Solution of Maintenance Strategy Selection Problem by using modified Fuzzy TOPSIS for of Material Handling Equipment

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Abstract:

In today's competitive production environment, maintenance is one of the most important issues. Today in manufacturing plants productive methods are used to improve operating capacities that change environmental factors that lead to a competitive market. There is thus an important role to play in achieving those goals in selecting and explaining an optimal maintenance plan. Furthermore, there is a lack of an integrated model consisting of available requirements and choices, a systematic approach to maintenance instructions and strong maintenance decisions. In this paper modified Fuzzy TOPSIS method has been used for the solution of maintenance strategy selection problem. Linguistic variable and triangular fuzzy number have been used for modification in multi-criteria decision-making to solve maintenance strategy selection problem. Five experts have been considered for six types of maintenance strategy and ten decision criteria have been used in this problem. In this paper breakdown maintenance strategy best one out of all maintenance strategy for material handling equipment.

Keywords: *Maintenance strategy selection; Multi-criteria decision-making; Fuzzy TOPSIS method; Triangular fuzzy number; Linguistic variables.*

1. Introduction

Proper plant maintenance will significantly reduce total operating costs while increasing plant profitability. In order to provide maintenance personnel with improved technological and management skills [1], new technology and management experience must be emerging. In many companies, there is a strong motivation to optimize their equipment and plants ' life. This means that plants and machinery can go further than their original design life. Damage and efficiency analysis has therefore recently become a critical tool to improve maintenance strategy, ensure safety and reduce costs [2].

Maintenance is an unavoidable cause of costs for many businesses. The maintenance function of these companies is corrective and is carried out only under emergency conditions. In view of certain key aspects such as product quality, protection of installations

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and rises in maintenance costs between 15% and 70% of total cost of production, this type of interference can now be no longer accepted. [3]. Many plants have different reliability, risk, and failure criteria for different machines. It is therefore evident that different maintenance strategies for different machines must be defined in a proper maintenance program. This makes it possible to preserve production plants ' reliability and availability at an acceptable level and to prevent unnecessary investments to implement an improper maintenance strategy [4].

In the evaluation of related factors the problem of choosing maintenance approaches is a multi-criteria decision-making (MCDM). A number of solutions were proposed using fuzzy principles to solve this problem. The paper suggests a new maintenance strategy that can be the most effective maintenance strategies, depending on the level of uncertainty and also the nature and importance of the maintenance requirements [5].

Of fact, making the best possible alternative is the way to make choices. In some cases, decision-making problems are the main problem given other parameters. TOPSIS describes ideal solutions as positive and ideal solutions as negative. For the cost criteria and for the benefit criteria the positive solution is minimum and the negative ideal solution is minimum for benefit criteria and maximum for cost criteria [4]. In other types, the best possible values for the criteria consist of the optimal solution and all the worst values for the acquisition of the criteria are negative ideal solutions. As TOPSIS is an effective MCDM tool, a number of researchers have already used TOPSIS to solve many decision-making issues. Some of them de-fuzzy scores and weight in crisp values, other information has been lost during de-fuzzification. [6-8].

For the positive, ideal solution and the ideal negative solution based on criteria, Chen developed normalized values [9]. Standardized values are always $(0, 0, 0)$ and $(1, 1, 1)$ respectively for the ideal negative solution and

ideal positive solution on parameters. $(0, 0, 0)$ and $(1, 1, 1)$ are extraordinary values that could be a long way from true min and high values, so that TOPSIS ' maximum and minimum estimates were not capable of extraordinary values. In Chen's work weight criteria are classified as triangular fuzzy numbers and triangular weight fuzzy numbers depending on loss of unusual values [5]. Chan's estimation is therefore very simple but incorrect triangle fuzzy numbers cannot be expressed. We have appointed fuzzy TOPSIS for the decision-making process of several criteria for a fluffy environment in order to avoid these problems [10].

The Fuzzy Technique for Order Preference by Similarity to Ideal Solution method (FTOPSIS) for the evaluation of maintenance strategies is used by some modification, In FTOPSIS Triangular Fuzzy Number (TFN) is used to model the uncertainty in the selection and the maintenance strategy selection problem is based on a fuzzy linguistic approach [11].

The remaining of this paper is organized as follows: in Section 2, the comprehensive detail of linguistic variable, fuzzy sets, and fuzzy numbers. In Section 3 the proposed fuzzy TOPSIS and the concepts behind it are introduced in details. In Section 4, the modified fuzzy TOPSIS ethod has been implemented for the solution of maintenance strategy selection problem. Finally, conclusions are given in Section 5.

2. Some Basic Concepts

Zadeh [12] first proposed the fuzzy set theory in order to deal with the vagueness of human thinking. A fuzzy collection is a class of things in which membership rates are constant. Such items are marked with a membership function that assigns a range of zero membership to one object. [12].

A linguistic variable is a variable with linguistic values. Intuitively easy-to-use linguistic terms were found to convey a

decision-maker's subjectivity and/or conceptual inaccuracy [13].

Depending on the situation, different fuzzy numbers can be used. It is often convenient for applications to work with triangle fuzzy number (TFN) and useful for promoting the representation and processing of information in a sophisticated environment because of its computational simplicity [14].

Definition 1. If all the decision makers are the highest in terms of performance of an alternative with respect to certain c_n parameters, then the alternative is the GPIS criteria c_n , named G^+.

Definition 2. If all the decision makers are the lowest in terms of performance of an alternative with respect to certain c_n parameters, then the alternative is the GPIS criteria c_n , named G^- .

In many MCDM implementations, such as supplier evaluation and selection, group decision-making and performance analysis, Fuzzy TOPSIS has been described as a dominant method [15]. Junior et al. (2014) conducted an analysis of the merits of the two techniques for MCDM problems between the fuzzy TOPSIS and the fuzzy analytical hierarchy (AHP) and found Fuzzy TOPSIS is the best way to find an ideal solution [16]. It can also be used to simplify the selection process and resolve ambiguities and uncertainty. Therefore, for a multi-criteria group decision-making scenario, we described Fuzzy TOPSIS process.

In this study TFNs are adopted in the fuzzy TOPSIS methods.

3. Proposed Fuzzy TOPSIS Method

Through MAX and MIN operations, we can find the positive ideal and negative ideal solutions, though against the criteria of positive ideal and negative ideal solution, this fuzzy number can be picked up by MAX and MIN operations which have been conceivable alternative cannot be found on rating. In this paper, another generally selected $TOPSIS$ that

replaces U_p and L_o operations for MAX and MIN operations. By U_p and L_o operations, a set of fuzzy numbers is ranked quickly. On this occasion, we effectively find the ideal solution and negative ideal solution, and the fuzzy number can be found extra on these conceivable alternatives against the criteria of the positive ideal and negative ideal solution.

The various steps of Fuzzy TOPSIS method are presented as follows:

STEP 1: Firstly, performance rating and weight are estimated with verbal terms. It represents the performances under linguistics classification, standardized by specialists, are:
very low (VL),
low (L),
medium low (ML),
medium (M),
medium high (MH),
high (H) *and*
very high (VH).

Choosing committee of experts for decision-making. $(E_k; k = 1, 2 \dots n)$ and then to alternative M_i against choosing the criteria $(C_j; j = 1, 2 \dots m)$ where $G_{ijk} = (g_{1ijk}, g_{2ijk}, g_{3ijk})$ is a triangular fuzzy number.

STEP 2: By using extension principle find the average performance rating of alternative M_i against criterion c_j, is G_{ij} as

$$G_{ijk} = \left(g_{1ijk}, g_{2ijk}, g_{3ijk}\right)$$
$$= {}^1/_p \times \left(G_{ij1} + G_{ij2} + \cdots + G_{ijp}\right)$$

By the extension principle, we have

$$g_{1ij} = \sum_{k=1}^{p} \frac{g_{1ijk}}{p}$$
$$g_{2ij} = \sum_{k=1}^{p} \frac{g_{2ijk}}{p}$$
$$g_{3ij} = \sum_{k=1}^{p} \frac{g_{3ijk}}{p}$$

STEP 3: The performance ratings of alternative $M_1, M_2, M_3 \dots$ composed a decision matrix that is, $G = [G_{ij}]_{mXn}$, $[G_{i1}, G_{i2}, \dots G_{in}]$ are the performance ratings of alternative M_i .

Let M^- and M^+ are the negative ideal solution and positive ideal solution respectively;
Thus
$M^- = [G_1^-, G_2^-, \ldots G_n^-]$ and
$M^+ = [G_1^+, G_2^+, \ldots G_n^+]$
where $G_j^- = L_o[G_{i1}, G_{i2}, \ldots G_{im}]$ and $G_j^+ = U_p[G_{i1}, G_{i2}, \ldots G_{im}]$ for $j = 1, 2, \ldots, n$.

STEP 4: Next find the distance from alternatives to the negative ideal solution (or positive ideal solution). Let d_{ij}^- and d_{ij}^+ be the distance from G_{ij} to G_j^- and G_j^+ respectively;
where $i = 1, 2, \ldots, m; j = 1, 2, \ldots, n$.
Let $A = (a_1, a_2, a_3)$ and $B = (b_1, b_2, b_3)$ be two triangular fuzzy numbers. So by the definition of distance,
$d(A, B) =$
$$\sqrt{\frac{1}{3}[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2}$$

STEP 5: Let $W_{jk} = (w_{1jk}, w_{2jk}, w_{3jk})$ are weight evaluated by expert and E_k under criterion C_j, where $j = 1, 2, \ldots, n; k = 1, 2, \ldots, p$
Suppose W_j be the average weight on criterion C_j is
$$W_j = (w_{1j}, w_{2j}, w_{3j})$$
$$= \frac{1}{p} \times (W_{j1} + W_{j2} + \cdots + W_{jp})$$
where $j = 1, 2, \ldots, n$.
From the extension principle,
$w_{1j} = \sum_{k=1}^{p} \frac{w_{1jk}}{p}$
$w_{2j} = \sum_{k=1}^{p} \frac{w_{2jk}}{p}$
$w_{3j} = \sum_{k=1}^{p} \frac{w_{3jk}}{p}$

STEP 6: The weight distance of alternative M_i to negative ideal solution M^- and ideal solution M^+ respectively are find D_i^- and D_i^+.
$D_i^- = \sum_{j=1}^{n} W_j \times d_{ij}^-$
and
$D_i^+ = \sum_{j=1}^{n} W_j \times d_{ij}^+$,
where $i = 1, 2, \ldots, m$.

STEP 7: Weighted distance of M_i can be find by $[D_i^-, D_i^+]$;
$LD^- = Lo(\{D_1^-, D_2^-, \ldots D_m^-\})$
$UD^- = Up(\{D_1^-, D_2^-, \ldots D_m^-\})$
$LD^+ = Lo(\{D_1^+, D_2^+, \ldots D_m^+\})$
$UD^+ = Up(\{D_1^+, D_2^+, \ldots D_m^+\})$

STEP 8: From these two operations Lo and Up, the negative ideal solution is $[LD^-, UD^+]$ and the ideal solution is $[UD^-, LD^+]$ find for weighted distance of all alternatives.

STEP 9: Let M_i^- are the distance from $[D_i^-, D_i^+]$ to $[LD^-, UD^+]$, and M_i^+ denote the distance from $[D_i^-, D_i^+]$ to $[UD^-, LD^+]$.
Define
$M_i^- = d(D_i^-, LD^-) + d(D_i^+, UD^+)$
And
$M_i^+ = d(D_i^-, UD^-) + d(D_i^+, LD^+)$
where $i = 1, 2, \ldots, m$.

STEP 10: Closeness coefficient M_i^* of alternative A_i is defined as:
$M_i^* = \frac{M_i^-}{M_i^- + M_i^+}$
where $i = 1, 2, \ldots, m$.
If $M_i^* = 0$, alternative M_i will be the poorest.
And $M_i^* = 1$ M_i is the best alternative.

4. Maintenance Strategy Selection Problem for Material Handling Equipment

In this problem their five experts, such as:
$E_1 = Expert\ 1$
$E_2 = Expert\ 2$
$E_3 = Expert\ 3$
$E_4 = Expert\ 4$
$E_5 = Expert\ 5$
And six maintenance strategies:
$M_1 =$ corrective maintenance,
$M_2 = preventive\ maintenance$,
$M_3 =$ condition based maintenance
$M_4 =$ opportunistic maintenance
$M_5 =$ predictive maintenance
$M_6 =$ breakdown Maintenance

Also this problem includes 10 evaluation criteria, such as:

C_1 = quality
C_2 = spare parts inventories
C_3 = purchasing cost of spare parts
C_4 = *maintenance labour cost*
C_5 = reliability
C_6 = safety
C_7 = maintenance time
C_8 = facilities
C_9 = cost of supporting equipment
C_{10} = environment

The different weights of priority of each criterion and strategy are calculated using the fuzzy TOPSIS method following the construction of the hierarchy. Linguistic variables are represented in Table 1.

Table I. Fuzzy numbers and corresponding linguistic variables

Linguistic Variables	Fuzzy Number
Very low (VL)	$(0.0, 0.0, 0.1)$
Low (L)	$(0.0, 0.1, 0.3)$
Medium low (ML)	$(0.1, 0.3, 0.5)$
Medium (M)	$(0.3, 0.5, 0.7)$
Medium high (MH)	$(0.5, 0.7, 0.9)$
High (H)	$(0.7, 0.9, 1.0)$
Very High (VH)	$(0.9, 1.0, 1.0)$

Step 1: The performance ratings of the six maintenance strategies in linguistic term is presented in Table 2.

Table II. Experts have assigned the correct rating in terms of linguistic variables for each criterion

C_j	M_1	M_2	M_3	M_4	M_5	M_6
C_1	H, VH, H, H, V	M, MH, M, M, I	H, H, VH, VH, M	M, MH, H, H, M	ML, M, MH, M	VH, H, VH, H, V
C_2	H, MH, M, MH	$M, ML, M, ML,$	L, VL, L, ML, L	$MH, H, H, MH,$	$L, VL, ML, ML,$	VH, H, H, H, M
C_3	H, MH, M, MH	$ML, M, M, ML,$	ML, M, MH, M, I	MH, H, M, MH	L, ML, M, ML, I	H, H, VH, VH, I
C_4	ML, M, H, H, M	H, M, L, ML, M	M, MH, M, ML, I	ML, ML, M, L, I	L, ML, ML, ML	H, VH, VH, H, V
C_5	$H, VH, VH, H,$	ML, M, M, MH	H, H, VH, H, MH	MH, H, M, M, H	ML, M, MH, M	H, H, VH, VH, I
C_6	H, MH, MH, H	MH, M, M, MH	H, H, VH, H, H	H, MH, M, M, N	M, MH, H, MH	$H, H, VH, MH,$
C_7	H, MH, H, H, M	$M, M, ML, ML,$	M, ML, ML, H, N	$M, ML, MH, H,$	MH, M, ML, M	VH, H, VH, VH
C_8	H, VH, H, MH	MH, M, M, MH	VH, H, VH, H, V	$M, ML, L, MH,$	H, MH, H, MH	MH, H, VH, VH
C_9	H, M, MH, M, I	$M, ML, ML, H,$	M, MH, MH, ML	$ML, ML, M, M,$	ML, L, ML, ML	VH, VH, H, VH
C_{10}	M, H, MH, H, V	H, MH, MH, H	$VH, H, VH, VH,$	M, H, MH, M, N	H, H, H, MH, M	VH, H, H, VH, I

Step 2: The average ratings of the six maintenance strategies is in Table 3.

Table III. Average ratings of maintenance strategies

C_j	M_1	M_2	M_3	M_4	M_5	M_6
C_1	0.78,0.94,1.0	0.38,0.58,0.7	0.74,0.90,0.9	0.54,0.74,0.9	0.34,0.54,0.7	0.82,0.96,1.0
C_2	0.54,0.74,0.4	0.16,0.34,0.5	0.02,0.12,0.3	0.54,0.74,0.9	0.02,0.16,0.3	0.70,0.88,0.9
C_3	0.54,0.74,0.9	0.30,0.50,0.6	0.26,0.46,0.6	0.50,0.70,0.8	0.16,0.34,0.5	0.78,0.94,1.0
C_4	0.42,0.62,0.7	0.24,0.42,0.6	0.26,0.46,0.6	0.16,0.34,0.5	0.12,0.30,0.5	0.82,0.96,1.0
C_5	0.74,0.90,0.9	0.34,0.54,0.7	0.70,0.88,0.9	0.50,0.70,0.8	0.26,0.46,0.6	0.78,0.94,1.0
C_6	0.58,0.78,0.9	0.46,0.66,0.8	0.74,0.92,1.0	0.46,0.66,0.8	0.46,0.66,0.8	0.66,0.84,0.9
C_7	0.62,0.82,0.9	0.30,0.50,0.6	0.26,0.46,0.6	0.42,0.62,0.8	0.20,0.38,0.5	0.86,0.98,1.0
C_8	0.66,0.84,0.9	0.38,0.58,0.8	0.82,0.96,1.0	0.20,0.38,0.5	0.58,0.78,0.9	0.78,0.92,0.9
C_9	0.46,0.66,0.8	0.34,0.54,0.7	0.38,0.58,0.7	0.18,0.38,0.5	0.12,0.30,0.5	0.86,0.98,1.0

| C_{10} | 0.62,0.80,0.9 | 0.62,0.82,0.9 | 0.82,0.96,1.0 | 0.46,0.66,0.8 | 0.62,0.82,0.9 | 0.78,0.91,1.0 |

Step 3: By the performance ratings of alternative composed a decision-making matrix G is in Table 4.

Table IV. Decision-making matrix

$G_1^+ =0.82,0.96,1.00$	$G_6^+ =0.74,0.92,1.00$	$G_1^- =0.34,0.54,0.74$	$G_6^- =0.46,0.66,0.84$
$G_2^+ = 0.70,0.88,0.98$	$G_7^+ =0.86,0.98,1.00$	$G_2^- =0.02,0.12,0.30$	$G_7^- =0.20,0.38,0.58$
$G_3^+ =0.78,0.94,1.00$	$G_8^+ =0.82,0.96,1.00$	$G_3^- =0.16,0.34,0.54$	$G_8^- =0.20,0.38,0.58$
$G_4^+ =0.82,0.96,1.00$	$G_9^+ =0.86,0.98,1.00$	$G_4^- =0.12,0.30,0.50$	$G_9^- =0.12,0.30,0.50$
$G_5^+ =0.78,0.94,1.00$	$G_{10}^+ = 0.82,0.96,1.00$	$G_5^- =0.26,0.46,0.66$	$G_{10}^- =0.46,0.66,0.84$

Step 4: The distance values for the six maintenance strategies on 10 criteria is in Table 5.

Table V. Distance values for maintenance strategies

C_j	M_1		M_2		M_3	
	d (G_{1j}, G_{j+})	d $(G_{1j}, G_{j}-)$	d(G_{2j}, G_{j+})	d$(G_{2j}, G_{j}-)$	d(G_{3j}, G_{j+})	d$(G_{3j}, G_{j}-)$
C_1	0.08246	0.3747	0.3589	0.0400	0.0589	0.3402
C_2	0.1311	0.5816	0.5089	0.2046	0.7077	0.0000
C_3	0.1894	0.3804	0.4189	0.1469	0.4533	0.1137
C_4	0.3286	0.3004	0.5125	0.1137	0.4758	0.1536
C_5	0.0346	0.4189	0.3747	0.0800	0.0589	0.3968
C_6	0.1275	0.1137	0.2392	0.0000	0.0000	0.2392
C_7	0.1681	0.4141	0.4642	0.1071	0.5033	0.0673
C_8	0.1178	0.4350	0.3514	0.2082	0.0000	0.5469
C_9	0.3098	0.3468	0.4252	0.2269	0.03824	0.2735
C_{10}	0.1549	0.1311	0.1428	0.1479	0.0000	0.2859
C_j	M_6		M_6		M_6	
	d(G_{4j}, G_{j+})	d$(G_{4j}, G_{j}-)$	d(G_{5j}, G_{j+})	d$(G_{5j}, G_{j}-)$	d(G_{6j}, G_{j+})	d$(G_{6j}, G_{j}-)$
C_1	0.2135	0.1876	0.3977	0.0000	0.0000	0.3977
C_2	0.1311	0.5816	0.6808	0.0327	0.0000	0.7077
C_3	0.2239	0.3468	0.5645	0.0000	0.0000	0.5540
C_4	0.5864	0.0400	0.6260	0.0000	0.0000	0.6260
C_5	0.2277	0.2274	0.4533	0.0000	0.0000	0.4532
C_6	0.2392	0.0000	0.2392	0.0000	0.0693	0.1701
C_7	0.3479	0.2269	0.5692	0.0000	0.0000	0.5692
C_8	0.5469	0.0000	0.1736	0.3934	0.0346	0.5125
C_9	0.5770	0.7394	0.6481	0.0000	0.0000	0.6481
C_{10}	0.2859	0.0000	0.1428	0.1479	0.0258	0.2622

Step 5: The linguistic weights and average ratings for 10 criteria are in Table 6-7.

Table VI. Linguistic weights for criteria

C_j	E_1	E_2	E_3	E_4	E_5
C_1	VH	H	VH	VH	H
C_2	MH	M	ML	L	VL
C_3	M	ML	M	MH	ML
C_4	MH	H	ML	M	M
C_5	VH	H	H	VH	VH
C_6	H	VH	H	VH	VH
C_7	MH	M	H	MH	H
C_8	H	MH	VH	H	MH
C_9	L	ML	M	M	VL
C_{10}	MH	H	VH	H	MH

Table VII. Average ratings

C_j	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	0.0,0.0,1.0,0.3	0.1,0.3,0.5	0.3,0.5,0.7	0.3,0.5,0.7	0.0,0.0,0.0,0.1
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

Calculated average weights against the 10 criteria from Table 7 are:

$W_1 = (0.82, 0.96, 1.00)$
$W_2 = (0.18, 0.32, 0.50)$
$W_3 = (0.26, 0.46, 0.66)$
$W_4 = (0.38, 0.58, 0.76)$
$W_5 = (0.82, 0.96, 1.00)$
$W_6 = (0.82, 0.96, 1.00)$
$W_7 = (0.54, 0.74, 0.90)$
$W_8 = (0.66, 0.84, 0.96)$
$W_9 = (0.14, 0.28, 0.46)$
$W_{10} = (0.66, 0.84, 0.96)$

Step 6: The weighted distance values of six maintenance strategies on 10 criteria are presented as follows.

$D_1^+ = (1.3209, 1.7071, 1.9826)$
$D_2^+ = (1.8293, 2.4644, 2.9810)$
$D_3^+ = (0.8680, 1.3035, 1.7613)$
$D_4^+ = (1.6803, 2.2561, 2.7167)$
$D_5^+ = (2.0081, 2.7557, 3.3931)$
$D_6^+ = (0.0969, 0.1175, 0.1276)$
$D_1^- = (1.7075, 2.2854, 2.7531)$
$D_2^- = (0.5413, 0.7561, 0.9483)$
$D_3^- = (1.5127, 1.9045, 2.1538)$
$D_4^- = (0.7764, 1.1422, 1.5094)$
$D_5^- = (0.4161, 0.5593, 0.6831)$

$D_6^- = (2.2559, 3.0780, 3.7704)$

Step 7: The values of weighted distance are given below

$LD^+ = (0.0969, 0.1175, 0.1276)$
$UD^+ = (2.0081, 2.7557, 3.3931)$
$LD^- = (0.4161, 0.5593, 0.6831)$
$UD^- = (2.2559, 3.0780, 3.7704)$

Step 8: Positive and negative ideal solutions from weighted distance are given below

$d(D_1^+, UD^+) = 1.0893$
$d(D_1^+, LD^+) = 1.5774$
$d(D_2^+, UD^+) = 0.8378$
$d(D_2^+, LD^+) = 2.3559$
$d(D_3^+, UD^+) = 1.4224$
$d(D_3^+, LD^+) = 1.2477$
$d(D_4^+, UD^+) = 0.5209$
$d(D_4^+, LD^+) = 2.1435$
$d(D_5^+, UD^+) = 0.0000$
$d(D_5^+, LD^+) = 2.6629$
$d(D_6^+, UD^+) = 2.6629$
$d(D_6^+, LD^+) = 0.0000$

and

$d(D_1^-, UD^-) = 0.8091$
$d(D_1^-, LD^-) = 1.7255$
$d(D_2^-, UD^-) = 2.3532$
$d(D_2^-, LD^-) = 0.2039$
$d(D_3^-, UD^-) = 1.2306$
$d(D_3^-, LD^-) = 1.3134$
$d(D_4^-, UD^-) = 1.9191$
$d(D_4^-, LD^-) = 0.6198$
$d(D_5^-, UD^-) = 2.5338$
$d(D_5^-, LD^-) = 0.0000$
$d(D_6^-, UD^-) = 0.0000$
$d(D_6^-, LD^-) = 2.5338$

Step 9: From these above distance values, M_i^+ and M_i^- can be calculated:

$M_1^+ = 2.3865 \quad M_1^- = 2.8148$
$M_2^+ = 4.7091 \quad M_2^- = 1.0417$
$M_3^+ = 2.4783 \quad M_3^- = 2.7358$
$M_4^+ = 4.0626 \quad M_4^- = 1.1407$
$M_5^+ = 5.1967 \quad M_5^- = 0.0000$
$M_6^+ = 0.0000 \quad M_6^- = 5.1967$

Step 10: Finally, all the results are evaluated, final Scores and ranks are given in Table 8.

$M_1^* = 0.5412$
$M_2^* = 0.1811$
$M_3^* = 0.5247$
$M_4^* = 0.2192$
$M_5^* = 0.0000$
$M_6^* = 1.0000$

Table VIII. Final Scores and ranks of strategies

Strategy	Final Scores	Ranks
M_1	0.5412	2
M_2	0.1811	5
M_3	0.5247	3
M_4	0.2192	4
M_5	0.0000	6
M_6	1.0000	1

Clearly, from Table 8 the ranking order is $M_6 > M_1 > M_3 > M_4 > M_2 > M_5$

Therefore, performances of M_6 is the best.

5. Result and Discussion

The result reported in [17] the same problem has been solved with the help of fuzzy SAW method the order ranking of maintenance strategy for material handling equipment. The results are as follows

$M6 > M1 > M3 > M4 > M2 > M5$.

And from the above experimentation we have the same results which showed 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.

6. Conclusion

In this paper modified Fuzzy TOPSIS method has been used for the solution of maintenance strategy selection problem. Linguistic variable and triangular fuzzy number have been used for modification in multi-criteria decision-making to solve maintenance strategy selection

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problem. Five experts have been considered for six types of maintenance strategy and ten decision criteria have been used in this problem. Two operators U_p and L_o, which satisfied fuzzy numbers of partial ordering relations for generalized of TOPSIS, these two operations are used to determine the negative ideal and positive ideal solutions in a fuzzy environment. Ultimately, it is concluded that the malfunction management approach for equipment for material handling is best of all maintenance strategies.

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