2, d_2) = (a_1 / d_2, b_1 / c_2, c_1 / b_2, d_1 / a_2)$

Building Linguistic variables set: It is difficult for decision maker to give an exact numerical value to express his opinion & the decision maker feel comfortable to describe in it fuzzy terms of “high” “low” or “very high” etc.These fuzzy terms can be expressed in trapezoidal fuzzy numbers. For the selection of maintenance alternatives trapezoidal fuzzy numbers are taken. The fuzzy numbers associated with the corresponding the linguistic variables are shown in Table 1.

Table 1: Fuzzy numbers and corresponding linguistic variables

Linguistic variable	Fuzzy number
Very high (VH)	(0.8,0.9,1,1)
High	(0.6,0.7,0.8,0.9)
Moderate high	(0.5,0.6,0.7,0.8)
Moderate	(0.4,0.5,0.5,0.6)
Moderate low	(0.2,0.3,0.4,0.5)
Low	(0.1,0.2,0.3,0.4)
Very low	(0.0,0.0,0.1,0.2

Determination of fuzzy weight for decision criteria**:** Following are the steps:

Step1: The linguistic variables assigned by the experts for each criteria are translated into fuzzy numbers and the same is represented in the matrix (fuzzy decision matrix).

Step2: Let A_{jik} be the fuzzy number assigned to an alternative A_i by the experts (E_k) for decision criteria, C_j the average of fuzzy number is given as:

$$A_{ij} = {}_{1p}\, a_{j\,i1}\, a_{j\,i2} + \ldots + a_{j\,ik}\,;\ K = 1, 2, \ldots\ldots\ldots\ldots, P. \quad \text{eq}\ldots\ldots 1$$

The average fuzzy score matrix for each criteria is obtained.

Step3: The crisp score (defuzzified values) for each criteria is obtained.Defuzzification of fuzzy number is an operation that produces a non fuzzy crisp value. Defuzzified is given by the following equations (Kaufmann & Gupta 1991).

Trapezoidal fuzzy number

$$e = (a+b+c+d)/4 \ldots\ldots\ldots\ldots\ldots\ldots \text{eq2}$$

Step4: The normalized weight for each criterion (C_j) is obtained as W_j, where j=1,2,3,……n normalized weight for each criterion is obtained by dividing the defuzzified scores of each criterion by the total of all the criteria.

Rating of suitable maintenance alternative: In similar way as procedure adopted for the calculation of weight criteria, the rating of suitable …..n .The maintenance alternative is derived as

☐ Maintenance alternatives suitable on each of the criteria are to be rated in the linguistic variables by the experts which is converted into fuzzy number & the same is represented in the matrix form (fuzzy decision matrix).

☐ The average fuzzy score matrix for each maintenance alternative are obtained.

☐ The crisp score (defuzzified value) for each maintenance alternative are obtained & same is represented in the matrix form as X_{ij} where i= 1, 2,… m & J = 1, 2, n

Where m is the number of maintenance alternative, n is the number criteria.

☐ TS = [Xij] [Wj]

☐ On the basis of total score obtained maintenance alternative against decision criteria overall scores are obtained, using simple average method, which provide final ranking of maintenance alternative for each critical equipment.

4. CASE STUDY:

The methodology proposed allows the experts to rank the suitable maintenance alternative in the bridge and roof company india limited in bhatinda(india) in the refinery construction works such as piping and tankages to do it many of the equipments used by this company alternative maintenance of such equipment is too necessary. The effect of maintenance activities that depends on preventive maintenance, break down maintenance, corrective maintenance, predictive maintenance and condition based maintenance. It is preferable to choose the best maintenance alternative on the basis of different decision criteria.

The advantage of fuzzy set theory facilities the assessment to be made on the basis of linguistic, quantitative and qualitative manner, for simplicity five experts (E_1,E_2,E_3, E_4,E_5) were consulted to get the linguistic variables in terms of importance of each criteria used to rank the five maintenance alternatives (A_1,A_2,A_3,A_4,A_5) For each equipments seven decision criteria as listed below:

1. Management Decision(C1)
2. Safety(Risk) (C2)
3. Workers behavior(C3)
4. Quality(C4)
5. Construction Difficulties(c5)
6. Reliability(C6)
7. Productivity(C7)

Determination of weights (W_j) for criteria:

Table 2. linguistic variables assigned by the experts decision criteria

Criteria	**Experts**				
	E1	**E2**	**E3**	**E4**	**E5**
C1	H	VH	MH	H	H
C2	VH	VH	H	H	VH
C3	M	H	M	MH	H
C4	MH	MH	H	VH	VH
C5	VH	VH	ML	H	MH
C6	H	VH	H	H	H
C7	VH	H	MH	VH	H

Table3.Now these linguistic variables are converted into fuzzy numbers.

The fuzzy decision matrix X_{C2} is as

0.6,0.7,0.8,0.9	0.8,0.9,1,1	0.5,0.6,0.7,0.8	0.6,0.7,0.8,0.9	0.6,0.7,0.8,0.9
0.8,0.9,1,1	0.8,0.9,1,1	0.6,0.7,0.8,0.9	0.6,0.7,0.8,0.9	0.8,0.9,1,1
0.4,0.5,0.5,0.6	0.6,0.7,0.8,0.9	0.4,0.5,0.5,0.6	0.5,0.6,0.7,0.8	0.6,0.7,0.8,0.9
0.5,0.6,0.7,0.8	0.5,0.6,0.7,0.8	0.6,0.7,0.8,0.9	0.8,0.9,1,1	0.8,0.9,1,1
0.8,0.9,1,1	0.8,0.9,1,1	0.2,0.3,0.4,0.5	0.6,0.7,0.8,0.9	0.5,0.6,0.7,0.8
0.6,0.7,0.8,0.9	0.8,0.9,1,1	0.6,0.7,0.8,0.9	0.6,0.7,0.8,0.9	0.6,0.7,0.8,0.9
0.8,0.9,1,1	0.6,0.7,0.8,0.9	0.5,0.6,0.7,0.8	0.8,0.9,1,1	0.6,0.7,0.8,0.9

Table4.The average fuzzy scores, defuzzified values & normalized weights of criteria are obtained & given in the Table 3.

Criteria	Average fuzzy score				Defuzzified value	Normalized weight
C_1	0.620	0.720	0.820	0.900	0.765	0.250
C_2	0.720	0.820	0.920	0.960	0.855	0.279
C_3	0.500	0.600	0.660	0.760	0.630	0.205
C_4	0.640	0.740	0.840	0.900	0.780	0.254
C_5	0.580	0.680	0.780	0.840	0.720	0.235
C_6	0.640	0.740	0.840	0.920	0.785	0.256
C_7	0.660	0.760	0.860	0.920	0800	0.261

Rating of maintenance alternative on the criterion (X_{ij}): Suitability of maintenance alternative against each criteria are to be rated & linguistic variables are assigned by the experts to the maintenance strategies table4 as defined in the table1. These linguistic variables are converted into fuzzy numbers. The average fuzzy score & defuzzified values are given in the Table.5.

Criteria	Experts					
	Maintenance alternative	E_1	E_2	E_3	E_4	E_5
C_1	A_1	VH	VH	H	H	MH
	A_2	MH	VH	MH	VH	M
	A_3	H	MH	H	H	VH
	A_4	VH	H	H	VH	MH
	A_5	VH	VH	H	H	MH
C_2	A_1	VH	H	H	M	MH
	A_2	H	MH	H	H	VH
	A_3	H	VH	M	H	VH
	A_4	VH	H	M	MH	H
	A_5	M	VH	H	M	VH
C_3	A_1	VH	MH	H	VH	M
	A_2	M	VH	M	H	H
	A_3	H	H	VH	M	MH
	A_4	VH	M	MH	VH	H
	A_5	VH	H	H	M	H
C_4	A_1	H	VH	VH	H	M
	A_2	VH	H	VH	VH	MH
	A_3	M	H	VH	H	MH
	A_4	MH	VH	H	H	H
	A_5	H	MH	VH	M	H
C_5	A_1	VH	H	H	VH	H
	A_2	VH	VH	M	H	VH
	A_3	H	H	H	M	VH
	A_4	VH	VH	H	H	MH
	A_5	H	MH	H	M	VH
C_6	A_1	H	H	VH	VH	H
	A_2	VH	MH	M	H	H
	A_3	H	M	H	VH	M
	A_4	M	M	H	H	M
	A_5	H	VH	H	H	VH
C_7	A_1	VH	H	M	H	M
	A_2	VH	VH	H	M	H
	A_3	H	H	M	H	VH
	A_4	VH	H	H	VH	M
	A_5	H	MH	H	MH	H

Table 6.Average fuzzy score and defuzzified scores

Criteria	Experts					
	Maintenance alternative	E_1	E_2	E_3	E_4	E_5
C_1	A_1	0.66	0.76	0.86	0.92	0.800
	A_2	0.600	0.700	0.78	0.84	0.730
	A_3	0.62	0.72	0.82	0.90	0.765
	A_4	0.66	0.76	0.86	0.92	0.800
	A_5	0.66	0.76	0.86	0.92	0.800
C_2	A_1	0.58	0.68	0.76	0.84	0.715
	A_2	0.62	0.72	0.82	0.90	0.765
	A_3	0.64	.074	0.82	0.88	0.770
	A_4	0.58	0.68	0.76	0.84	0.715
	A_5	0.60	0.70	0.76	0.82	0.720
C_3	A_1	0.62	0.72	0.80	0.86	0.750
	A_2	0.56	0.66	0.72	0.80	0.685
	A_3	0.58	0.76	0.76	0.82	0.730
	A_4	0.62	0.72	0.80	0.86	0.750
	A_5	0.60	0.70	0.78	0.86	0.735
C_4	A_1	0.64	0.74	0.82	0.88	0.770
	A_2	0.70	0.80	0.90	0.94	0.835
	A_3	0.58	0.68	0.76	0.84	0.715
	A_4	0.62	0.72	0.82	0.90	0.765
	A_5	0.58	0.68	0.76	0.84	0.715
C_5	A_1	0.68	0.78	0.86	0.94	0.815
	A_2	0.68	0.78	0.84	0.9	0.800
	A_3	0.60	0.70	0.78	0.86	0.735
	A_4	0.66	0.76	0.86	0.92	0.800
	A_5	0.56	0.66	0.74	0.82	0.695
C_6	A_1	0.68	0.78	0.88	0.94	0.820
	A_2	0.58	0.68	0.76	0.84	0.715
	A_3	0.56	0.66	0.72	0.80	0.685
	A_4	0.48	0.58	0.62	0.72	0.600
	A_5	0.68	0.78	0.88	0.94	0.820
C_7	A_1	0.56	0.66	0.72	0.80	0.548
	A_2	0.64	0.74	0.82	0.88	0.400
	A_3	0.60	0.70	0.78	0.86	0.735
	A_4	0.64	0.74	0.82	0.88	0.770
	A_5	0.56	0.66	0.76	0.86	0.710

Using the simple additive weighting method, the total scores (TS) for each maintenance alternatives can be calculated as follows :

	A_1	A_2	A_3	A_4	A_5	Wj
C_1	0.8	0.73	0.765	0.8	0.8	0.25
C_2	0.715	0.765	0.77	0.715	0.72	0.279
C_3	0.75	0.685	0.73	0.75	0.735	0.205
C_4	0.77	0.835	0.715	0.765	0.715	0.254
C_5	0.815	0.8	0.735	0.8	0.695	0.235
C_6	0.82	0.715	0.685	0.6	0.82	0.256
C_7	0.548	0.4	0.735	0.77	0.71	0.261

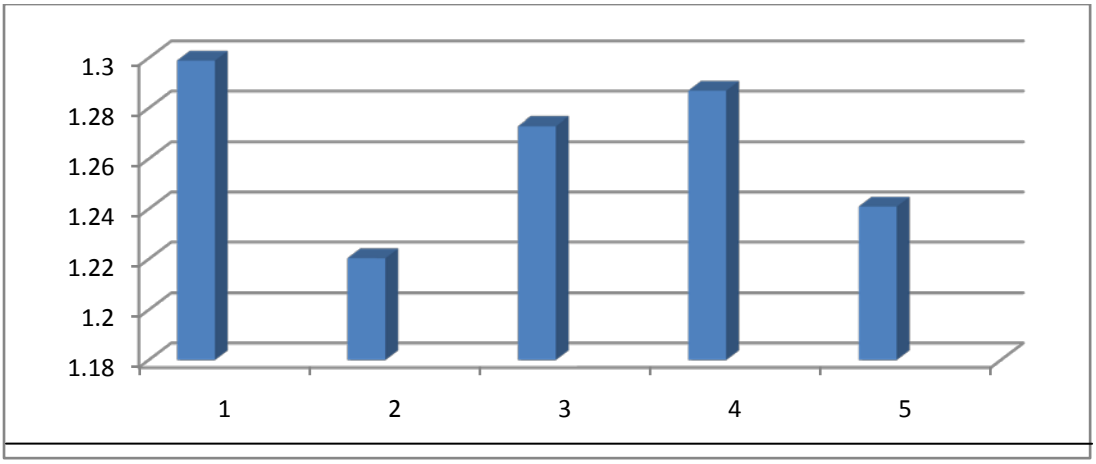
$$TS = [X\ ij\ ]\ [Wj]$$

Total score for maintenance alternatives (A_1) on the criterion is obtained as (.800×.250) + (.715×.279) + (.750×.205) + (.770×.254) + (.815×.235) + (.820×.256) + (.548×.261) +
= 1.299. Similarly, Total score for maintenance alternatives (A_2), (A_3) (A_4), (A_5) for Diesel generator (M_1) are obtained. In the selection of maintenance alternatives for any equipment for construction company, quantities & qualitative criteria, each has equal weight age. Hence the final score & ranking of maintenance alternative are given in the Table.

Table No 7. Final scores and ranking of maintenance alternative for Diesel generator (M_1)

Maintenance alternatives	A_1	A_2	A_3	A_4	A_5
final score	1.299	1.22	1.273	1.287	1.241
Rank	1	5	3	2	4

Graph showing final score Vs rank



5. RESULT & DISCUSSION:

With the fuzzy multi criteria decision approach the order ranking of maintenance alternative for **Diesel generator** M_1 are as $A_1 > A_4 > A_3 > A_5 > A_2$.The results shows that A_1,is the best maintenance alternative for M_1. Since fuzzy logic incorporates the linguistic variable more practically & also help in eliminating the imprecision & vagueness.

6. CONCLUSION:

In this paper the selection of maintenance alternative for different equipment in construction company is studied. An optimal maintenance alternative can improve availability & reliability levels of plants equipments & reduce unnecessary investment in maintenance. The evaluation of maintenance alternative for each equipment is a multiple criteria decision making (MCDM)problem, considering the imprecise judgments of experts views with trapezoidal fuzzy number & the fuzzy simple average method is used for different maintenance alternative for each equipment in construction company & useful for other similar MCDM problems.

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