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Application of MCDM approaches: A study of evaluating performance and selection of machines in an automobile industry

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ABSTRACT

Multiple Criteria Decision Making (MCDM) is all about making choices in the presence of multiple conflicting criteria. MCDM process plays an important role in the field of engineering, government activities and different field of science and technology. Multi-criteria decision making methods have evolved to accommodate various types of applications. Some methods have been developed, with even small variations to existing methods causing the creation of new branches of research. This report performs a case study of tyre curing electric chamber performance and selection by evaluating data taken from industrial experts at automobile industry by four deterministic multi-criteria decision making methods are to be studied. So as to choose the best alternative among the available options against the conflicting criteria.

Key words: Tyre curing electric chamber, AHP, SAW, WPM, TOPSIS

INTRODUCTION

MCDM – An Overview: Now in a day's evaluating the performance of a company has a major importance not only for managers, creditors and investors but also for the companies taking place in the same field. Multi-Criteria Decision Making (MCDM) has been seen an highly amount of use over the last several decades. Its (MCDM) role in different application areas has increased significantly, especially as new methods develop and as old methods improve. This report analyzes several common multi-criteria decision making methods and determines their applicability to different situations (tyre curing electric chamber selection) by evaluating their data taken from industrial expert for performance and selection.

Kwong et al. [1] has introduced fuzzy number in the pairwise comparison of AHP. An AHP based on fuzzy scales has been proposed to determine the importance weights of customer requirements. This approach has improved the imprecise ranking of customer requirements which is based on the conventional AHP.

The main purpose of Albayrak, et al. in [2], is to solve the human performance improvement problem by employing AHP method. As it is well-known, the AHP consist of decomposing a complex problem into its components into sets locating into levels to generate a hierarchy structure. The aim of constructing such a hierarchy is to determine the impact of lower-level elements on an upper level criterion, which is achieved by pairwise comparison provided by the decision makers (DMs).

The comparisons are made using a scale of absolute judgements that represents, how much more, one element dominates another with respect to a given attribute by Thomas L. Saaty in [3]. The judgements may be inconsistent, and how to measure inconsistency and improve the judgements, when possible to obtain better consistency is a concern of the AHP.

The weapon selection problem is a strategic issue and has a significant impact on the efficiency of defence systems. On the other hand, selecting the optimal weapon among many alternatives is a multi-criteria decision-making (MCDM) problem. Metin et al. in [4] develops an evaluation model based on the analytic hierarchy process (AHP) and the technique for order performance by similarity to ideal solution (TOPSIS), to help the actors in defence industries for the selection of optimal weapon in a fuzzy environment where the vagueness and subjectivity are handled with linguistic values parameterized by triangular fuzzy numbers. The AHP is used to analyze the structure of the weapon selection problem and to determine weights of the criteria, and fuzzy TOPSIS method is used to obtain final ranking.

A MCDM methodology for Personnel selection. To increase the efficiency and ease-of-use of the proposed model. Afshariet et al. [5] has applied seven criteria that they are qualitative and positive for selecting the best one amongst five personnel and also ranking them. Finally the introduced method is used in a case study.

For selection of a maintenance policy, an MCDM approach is required which should address the problem with crisp data, fuzzy numbers, and linguistic terms. A research has been carried out by Chan et al. [6] on the selection of maintenance policy on the basis of several selection criteria. The research has been considered as a strategic decision because the selection has been made at the plant or organization level instead of the equipment level. Moreover, a distance-based fuzzy MCDM approach has been employed.

For selection of alternatives Sharma in [7] has studied multi attribute decision making techniques using three different decision support tools namely Simple Additive Weighting Method (SAW), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Analytical Hierarchy Process (AHP). The observations suggest that Multi Criteria Decision Making (MCDM) methods should be used as decision support tools and not as the means for deriving the final answer.

This paper presents a review of the applications of simple additive weighting (SAW) and fuzzy simple additive weighting (FSAW) from 2003 to 2013. Two classifications of individual approaches and integrated approaches were made in this paper by Lazim et al. in [8]. Related articles appearing in international journals from 2003 to 2013 are gathered and analyzed. From the observation, it was noticed that ten out of nineteen articles or fifty two percent applied SAW or FSAW in the management selection process. This review provides the most prevalent application of the methods and also aids researchers in choosing the appropriate applications of SAW based methods. This paper would offer useful information for other researchers since it provides the latest evidence about SAW and FSAW.

The purpose of methodology to provide decision methods for project managers in construction companies has been studied by Pangsri in [9]. The methodology has been combined into three methods consisting of Delphi method, Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The observations have shown all methods provide the systematic approach for group decision making that can help project manager prioritize project and this information can help them provide master plan in project management and can be applied in other companies which tend to decide for project selection problem.

This paper presents an integrated multi-criteria decision making (MCDM) model of a fuzzy AHP (analytic hierarchy process) and fuzzy ARAS (additive ratio assessment) for conveyor evaluation and selection. In this model, Nguyen in [10] linguistic terms represented as triangular fuzzy numbers are used to quantify experts' uncertain assessments of alternatives with respect to the criteria. The fuzzy set is then integrated into the AHP to determine the weights of the criteria. Finally, a fuzzy ARAS is used to calculate the weights of the alternatives. To demonstrate the effectiveness of the proposed model, a case study is performed of a practical example, and the results obtained demonstrate practical potential for the implementation of FMCs.

In Temiz et al. [11] have studied the selection of construction equipment by using multi-criteria decision making methods. They applied two different MCDM methods (AHP and PROMETHEE) were applied to construction equipment selection problem and also to compare those MCDM methods. The AHP and PROMETHEE methods were used to rank the four alternatives defined by the decision makers. The results show that the methods are consistent with each other as well as the decision makers' initial assessments of the alternatives.

METHODOLOGY

Collected data for analyses

Table -1 Decision Matrix

	C1	C2	C3	C4	C5	C6	C7
A1	24.5	8	125	3.67	2	8	6
A2	24.0	8	125	3.95	3	7	5
A3	24.0	8	125	4.75	2	7	5
A4	24.0	8	125	4.25	2	8	6
A5	24.0	7	120	3.50	2	7	6

Table -2 Normalized decision matrix

	C1	C2	C3	C4	C5	C6	C7
A1	1.000	1.000	1.000	0.773	0.667	1.000	1.000
A2	0.980	1.000	1.000	0.832	1.000	0.875	0.833
A3	0.980	1.000	1.000	1.000	0.667	0.875	0.833
A4	0.980	1.000	1.000	0.895	0.667	1.000	1.000
A5	0.980	0.875	0.960	0.737	0.667	0.875	1.000

The AHP method

AHP was proposed by T. Saaty in 1980s to model subjective decision-making processes based on multiple criterion in a hierarchical system. From that moment on, it has been widely used in corporate planning, portfolio selection and benefit/cost by government organisation for resource allocation purposes. It should be highlighted that all decision problems are considered as a hierarchical structure in the AHP.

To implement this method, the solution steps are as follows.

Step-1: Define the problem and determine the kind of knowledge sought.

Step-2: Structure the decision hierarchy from the top with the goal of the decision.

Step-3: Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it.

Step-4: Use the priorities obtained from the comparisons to weight the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained.

Table -3 Pairwise Comparison Scale

Degree of preferences	**Verbal judgement of performance**
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Demonstrated importance
9	Absolute importance
2,4,6,8	Intermediate preference between two judgements

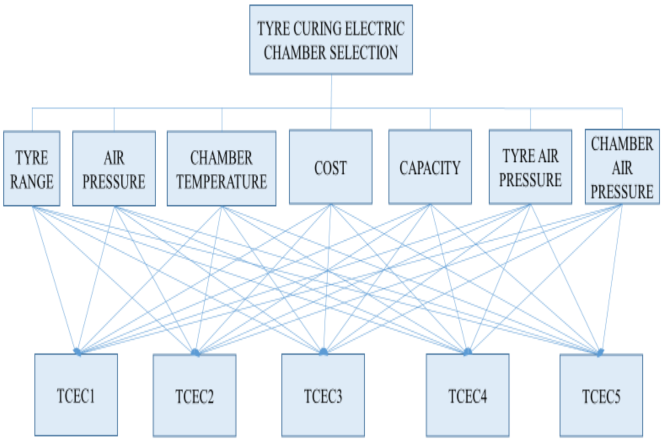

Fig. 1 Hierarchy show the complexity of tyre curing electric chamber selection case study

Table -4 Pairwise comparisons and criteria weights

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**Weight**
C1	1	3	7	2	8	4	6	0.342
C2	1/3	1	5	½	6	2	5	0.166
C3	1/7	1/5	1	1/7	2	¼	3	0.046
C4	½	2	7	1	7	3	8	0.260
C5	1/8	1/6	½	1/7	1	¼	2	0.047
C6	¼	½	4	1/3	4	1	4	0.109
C7	1/6	1/5	1/3	1/8	½	¼	1	0.027

Calculating the consistency ratio:

λmax = Avg. of the A4 matrix = 52.019/7= 7.431

Consistency Index (CI) = (λ_{max} - M)/M – 1 (1)

= (7.431-7)/7-1 = 0.071

Where, M is the size of A1 matrix = 7

Table -5 Random index values

No. of element	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Consistency Ratio = Consistency Index/Random Index

CR = CI/RI (2)

= 0.071/1.35=0.052

As per Saaty that a consistency ratio (CR) of 0.10 or less is acceptable to continue the AHP analysis. So, in this case weight are acceptable.

Table -6 Weights are given below

	C1	C2	C3	C4	C5	C6	C7
Weight	0.342	0.166	0.046	0.260	0.047	0.109	0.027

The SAW method

The SAW is the most popular method in MADM problems, the gaps of alternatives can be improved to build a new best alternative for achieving aspired/desired levels in each attributes and the best alternative can be derived by the following equation:

$$u_i(x) = \sum_{j=1}^{n} w_j r_{ij}(x) \quad (3)$$

Table -7 Defining the score of alternatives by simple additive weighting (SAW) method

	C1	C2	C3	C4	C5	C6	C7	Score
A1	1.00	1.000	1.00	0.773	0.667	1.000	1.000	0.922
A2	0.98	1.000	1.00	0.832	1.000	0.875	0.833	0.928
A3	0.98	1.000	1.00	1.000	0.667	0.875	0.833	0.956
A4	0.98	1.000	1.00	0.895	0.667	1.000	1.000	0.947
A5	0.98	0.875	0.96	0.737	0.667	0.875	1.000	0.877
Wt.	0.342	0.166	0.046	0.260	0.047	0.109	0.027	

So, the ranking of alternatives with SAW method are A3>A4>A2>A1>A5.

The WPM

Weighted Product Method (WPM) is also a another scoring method where the weighted product of the criterion is used to select the best alternative.

The score computing procedure in terms of step 1 and step 2 are similar to SAW.

Step 3: Construct weighted normalized decision matrix

$$vij = rij^{wij} \quad (4)$$

Step 4: Calculate the each alternative.

$$Mi = \prod_{j=1}^{m} vij \quad (5)$$

Step 5: Select the max. score for best alternatives.

Table -8 Defining the score of alternatives by weighted product method (WPM)

	C1	C2	C3	C4	C5	C6	C7	Score
A1	1.00	1.000	1.00	0.773	0.667	1.000	1.000	0.918
A2	0.98	1.000	1.00	0.832	1.000	0.875	0.833	0.928
A3	0.98	1.000	1.00	1.000	0.667	0.875	0.833	0.956
A4	0.98	1.000	1.00	0.895	0.667	1.000	1.000	0.947
A5	0.98	0.875	0.96	0.737	0.667	0.875	1.000	0.866
Wt.	0.342	0.166	0.046	0.260	0.047	0.109	0.027	

So, the ranking of alternatives with WPM are A3>A4>A2>A1>A5.

The TOPSIS method

TOPSIS technique has been commonly used to solve decision-making problems. This technique is based on the comparison between all the alternatives included in the problem. This proposed technique can be highly useful in large scale decision-making problems as often found in aviation and automotive industries.

Ranking of alternatives by Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method:

Step1: Normalize the decision matrix, using equation,

$$R_{ij} = \bar{x_{ij}} \Big/ \sqrt{\sum_{k=1}^{n} x_{ik}^2} \quad (6)$$

Table -9 Normalize decision matrix

	C1	C2	C3	C4	C5	C6	C7
A1	0.454	0.458	0.451	0.405	0.400	0.482	0.477
A2	0.445	0.458	0.451	0.436	0.600	0.422	0.398
A3	0.445	0.458	0.451	0.525	0.400	0.422	0.398
A4	0.445	0.458	0.451	0.469	0.400	0.482	0.477
A5	0.445	0.401	0.433	0.387	0.400	0.422	0.477

Step 2: Weighted normalized decision matrix constructed by multiplying the normalized decision matrix Rij with the associated weights wj as follows:

$$V_{ij} = w_j R_{ij} \quad (7)$$

Table -10 Weighted normalize decision matrix

	C1	C2	C3	C4	C5	C6	C7
A1	0.155	0.076	0.021	0.105	0.019	0.053	0.013
A2	0.152	0.076	0.021	0.113	0.028	0.046	0.011
A3	0.152	0.076	0.021	0.137	0.019	0.046	0.011
A4	0.152	0.076	0.021	0.122	0.019	0.053	0.013
A5	0.152	0.067	0.020	0.101	0.019	0.046	0.013
Wt.	0.342	0.166	0.046	0.260	0.047	0.109	0.027

Step 3: Determine PIS and NIS : The PIS and NIS can be expressed as:

$$V^* = \{(\sum max\, V_{ij}\ max, j \in B), (\sum min\, V_{ij}\ , j \in C)\} = V_1^*, V_2^*, \ldots\ V_n^* \quad (8)$$

$$V^- = \{(\sum min\, V_{ij}\ max, j \in B), (\sum max\, V_{ij}\ , j \in C)\} = V_1^-, V_2^-, \ldots\ V_n^- \quad (9)$$

V^* = [0.155, 0.076, 0.021, 0.137, 0.028, 0.053, 0.013]

V^- = [0.152, 0.067, 0.020, 0.101, 0.019, 0.046, 0.011]

Step 4: Compute the separation measurement by using

$$S^* = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^*)^2} \quad (10)$$

$$S^- = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^-)^2} \quad (11)$$

Table -11 Separation measurement

Positive ideal Solution	Negative ideal Solution
S1* = 0.0332	$S1^-$ = 0.0126
S2* = 0.0253	$S2^-$ = 0.0175
S3* = 0.0120	$S3^-$ = 0.0371
S4* = 0.0177	$S4^-$ = 0.0093
S5* = 0.0389	$S5^-$ = 0.0020

Step 5: Determine the relative closeness to Positive ideal solution by using equation,

$$C_i = S^-/(S^* + S^-) \quad (12)$$

Table -12 Relative closeness values

C1*	0.275
C2*	0.409
C3*	0.244
C4*	0.344
C5*	0.490

The closeness rating is the no. between ‘0’ and ‘1’, with ‘0’ being the worst possible and ‘1’ the best possible solution. So, the ranking of alternatives with TOPSIS: A5>A2>A4>A1>A3.

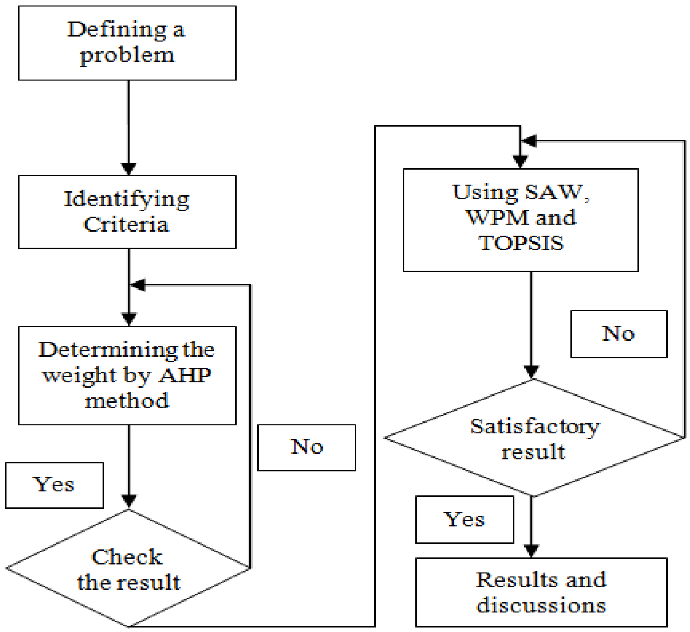

Fig. 2 Research Framework

CONCLUSIONS

Based on various case studies the development in the manufacturing sector are rapidly growing. However, numerous an automobile equipment is available in the market with different qualities and costs make the automobile equipment selection process is a very difficult task. For that reason, the MCDM methods, which play an important role to counter and rank the alternatives analytically, are widely used to solve the equipment selection problem.

The aim of this paper is proper selection of any machine in manufacturing industry or any equipment in any industry by using proposed model.

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