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Research Article

Exploring Fuzzy SAW Method for Maintenance Strategy Selection Problem of Material Handling Equipment

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Abstract

This paper proposes and presents a different approach of selection an appropriate maintenance strategy of material handling equipments in Punj Lloyd plant Gwalior (India) using Fuzzy Simple Additive Weighting (FSAW) method. In this paper by the experts weights are assigned in linguistic variables, these linguistic variables are translated into triangular fuzzy numbers (TFN) to the Multi-Criteria Decision-Making (MCDM) problem. Basic six types of maintenance strategy are corrective maintenance, preventive maintenance, condition based maintenance, opportunistic maintenance, predictive maintenance, and breakdown Maintenance and ten maintenance decision criteria namely quality, spare parts inventories, purchasing cost of spare parts, maintenance labour cost, Reliability, safety, Maintenance time, Facilities, cost of supporting equipment, and environment. In this paper breakdown maintenance strategy best one out of all maintenance strategy for material handling equipment in Punj Lloyd plant Gwalior (India).

Keywords: *Multi-criteria decision-making (MCDM), Maintenance strategy selection, Fuzzy SAW method, Linguistic variables, Triangular fuzzy number (TFN).*

Introduction and literature review

Proper maintenance of the plant equipment can significantly reduce the overall operating cost, while boosting the productivity of the plant. The development of new technologies and managerial practices means that maintenance staff must be endowed with growing technical and managerial skills (Massimo Bertolini *et al*,2006). In many industries there is a strong incentive to maximize their plant and machinery lifetime. This means plant and machinery may be kept running beyond their original design lifetime to do so. Therefore, risk and reliability analysis has recently become a critical decision tool to optimize maintenance strategy in order to ensure safety and minimize costs (Yatomi Masataka *et al*,2004). Many companies think of maintenance as an inevitable source of cost. For these companies maintenance operation have a corrective function and are only executed in emergency conditions. Today, this form of intervention is no longer acceptable because of certain critical elements such as product quality, plant safety, and the increase in maintenance department costs which can represent from 15 to 70% of total production costs (Asis Sarkar *et al*,2011). Most plants are equipped with various machines, which have different reliability requirements, risk levels and failure effect. Therefore, it is clear that a proper maintenance program must define different maintenance strategies for different machines. Thus, the reliability and availability of production facilities can be kept in an acceptable level and the unnecessary investment needed to implement an unsuitable maintenance strategy may be avoided (Mohammad akhshabi *et al*,2011). The maintenance strategy selection problem which is a multi-criteria decision-making (MCDM) problem faces the problem in estimating the related factors. To solve this problem, some approaches using fuzzy concepts have been proposed. In this paper, a new approach to the maintenance strategy selection problem is proposed which can determine the best maintenance strategy by considering the uncertainty level and also all the variety in maintenance criteria and their importance (Azizollah Jafari *et al*,2008). The Fuzzy Simple Additive Weighting (FSAW) for the evaluation of maintenance strategies is used, Triangular Fuzzy Number (TFN) in Fuzzy Simple Additive Weighting (FSAW) to model the uncertainty in the selection process is used and a fuzzy linguistic approach for the maintenance strategy selection problem is used.

In the literature, related fuzzy SAW method following works is to we done. Azizollah Jafari, Mehdi Jafarian, Abalfazl Zareei, Farzad Zaerpour (2008) using fuzzy Delphi method in maintenance strategy selection problem. In this study SAW method is used for rank ordering the

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maintenance strategy. Ting-Yu Chen (2012) comparative analysis of SAW and TOPSIS based on interval-valued fuzzy sets: Discussions on score function and weight constraints. Widayanti-Deni, Oka-Sudana, Arya-Sasmita (2013) analysis and implementation fuzzy multi-attribute decision making SAW method for selection of high achieving students in faculty level. Hossein Rajaie, Ayoub Hazrati, Abbas Rashidi evaluation of contractors in developing countries using fuzzy SAW method. Shalini Gupta, Alok Gupta (2012) a fuzzy multi criteria decision making approach for vendor evaluation in a supply chain. Mahdi Zarghaami, Reza Ardakanian, Azizolah Memariani (2007) fuzzy multi attribute decision making on water resources projects case study: ranking water transfers to zayanderud basin in iran. In this study fuzzy SAW method is used. E. Manokaran, S. Subhashini, S. Senthilvel, R. Muruganandham K. Ravichandran (2011) application of multi criteria decision making tools and validation with optimization technique-case study using TOPSIS, ANN and SAW.

Fuzzy sets, linguistic variable and fuzzy numbers

In order to deal with vagueness of human thought, Zadeh (Zadeh L. A *et al*,1965) first introduced the fuzzy set theory. A fuzzy set is a class of objects with a continuum of grades of membership. Such of objects a set is characterized by a membership function which assigns to each object a grade of membership ranging between zero and one (Zadeh L. A *et al*,1965).

A linguistic variable is a variable the values of which are linguistic terms. Linguistic terms have been found intuitively easy to use in expressing the subjectiveness and/or qualitative imprecision of a decision maker's assessments (Zadeh L. A *et al*,1975).

It is possible to use different fuzzy numbers according to the situation. In applications it is often convenient to work with triangular fuzzy numbers (TFNs) because of their computational simplicity, and they are useful in promoting representation and information processing in a fuzzy environment (Irfan Ertugrul*et al*,2008). In this study TFNs are adopted in the fuzzy SAW methods.

Table 1: Fuzzy numbers and corresponding linguistic variables

S No	Linguistic variable	Code	Fuzzy number
1	Very low	VL	(0.0, 0.0, 0.1)
2	Low	L	(0.0, 0.1, 0.3)
3	Medium low	ML	(0.1, 0.3, 0.5)
4	Medium	M	(0.3, 0.5, 0.7)
5	Medium high	MH	(0.5, 0.7, 0.9)
6	High	H	(0.7, 0.9, 1.0)
7	Very high	VH	(0.9, 1.0, 1.0)

Triangular fuzzy numbers can be defined as a triplet (a, b, c). The parameters a, b, and c respectively, indicate the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event. A triangular fuzzy number X is shown in fig. 1 (Deng H *et al*,1999).

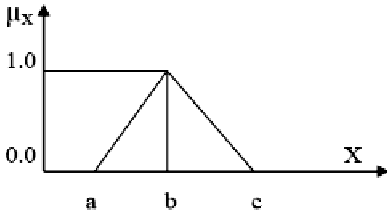

Fig. 1

The fuzzy saw method

In fuzzy MCDM problems, criteria values and the relative weights are usually characterized by fuzzy numbers. A fuzzy number is a convex fuzzy set, characterized by a given interval of real numbers, each with a grade of membership between 0 and 1 (Ying-Ming Wang *et al*,2006).

Simple Additive Weight (SAW) method: Churchman and Ackoff (1945) first utilized the SAW method to with a portfolio selection problem. The SAW method is probably the best known and widely used method for its multiple attribute decision making MADM. Because of its simplicity, SAW is the most popular method in MADM problems. SAW method also known as the term is often weighted summation method. The basic concept of SAW method is to find a weighted sum of rating the performance of each alternative on all attributes. SAW method requires a process of normalizing the decision matrix to a scale that can be compared with all the rating of the alternatives (Widayanti-Deni *et al*,2013). Fuzzy SAW method is the combination of both fuzzy MCDM method and SAW method.

The various steps of Fuzzy SAW method are presented as follows

STEP-1: Choosing the criteria that will be used as a reference in decision-making, namely (C_j; j = 1, 2…m) and form a committee of experts (E_k; k = 1, 2 … n) for decision-making.

STEP -2: Assigned the suitable rating of each criterion by the experts in terms of linguistic variables.

STEP-3: Determine the fuzzy decision matrix DM_{ij} for all criteria in terms of fuzzy triangular numbers.

$$DM_{jk} = \begin{bmatrix} X11 & X12 & \cdots & X1n \\ \vdots & & \ddots & \vdots \\ Xm1 & Xm2 & \cdots & Xmn \end{bmatrix}$$

STEP-4: Determine the average fuzzy scores (A_{jk}), defuzzified values (e) and normalized weight (W_j) of each criteria.

Average fuzzy score (A_{jk}) = ($f^k_{j1} + f^k_{j2} + \ldots + f^k_{jn}$) / n; j = 1, 2…m; k = 1, 2…n

Defuzzified values (e) = (a + b + c) / 3

The normalized weight (W_j) for each criterion is obtained by dividing the diffuzzified scores of each criterion by the total of diffuzified scores the entire criterion.

STEP-5: Assigned the suitable rating in terms of linguistic variables by the experts for each maintenance strategy (M_i; i = 1, 2…6) of all the criteria of material handling equipment.

STEP-6: Determine average fuzzy score and defuzzified scores of each maintenance strategy of all the criteria of material handling equipment.

STEP-7: Determine decision matrix for all criteria and maintenance strategy [X_{ij}]

STEP-8: Determine normalized matrix for all criteria and maintenance strategy [R_{ij}].

$r_{ij} = x_{ij} / \max(x_{1j}, x_{2j}, x_{3j}, x_{4j}, x_{5j}, x_{6j})$; i = 1, 2…6

STEP-8: Determine the Total Scores (TS) for each maintenance strategy by Simple Additive Weighting (SAW) method.

TS = [R_{ij}] [W_j]

STEP-9: The final results obtained from the ranking the sum of normalized matrix [X_{ij}] multiplication with the normalized weight (W_j) in order to obtain the greatest value is selected as the best maintenance strategy (M_i) as a solution.

STEP-10: Final scores and Ranks for selection of maintenance strategy problem.

A case study: In this research selection of maintenance strategy of material handling equipment in Punj Lloyd plant Gwalior. In this research five experts (E_1, E_2, E_3, E_4, and E_5) and six maintenance strategies (corrective maintenance M_1, preventive maintenance M_2, condition based maintenance M_3, opportunistic maintenance M_4, predictive maintenance M_5, and breakdown Maintenance M_6). This research framework includes 10 evaluation criteria, such as quality (C_1), spare parts inventories (C_2), purchasing cost of spare parts (C_3), maintenance labour cost (C_4), Reliability (C_5), safety (C_6), Maintenance time (C_7), Facilities (C_8), cost of supporting equipment (C_9), and environment (C_{10}). After the construction of the hierarchy the different priority weights of each criteria and strategy are calculated using the fuzzy SAW method.

Table 2: Assigned the suitable rating of each criterion by the experts in terms of linguistic variables.

S No	Criteria	Code	Experts				
			E_1	E_2	E_3	E_4	E_5
1	Quality	C_1	VH	H	VH	VH	H
2	Spare parts inventories	C_2	MH	M	ML	L	VL
3	Purchasing of spare parts	C_3	M	ML	M	MH	ML
4	Maintenance labour cost	C_4	MH	H	ML	M	M
5	Reliability	C_5	VH	H	H	VH	VH
6	Safety	C_6	H	VH	H	VH	VH
7	Maintenance time	C_7	MH	M	H	MH	H
8	Facilities	C_8	H	MH	VH	H	MH
9	Cost of supporting equipment	C_9	L	ML	M	M	VL
10	Environment	C_{10}	MH	H	VH	H	MH

Table 3: Determine the fuzzy decision matrix DM_{ij} for all criteria in terms of fuzzy triangular numbers.

	E_1	E_2	E_3	E_4	E_5
C_1	(0.9,1.0, 1.0)	(0.7,0.9, 1.0)	(0.9,1.0, 1.0)	(0.9,1.0, 1.0)	(0.7,0.9, 1.0)
C_2	(0.5,0.7, 0.9)	(0.3,0.5, 0.7)	(0.1,0.3, 0.5)	(0.0,0.1, 0.3)	(0.0,0.0, 0.1)
C_3	(0.3,0.5, 0.7)	(0.1,0.3, 0.5)	(0.3,0.5, 0.7)	(0.5,0.7, 0.9)	(0.1,0.3, 0.5)
C_4	(0.5,0.7, 0.9)	(0.7,0.9, 1.0)	(0.1,0.3, 0.5)	(0.3,0.5, 0.7)	(0.3,0.5, 0.7)
C_5	(0.9,1.0, 1.0)	(0.7,0.9, 1.0)	(0.7,0.9, 1.0)	(0.9,1.0, 1.0)	(0.9,1.0, 1.0)
C_6	(0.7,0.9, 1.0)	(0.9,1.0, 1.0)	(0.7,0.9, 1.0)	(0.9,1.0, 1.0)	(0.9,1.0, 1.0)
C_7	(0.5,0.7, 0.9)	(0.3,0.5, 0.7)	(0.7,0.9, 1.0)	(0.5,0.7, 0.9)	(0.7,0.9, 1.0)
C_8	(0.7,0.9, 1.0)	(0.5,0.7, 0.9)	(0.9,1.0, 1.0)	(0.7,0.9, 1.0)	(0.5,0.7, 0.9)
C_9	(0.0,0.1, 0.3)	(0.1,0.3, 0.5)	(0.3,0.5, 0.7)	(0.3,0.5, 0.7)	(0.0,0.0, 0.1)
C_{10}	(0.5,0.7, 0.9)	(0.7,0.9, 1.0)	(0.9,1.0, 1.0)	(0.7,0.9, 1.0)	(0.5,0.7, 0.9)

Table 4: Determine the average fuzzy scores (A_{jk}), defuzzified values (e) and normalized weight (W_j) of each criteria.

Criteria (C_j)	Average fuzzy scores (A_{jk})			Deffuzzified value (e)	Normalized weight (W_j)
C_1	0.82	0.96	1	0.927	0.152
C_2	0.18	0.32	0.5	0.333	0.055
C_3	0.26	0.46	0.66	0.46	0.076
C_4	0.38	0.58	0.76	0.573	0.094
C_5	0.82	0.96	1	0.927	0.152
C_6	0.82	0.96	1	0.927	0.152
C_7	0.54	0.74	0.9	0.727	0.12
C_8	0.66	0.84	0.96	0.82	0.135
C_9	0.14	0.28	0.46	0.293	0.048
C_{10}	0.66	84	0.96	0.82	0.135

Table 5: Assigned the suitable rating in terms of linguistic variables by the experts for each maintenance strategy of all the criteria of material handling equipment.

Criteria	Strategies	Experts				
		E_1	**E_2**	**E_3**	**E_4**	**E_5**
C_1	M_1	H	VH	H	H	VH
	M_2	M	MH	M	M	MH
	M_3	H	H	VH	VH	MH
	M_4	M	MH	H	H	MH
	M_5	ML	M	MH	MH	M
	M_6	VH	H	VH	H	VH
C_2	M_1	H	MH	M	MH	H
	M_2	M	ML	L	ML	M
	M_3	L	VL	L	ML	L
	M_4	MH	H	H	MH	M
	M_5	L	VL	ML	ML	L
	M_6	VH	H	H	H	MH
C_3	M_1	H	MH	M	MH	H
	M_2	ML	M	M	ML	H
	M_3	ML	M	MH	M	ML
	M_4	MH	H	M	MH	MH
	M_5	L	ML	M	ML	M
	M_6	H	H	VH	VH	H
C_4	M_1	ML	M	H	H	M
	M_2	H	M	L	ML	ML
	M_3	M	MH	M	ML	ML
	M_4	ML	ML	M	L	M
	M_5	L	ML	ML	ML	M
	M_6	H	VH	VH	H	VH
C_5	M_1	H	VH	VH	H	MH
	M_2	ML	M	M	MH	MH
	M_3	H	H	VH	H	MH
	M_4	MH	H	M	M	H
	M_5	ML	M	MH	M	ML
	M_6	H	H	VH	VH	H
C_6	M_1	H	MH	MH	H	MH
	M_2	MH	M	M	MH	H
	M_3	H	H	VH	H	H
	M_4	H	MH	M	M	MH
	M_5	M	MH	H	MH	M
	M_6	H	H	VH	MH	MH
C_7	M_1	H	MH	H	H	MH
	M_2	M	M	ML	ML	H
	M_3	M	ML	ML	H	ML
	M_4	M	ML	MH	H	MH
	M_5	MH	M	ML	ML	L
	M_6	VH	H	VH	VH	VH
C_8	M_1	H	VH	H	MH	MH
	M_2	MH	M	M	MH	M
	M_3	VH	H	VH	H	VH
	M_4	M	ML	L	MH	ML
	M_5	H	MH	H	MH	MH
	M_6	MH	H	VH	VH	VH
C_9	M_1	H	M	MH	M	MH
	M_2	M	ML	ML	H	MH
	M_3	M	MH	MH	ML	MH
	M_4	ML	ML	M	M	ML
	M_5	ML	L	ML	ML	M
	M_6	VH	VH	H	VH	VH
C_{10}	M_1	M	H	MH	H	VH
	M_2	H	MH	MH	H	H
	M_3	VH	H	VH	VH	H
	M_4	M	H	MH	M	MH
	M_5	H	H	H	MH	MH
	M_6	VH	H	H	VH	H

TABLE 6: Determine average fuzzy score and defuzzified scores of each maintenance strategy of all the criteria of material handling equipment

Criteria	Strategies	Average fuzzy scores			Difuzzified scores
C_1	M_1	0.78	0.94	1	0.907
	M_2	0.38	0.58	0.78	0.58
	M_3	0.74	0.9	0.98	0.873
	M_4	0.54	0.74	0.9	0.727
	M_5	0.34	0.54	0.74	0.54
	M_6	0.82	0.96	1	0.927
C_2	M_1	0.54	0.74	0.9	0.727
	M_2	0.16	0.34	0.54	0.347
	M_3	0.02	0.12	0.3	0.147
	M_4	0.54	0.74	0.9	0.727
	M_5	0.04	0.16	0.34	0.18
	M_6	0.7	0.88	0.98	0.853
C_3	M_1	0.54	0.74	0.9	0.727
	M_2	0.3	0.5	0.68	0.493
	M_3	0.26	0.46	0.66	0.46
	M_4	0.5	0.7	0.88	0.693

	M_5	0.16	0.34	0.54	0.347
	M_6	0.78	0.94	1	0.907
C_4	M_1	0.42	0.62	0.78	0.607
	M_2	0.24	0.42	0.64	0.433
	M_3	0.26	0.46	0.66	0.46
	M_4	0.16	0.34	0.54	0.347
	M_5	0.12	0.3	0.5	0.307
	M_6	0.82	0.96	1	0.927
C_5	M_1	0.74	0.9	0.98	0.873
	M_2	0.34	0.54	0.74	0.54
	M_3	0.7	0.88	0.98	0.853
	M_4	0.5	0.7	0.86	0.687
	M_5	0.26	0.46	0.66	0.46
	M_6	0.78	0.94	1	0.907
C_6	M_1	0.58	0.78	0.94	0.767
	M_2	0.46	0.66	0.84	0.653
	M_3	0.74	0.92	1	0.887
	M_4	0.46	0.66	0.84	0.653
	M_5	0.46	0.66	0.84	0.653
	M_6	0.66	0.84	0.96	0.82
C_7	M_1	0.62	0.82	0.96	0.8
	M_2	0.3	0.5	0.68	0.493
	M_3	0.26	0.46	0.64	0.453
	M_4	0.42	0.62	0.8	0.613
	M_5	0.2	0.38	0.58	0.387
	M_6	0.86	0.98	1	0.947
C_8	M_1	0.66	0.84	0.96	0.82
	M_2	0.38	0.58	0.78	0.58
	M_3	0.82	0.96	1	0.927
	M_4	0.2	0.38	0.58	0.387
	M_5	0.58	0.78	0.94	0.767
	M_6	0.78	0.92	0.98	0.893
C_9	M_1	0.46	0.66	0.84	0.653
	M_2	0.34	0.54	0.72	0.54
	M_3	0.38	0.58	0.78	0.58
	M_4	0.18	0.38	0.58	0.38
	M_5	0.12	0.3	0.5	0.307
	M_6	0.86	0.98	1	0.947
C_{10}	M_1	0.62	0.8	0.92	0.78
	M_2	0.62	0.82	0.96	0.8
	M_3	0.82	0.96	1	0.927
	M_4	0.46	0.66	0.84	0.653
	M_5	0.62	0.82	0.96	0.8
	M_6	0.78	0.94	1	0.907

Table 7: Determine decision matrix for all criteria and maintenance strategy $[X_{ij}]$.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
M_1	0.907	0.727	0.727	0.607	0.873	0.767	0.8	0.82	0.653	0.78
M_2	0.58	0.347	0.493	0.433	0.54	0.653	0.493	0.58	0.54	0.8
M_3	0.873	0.147	0.46	0.46	0.853	0.887	0.453	0.927	0.58	0.927
M_4	0.727	0.727	0.693	0.347	0.687	0.653	0.613	0.387	0.38	0.653
M_5	0.54	0.18	0.347	0.307	0.46	0.653	0.387	0.767	0.307	0.8
M_6	0.927	0.853	0.907	0.927	0.907	0.82	0.947	0.893	0.947	0.907

Table 8: Determine normalized matrix for all criteria and maintenance strategy $[R_{ij}]$.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
M_1	0.978	0.852	0.802	0.655	0.963	0.865	0.845	0.885	0.69	0.841
M_2	0.626	0.407	0.544	0.467	0.595	0.736	0.521	0.626	0.57	0.863
M_3	0.942	0.172	0.507	0.496	0.94	1	0.478	1	0.612	1
M_4	0.784	0.852	0.764	0.374	0.757	0.736	0.647	0.417	0.401	0.704
M_5	0.583	0.211	0.383	0.331	0.507	0.736	0.409	0.827	0.324	0.863
M_6	1	1	1	1	1	0.924	1	0.963	1	0.978

Table 9: Determine the Total Scores (TS) for each maintenance strategy by Simple Additive Weighting (SAW) method.

$TS = [R_{ij}]\,[W_j]$

$$\begin{bmatrix} 0.978 & 0.852 & 0.802 & 0.655 & 0.963 & 0.865 & 0.845 & 0.885 & 0.690 & 0.841 \\ 0.626 & 0.407 & 0.544 & 0.467 & 0.595 & 0.736 & 0.521 & 0.626 & 0.570 & 0.863 \\ 0.942 & 0.172 & 0.507 & 0.496 & 0.940 & 1.000 & 0.478 & 1.000 & 0.612 & 1.000 \\ 0.784 & 0.852 & 0.764 & 0.374 & 0.757 & 0.736 & 0.647 & 0.417 & 0.401 & 0.704 \\ 0.583 & 0.211 & 0.383 & 0.331 & 0.507 & 0.736 & 0.409 & 0.827 & 0.324 & 0.863 \\ 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 0.924 & 1.000 & 0.963 & 1.000 & 0.978 \end{bmatrix} \begin{bmatrix} 0.152 \\ 0.055 \\ 0.076 \\ 0.094 \\ 0.152 \\ 0.152 \\ 0.120 \\ 0.135 \\ 0.048 \\ 0.135 \end{bmatrix}$$

Total score for maintenance strategy (M_1) on the criterion is obtained as (0.978 * 0.152) + (0.852 * 0.055) + (0.802 * 0.076) + (0.655 * 0.094) + (0.963 * 0.152) + (0.865 * 0.152) + (0.845 * 0.120) + (0.885 * 0.135) + (0.690 * 0.048) + (0.841 * 0.135) = 0.963. Similarly, total score for maintenance strategies (M_2), (M_3), (M_4), (M_5), and (M_6) for material handling equipment.

Table 10: Final scores and Ranks for selection of maintenance strategy problem.

Strategy	**Final Scores**	**Ranks**
M_1	0.963	2
M_2	0.696	5
M_3	0.889	3
M_4	0.734	4
M_5	0.642	6
M_6	1.099	1

Result

With the help of fuzzy SAW method the order ranking of maintenance strategy for material handling equipment are as $M_6 > M_1 > M_3 > M_4 > M_2 > M_5$. The result show that breakdown maintenance (M_6) is the best maintenance strategy for material handling equipment and predictive maintenance (M_5) is the poor maintenance strategy for material handling equipment.

Conclusion

In maintenance department of Punj Lloyd plant Gwalior is difficult problem for selecting the maintenance strategy. This study presents a multi-criteria decision making (MCDM) for evaluation of maintenance strategy for material handling equipment by implementing Fuzzy Simple Additive Weighting (FSAW) method. An optimal maintenance strategy can improve reliability levels of material handling equipment and reduce unnecessary investment in maintenance of material handling equipment.

Finally, observing all these results, Fuzzy Simple Additive Weighting (FSAW) method proposes breakdown maintenance (M_6) strategy as the best choice.

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References

Massimo Bertolini, Maurizio Bevilacqua. (2006),A combined goal programming-AHP approach to maintenance selection problem. *Reliability Engineering and System Safety*; 91(7):839-848

Yatomi Masataka, Takahashi Jun, Baba Hidenari, Kohinata Toshiharu, Fuji Akio (2004), Application of risk-based maintenance on materials handling system ; 37(2).

Asis Sarkar, Dhiren Kumar Behera, Bijan Sarkar (2011),The maintenance strategy selection of a gas turbine power plant system. JIOM ; 2(1): 09-16.

Mohammad akhshabi (2011),A new fuzzy multi criteria model for maintenance policy. *Middle-East Journal of scientific Research* ; 10(1):33-38.

Azizollah Jafari, Mehdi Jafarian, Abalfazl Zareei, Farzad Zaerpour (2008), Using Fuzzy Delphi Method in Maintenance Strategy Selection Problem. *Journal of Uncertain Systems* ; 2(4):289-298.

Zadeh L. A (1965), fuzzy sets. Information control ; 8:338-353.

L. A. Zadeh (1975), The concept of a linguistic variable and its application approximate reasoning, part 1, 2, and part 3, Information Sciences ; 8(3):199-249, (1975); 8(4):301-357, (1975); 9(1):43-80.

Irfan Ertugrul, Nilsen Karakasoglu (2008), Comparison of fuzzy AHP and Fuzzy TOPSIS methods for facility location selection. *International Journal advanced Manufacturing Technology* ; 39:783-795.

Deng H (1999),Multi criteria analysis with fuzzy pair-wise comparison. International Journal Approximate Reason ; 21:215-231.

Ying-Ming Wang, Taha M. S. Elhag (2006), Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment. *Expert systems with applications* ; 31:309-319.

Widayanti-Deni, Oka-Sudana, Arya-Sasmita (2013), Analysis and implementation fuzzy multi-attribute decision making SAW method for selection of achieving students in faculty level. *International journal of computer science* ; 10(2):674-680.