

A FUZZY APPROACH FOR SELECTION OF MAINTENANCE ALTERNATIVES IN CONSTRUCTION COMPANY

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Abstract

This paper present a fuzzy approach for selection of maintenance alternative for air compressor used in construction company. The maintenance alternative are predictive maintenance, condition based maintenance, corrective maintenance break down and preventive maintenance,. Here we have to find out which maintenance which maintenance alternatives will be best suited for the maintenance of air compressor. To do this multi criteria decision making (MCDM) methodology applied.

Key-words: Fuzzy Sets, Rank, Maintenance alternative.

Introduction

Traditional method used for the Selection of maintenance alternatives is difficult but these method are in adequate, because of not considered qualitative factor like administrative problem. It is very difficult to quantify the qualitative factor in numerical value. This factor can be expressed in linguistic terms which can be translated to mathematical measures by using system theory & fuzzy sets. In present work maintenance of air compressor in bridge & roof company is studied. To do this five maintenance alternatives policies are considered as break down maintenance (A_1), predictive maintenance (A_2), condition based maintenance(A_3), corrective maintenance(A_4), and preventive maintenance (A_5).The methodology used in this paper involves ranking of equipments fuzzy multiple criteria decision making method, ranking and evaluation of maintenance alternatives.

Literature Review

Fuzzy set theory (Zadeh1965) provides a useful tool to deal with decision in which the phenomena are imprecise & vague. . 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. Ng(1996) .(Hipel1993). studied different decision support system for constructor contractor prequalification and developed a cased-based reasoning approach to

prequalify contractors. Hanna and Russell(1997) develop neural network contractor prequalification model to solve CCPQ problem. Lin & Chen (2004) developed a fuzzy linguistic approach for bid decision making process. The effective maintenance contributes to maximizing process profitability in term of reducing operating and manufacturing cost. Li.et. (2005) propose a multi layer fuzzy pattern recognition method for selection of contractor D.Singh et.al. (2005) propose a fuzzy decision frame work for alternatives selection. 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.Manish kumar Dr.Pratesh jayaswal, and Dharmendra goad(2012)developed maintenance alternative in construction company.

Fuzzy sets and Theory

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

$$A_i = (a, b, c, d);$$

$$i = 1 \dots m$$

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

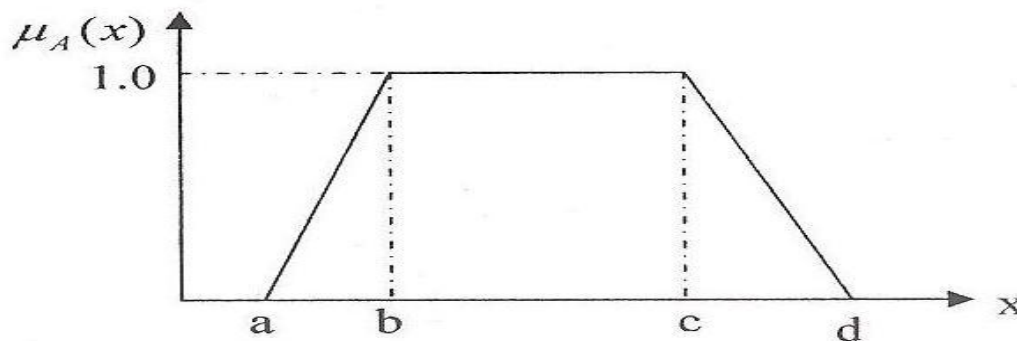


Fig-1 Trapezoidal membership function

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

Operations on fuzzy numbers:

Let A & B be the two fuzzy numbers parameterized by A= (a1, b1, c1, d1) & B= (a2, b2, c2, d2) respectively. Then the operations [+ , - , × , ÷] of trapezoidal fuzzy number can be expressed as (Kaufmann & gupta1991).

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

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

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

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

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_{ijk} 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:

$$A_{ij} = \frac{1}{p} (a_{j1} + a_{j2} + \dots + a_{jk}) ; K = 1, 2, \dots, P. \text{ eq. } 1$$

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).

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

Step4: The normalized weight for each criterion (C_j) is obtained as W_j , where $j=1,2,3,\dots,n$ 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 \dots,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 $i= 1, 2,\dots m$ & $J = 1, 2, n$

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

- $TS = [X_{ij}] [W_j]$
- 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.

Case Study

The methodology proposed for selection of maintenance alternative for air compressor 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 break down maintenance (A_1), predictive maintenance (A_2), condition based maintenance (A_3), corrective maintenance(A_4), and preventive maintenance (A_5). It is preferable to choose the best maintenance alternative on the basis of different decision criteria.

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) The advantage of fuzzy set theory facilities the assessment to be made on the basis of linguistic, quantitative and qualitative manner For each equipments seven decision criteria as listed below:

1. Caste (C_1)
2. Safety (Risk) (C_2)
3. Operational flexibility (C_3)
4. Quality (C_4)
5. Productivity (C_5)
6. Reliability (C_6)
7. Construction Difficulties(C_7)

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	H	VH	MH	H
C2	MH	VH	H	M	H
C3	VH	VH	ML	MH	MH
C4	H	H	M	H	VH
C5	VH	MH	VH	M	L
C6	VH	L	VH	H	H
C7	H	VH	H	MH	ML

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	0.6,0.7,0.8,0.9	0.8,0.9,1,1	0.5,0.6,0.7,0.8	0.6,0.7,0.8,0.9
0.5,0.6,0.7,0.8	0.8,0.9,1,1	0.6,0.7,0.8,0.9	0.4,0.5,0.5,0.6	0.6,0.7,0.8,0.9
0.8,0.9,1,1	0.8,0.9,1,1	0.2,0.3,0.4,0.5	0.5,0.6,0.7,0.8	0.5,0.6,0.7,0.8
0.6,0.7,0.8,0.9	0.6,0.7,0.8,0.9	0.4,0.5,0.5,0.6	0.6,0.7,0.8,0.9	0.8,0.9,1,1
0.8,0.9,1,1	0.5,0.6,0.7,0.8	0.8,0.9,1,1	0.4,0.5,0.5,0.6	0.1,0.2,0.3,0.4
0.8,0.9,1,1	0.1,0.2,0.3,0.4	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	0.2,0.3,0.4,0.5

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	0.580	0.680	0.760	0.840	0.715	0.233
C ₃	0.560	0.660	0.760	0.820	0.700	0.228
C ₄	0.600	0.700	0.780	0.860	0.735	0.240
C ₅	0.520	0.620	0.700	0.760	0.650	0.212
C ₆	0.580	0.720	0.780	0.840	0.730	0.238
C ₇	0.540	0.640	0.740	0.820	0.685	0.223

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	M	VH	M	H	VH
	A ₂	VH	H	M	VH	H
	A ₃	H	VH	H	M	MH
	A ₄	VH	H	H	MH	VH
	A ₅	MH	VH	M	MH	VH
C ₂	A ₁	H	H	VH	M	MH
	A ₂	H	H	MH	H	VH
	A ₃	VH	VH	MH	H	H
	A ₄	VH	H	H	MH	H
	A ₅	H	VH	H	MH	VH
C ₃	A ₁	H	MH	H	MH	H
	A ₂	VH	H	M	H	H
	A ₃	H	H	VH	M	M
	A ₄	M	M	M	H	H
	A ₅	VH	MH	H	M	H
C ₄	A ₁	H	MH	VH	H	M
	A ₂	VH	H	H	H	M
	A ₃	H	H	VH	H	VH
	A ₄	MH	VH	H	H	H
	A ₅	VH	MH	VH	VH	H
C ₅	A ₁	M	H	H	VH	H
	A ₂	H	VH	M	H	MH
	A ₃	M	H	VH	MH	VH
	A ₄	VH	VH	H	H	M
	A ₅	VH	M	H	H	VH
C ₆	A ₁	H	H	VH	VH	H
	A ₂	VH	M	M	H	H
	A ₃	H	H	H	VH	VH
	A ₄	MH	VH	H	H	VH
	A ₅	H	VH	M	VH	VH
C ₇	A ₁	VH	H	MH	H	M
	A ₂	VH	MH	H	M	H
	A ₃	H	H	M	VH	VH
	A ₄	VH	M	H	VH	MH
	A ₅	H	M	H	M	VH

Table 6. Average fuzzy score and defuzzified scores

Criteria	Maintenance alternative	Experts				Defuzzified value
		E ₁	E ₂	E ₃	E ₄	
C ₁	A ₁	0.60	0.70	0.76	0.82	0.720
	A ₂	0.64	0.74	0.82	0.88	0.770
	A ₃	0.58	0.68	0.76	0.84	0.715
	A ₄	0.66	0.76	0.86	0.92	0.800
	A ₅	0.60	0.70	0.78	0.94	0.730
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	0.66	0.76	0.86	0.92	0.800
	A ₄	0.62	0.72	0.82	0.90	0.765
	A ₅	0.66	0.76	0.86	0.92	0.800
C ₃	A ₁	0.56	0.66	0.76	0.86	0.710
	A ₂	0.60	0.70	0.78	0.86	0.735
	A ₃	0.56	0.66	0.72	0.80	0.548
	A ₄	0.48	0.58	0.62	0.72	0.600
	A ₅	0.58	0.68	0.76	0.84	0.715
C ₄	A ₁	0.56	0.66	0.74	0.82	0.695
	A ₂	0.60	0.70	0.78	0.86	0.735
	A ₃	0.68	0.78	0.86	0.94	0.815
	A ₄	0.62	0.72	0.82	0.90	0.765
	A ₅	0.70	0.80	0.90	0.94	0.835
C ₅	A ₁	0.60	0.70	0.78	0.86	0.735
	A ₂	0.58	0.76	0.76	0.82	0.730
	A ₃	0.62	0.72	0.80	0.86	0.750
	A ₄	0.64	0.74	0.82	0.88	0.770
	A ₅	0.64	0.74	0.82	0.88	0.770
C ₆	A ₁	0.68	0.78	0.88	0.94	0.820
	A ₂	0.56	0.66	0.72	0.80	0.685
	A ₃	0.68	0.78	0.88	0.94	0.820
	A ₄	0.66	0.76	0.86	0.92	0.800
	A ₅	0.68	0.78	0.84	0.90	0.800
C ₇	A ₁	0.58	0.68	0.76	0.84	0.715
	A ₂	0.58	0.68	0.76	0.84	0.715
	A ₃	0.64	0.74	0.82	0.88	0.770
	A ₄	0.62	0.72	0.80	0.86	0.750
	A ₅	0.56	0.66	0.72	0.80	0.685

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	W _j
C ₁	0.720	0.770	0.715	0.800	0.730	0.250
C ₂	0.715	0.765	0.800	0.765	0.800	0.233
C ₃	0.710	0.735	0.548	0.600	0.715	0.228
C ₄	0.695	0.735	0.815	0.765	0.835	0.240
C ₅	0.735	0.730	0.750	0.770	0.770	0.212
C ₆	0.820	0.685	0.820	0.800	0.800	0.238
C ₇	0.715	0.715	0.770	0.750	0.685	0.223

$$TS = [X_{ij}] [W_j]$$

Total score for maintenance alternatives (A₁) on the criterion is obtained as (.720×.250) + (.715×.233) + (.710×.228) + (.695×.240) + (.735×.212) + (.820×.238) + (.715×.223) + = 1.19. Similarly, Total score for maintenance alternatives (A₂), (A₃) (A₄), (A₅) for Air compressor 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 Air compressor

Maintenance alternatives	A ₁	A ₂	A ₃	A ₄	A ₅
final score	1.19	1.18	1.21	1.22	1.24
Rank	4	5	3	2	1

Result & discussion:

With the fuzzy multi criteria decision approach the order ranking of maintenance alternative for Air compressor M₁ are as A₅ >A₄>A₃ > A₁ >A₂.The results shows that (Preventive maintenance)A₅,is the best maintenance alternative for Air compressor. Since fuzzy logic

incorporates the linguistic variable more practically & also help in eliminating the imprecision & vagueness.

Conclusion:

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

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