iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 Issue: V Month of publication: May 2018

DOI: http://doi.org/10.22214/ijraset.2018.5145

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

Multi Criteria Decision Making (MCDM) Methods and its applications

Girish P Bhole[1], Dr. Tushar Deshmukh[2]
[1, 2]Mechanical Engineering Department, Sant Gadge Baba Amravati University, Amravati, India.

Abstract: Multi Criteria Decision Making (MCDM) is the quantitative and qualitative method, problem has many solution but to find the solution and to get the appropriate decision regarding the solution is the application of MCDM. This paper gives the information about all the MCDM methods with the applications of maximum MCDM methods to various fields as per the literature. The aim is revel MCDM methods and their applications to understand the nature of MCDM for various problems. The utilization of MCDM to other field gives an idea for the new research area. The review helps to find the problems studied by different researcher and the solution they interpreted by using MCDM methods like ELECTRA, PROMETHEE, TOPSIS, AHP,GP etc. AHP, TOPSIS, MAUT were the most used methods but hybrid or integrated methods gives the solution for problem like location, finance, bankrupt, construction bridges, waste water and many more. This combination creates the new era in MCDM history.
Keywords: MCDM, AHP, TOPSIS, PROMETHEE, ELECTRA, GP, MAUT/MAVT, review

I. INTRODUCTION

MCDM is a technique that associate the alternative decision with qualitative and quantitative results in a compact solutions. These methods can be used for numerous problems encountered in industries and our life to get the sets of decision. MCDM is the decision-making technique used from many decades to judge different alternatives such as policy, strategy, choice get the solution of problems. The journey of MCDM is very old but the development started from 1940s and the 1950s, in 1944 Von Neumann and Morgenstern introduced the utility theory, which become a major procedural streams for modern decision science. The work continue to develop right from goal programming[19]. [18] extended utility theory and [87] form the school of MCDA. The MCDA is now applied to real world problem. The contributions of researcher gives the way to advance computing and develop the user friendly decision making support system. [16-19]

There are many problems in the world's and MCDM is the tools to get the optimize solution of it. Many books were published on MCDM [2-6] to understand the methods and their procedure easily. [52] used AHP to get optimal solution for highway traffic signals. The tool MCDM is being used by many researchers in decision-making process to ensure the most appropriate alternative. They applied MCDM in many ways like [32,122], take the benefits of MAUT and TOPSIS to select the location of land, [54,110,163],uses DEA, Fuzzy GP, VIKOR for waste treatment.[65] applied CBR for finding bankrupt. [56,148,150] applied AHP, VIKOR for health monitoring system and health care system. [202] made a hybrid method by combining three methods including Affinity Diagram, AHP and fuzzy TOPSIS for the improvement of city sustainability by evaluating four city logistics initiatives. For project selection, applied AHP and ANP combination give the decision of project investment studied by [201]. The most famous tool of the multi-criteria decision making methods is the MAUT, AHP, and in recent combination of methods and fuzzy based decision are the methodology for solving complex decisions. It can be applied to business, real life problems, portfolio, governmental sectors and many more.

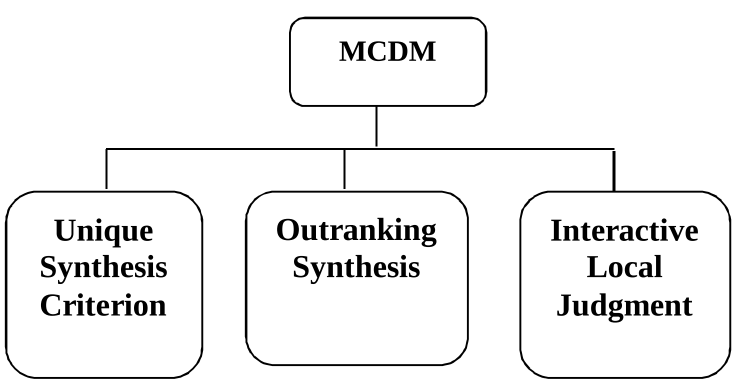
The paper aims to reveal most of the Decision Making methods and the study on these methods, like their classifications, strength, applications etc. The review got many research papers on MCDM who discuss and reveal the strength of the MCDM more clearly and prove the area where MCDM can be used like, supplier selection, supply chain management, health monitoring system, Infrastructure, waste management, strategic management, production management, location selection and many more.

A. MCDM Methods and their Classifications

Your paper must use a page size corresponding to A4 which is 210mm (8.27") wide and 297mm (11.69") long. The margins must be set as follows. MCDM is a potential tool for analysing complex problem by judging different alternatives like policy, scenario, strategy, weightage etc. on various criteria for selecting the best alternative using the mathematical calculation. There are various types of MCDM methods available in the literature. The characteristics of each method is different and it is classify as deterministic, stochastic, or fuzzy MCDM methods and many more [1]. There are number of MCDM methods like [1-16]

1) Aggregated Indices Randomization Method (AIRM)
2) Analytic hierarchy process (AHP)
3) Analytic network process (ANP)
4) Data Envelopment Analysis (DEA)
5) Best worst method (BWM)
6) Characteristic Objects METhod (COMET)
7) Choosing By Advantages (CBA)
8) Data envelopment analysis
9) Decision EXpert (DEX)
10) Disaggregation – Aggregation Approaches (UTA, UTAII, UTADIS)
11) Rough set (Rough set approach)
12) Dominance-based rough set approach (DRSA)
13) ELECTRE (Outranking) Elimination and Choice Translating Reality
14) Evaluation Based on Distance from Average Solution (EDAS)[34]
15) Evidential reasoning approach (ER)
16) Goal programming (GP)
17) Grey relational analysis (GRA)
18) Inner product of vectors (IPV)
19) Measuring Attractiveness by a categorical Based Evaluation Technique (MACBETH)
20) Multi-Attribute Global Inference of Quality (MAGIQ)
21) Multi-attribute utility theory (MAUT)
22) Multi-attribute value theory (MAVT)
23) New Approach to Appraisal (NATA)
24) Non structural Fuzzy Decision Support System (NSFDSS)
25) Potentially All Pairwise Rankings of all possible Alternatives (PAPRIKA)
26) PROMETHEE (Outranking) Preference Ranking Organization Method for Enrichment
27) Evaluation
28) Stochastic Multi criteria Acceptability Analysis (SMAA)
29) Superiority and inferiority ranking method (SIR method)
30) Technique for the Order of Prioritisation by Similarity to Ideal Solution (TOPSIS)
31) PROMETHEE: PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluations)
32) Value analysis (VA)
33) Value engineering (VE)
34) VIKOR method (VlseKriterijumska Optimizacija I Kompromisno).
35) WSM: Weighted Sum Model
36) Weighted Product Model (WPM)

As per the literature methods which are mostly used in study are AHP, ANP, ELECTRE, GP, MAUT, MAVT, PROMETHEE, TOPSIS, WSM. The MCDM method is divided in to three different categories [1, 2, 10]. As Shown below.



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37) Unique synthesis criterion approach: It consists of accumulating all dissimilar interpretation into a unique function, which will optimized. Methods came under this categories are, MAUT [11], SMART family [12] and AHP [13], TOPSIS, etc.
38) Outranking synthesis approach: It aims in the improvement of a relation therefore known an outranking relationship, it gives the preference to the decision-makers, based on information available to explored solution of his/her problems. Like: ELECTRE [1,2,10-14] and PROMETHEE [1,2,10-14].
39) Interactive local judgment approach: This method proposes alternate calculation steps with developed linear programming way with multi objective to get successive compromising solutions. These methods are clearly superior for decision makers due to interactive and successive evaluation of the solution using mathematical calculation and programming tools to get the appropriate decision [1,2,10,12,14,16].

During literature review it is found that decision making techniques can be utilized by analysis of alternatives i.e. number of alternatives and options then determining the relevant criteria and alternatives to get the numerical measures with the relative importance to the criteria and find the impact of the alternatives on these criteria and finally process the numerical values to determine a ranking of each alternative

II. MCDM METHODS AND THEIR APPLICATIONS

In the previous article it is seen that there are various methods of MCDM, the important methods which are more active from last decades are discuss below.

A. *Multi-Attribute Utility Theory(MAUT)*

MAUT was proposed by [24] and developed by using a quasi-additive and multi-linear utility function. [18,25,27] developed this method and make this method as most operated method. The method is developed to handle multiple objectives, intangible factors, risk, qualitative data and time sequence effects in ex-ante appraisals based on the decision-maker's preferences [28]. To steps for MAUT are as follows[28]:

Step: 1 sets the project alternatives.

Step:2 sets the probability distribution for outcomes associated with each alternatives for each attributes.

Step:3 to set the utility function for the range of outcomes on each attributes.

Step:4 uses the global function to fond the expected utility of each alternatives.

Step:5 chose the combination with highest expected utility; goes up to the function U maximized.

B. *Analytical Hierarchy Process (AHP)*

Your paper must use a page size corresponding to A4 which is 210mm (8.27") wide and 297mm (11.69") long. The margins must be set as follows:

Top = Bottom= 19mm (0.75")

Left = Right = 14.32mm (0.56")

AHP is a similar and popular method like MAUT/MAVT proposed by [44] it is basically a pairwise comparison-based method. This MCDM method formulate the problem as hierarchy by including several stages. First stage is the goal, second is decision criteria and then the sub criteria and at last it shows the alternatives. Each stage is compared pair wise that's why it is known as pair wise comparison method. Another MCDM Method named Analytic network process (ANP) [45]this method is formed to use where AHP is insufficient to get alternatives there ANP can be used as it explain the interlinking of the problems between the criteria. In both the method AHP/ANP a scale of 1-9 is used to compare the alternatives. AHP is further lined with Fuzzy AHP which gives the much more important variables to get the alternatives based on their corresponding fuzzy numbers [46,47,48,49] and even fuzzy ANP [50,51] combined AHP MAUT and formed a theorem that the two MCDM techniques resulted in a consistent preference structure. It's main aim to focus on creating a language that easily compared techniques and provided a scaling technique. [70] uses AHP in combination with the Balanced Scorecard (BSC) and formed a framework which reveals the necessary criteria and alternatives, here AHP was used in comparisons, weighting, and rankings. The paper find better raking when combination is used.

Step to apply the AHP method is as follows.

Step – 1. Multiply each value in the first column of the pairwise comparison matrix by corresponding relative priority matrix.

Step – 2. Repeat Step – 1 for remaining columns.

Step – 3. Add the vectors resulted from step-1 and 2.

Step – 4. Divide each elements of the vector of weighed sums obtained in step 1-3 by the corresponding priority value.

Step – 5. Compute the average of the values found in step –4. Let λ be the average.

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Step – 6. Compute the consistency index (CI), which is defined as (λ - n) / (n-1).
Compute the random index, RI, using ratio:
RI = 1.98 (n-2)/n
Accept the matrix if consistency ratio, CR, is less than 0.10, where CR is
CR = CI / RI
Consistency Ratio CR = (CI/CR)
If the Consistency Ratio (CI/CR) <0.10, so the degree of consistency is satisfactory. The decision maker's comparison is probably consistent enough to be useful.

In AHP, several products and alternatives are evaluated, and by means of pair comparisons, the weight of each evaluation item and the evaluation values for each product and alternatives are found for each evaluation item, but the results of pair comparisons are not 0,1, but rather the degree is given by a numerical value. In fuzzy AHP, the weight is expressed by possibility measure or necessary measure, and in addition, the conventional condition that the total of various weights be 1 is relaxed.

TABLE I SCALE USED FOR PAIR WISE COMPARISON

Intensity of Importance	Definition
1	Equal importance
3	Weak importance of one over other
5	Strong Importance
7	Demonstrated Importance
9	Absolute Importance
2,4,6,8	Intermediate Values
Reciprocals of the above	If activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.
1.1 – 1.9	When elements are close and nearly indistinguishable

C. Case Based Reasoning (CBR)

[61]proposed a method in which solutions of past problems are considered to solve the new problems. It is a prominent type of parallel solution making method. It is considered as the powerful method for computer reasoning. The CBR involves four stages.
Retrieve: - the target problem and to find the most similar case.
Reuse: - to map the past case with the new one to get the solution.
Revise: - after applying the previous solution test the problem for the real solution and if needed revise it.
Retain: - make the new solution a part of the new case

D. Data Envelopment Analysis (DEA)

[71] proposed DEA in Royal statistical society. [72] state that it is a non-parametric method in economics and operation research and mostly used in measuring production efficiency. DEA is based on linear programing method and used for production and cost data. DEA is a tool for estimating the efficiency of a system in a non-parametric framework.
DEA gives a better model of road safety [73],[74] uses DEA for examine the efficiency of rice farmer in west Bengal.

Following equation gives efficiency measurement.

$$Eff = \frac{\sum_r u_r y_{rj}}{\sum_i u_i y_{ri}}$$

Where y_{rj}: The amount of the r^{th} output from DMUj, ur: The weight given to the rth output, xij : The amount of the ith input used by DMUj, vi: The weight given to the ith input. To measure the efficiency of DMU j0 model 1 is used to form model 2 and 3 and this measure the efficiency

E. Electre

It was proposed by [87], this method uses two basic indices i.e. concordance index and the discordance index to find a kernel solution. It gives the relation between alternatives based on ranking. The ELECTRE I is the basic method which cannot be used for ranking therefore ELECTRE II is proposed by [88] to overcome the issues of ELECTRE I. while ELECTRE III [88] gives the fuzzy based outranking and ELECTRE IV [89] simply the ELECTRE III

F. SMART

[94] proposed a unique synthesis criterion approach. This method has more similarity with MAUT. It also require two assumptions, namely "utility independence and preferential independence"[167]. This method has the ability to conveniently convert importance weights into actual numbers. It is a linear additive model which means that an overall value of a given alternative is calculated as the total sum of the performance score (value) of each criterion (attribute) multiplied with the weight of that criterion. The stages in the analysis are[14],

Stage 1: Identify the decision-maker(s)
Stage 2: Identify the issue of issues: Utility depends on the context and purpose of the decision
Stage 3: Identify the alternatives: This step would identify the outcomes of possible actions, a data gathering process.
Stage 4: Identify the criteria:
Stage 5: Assign values for each criteria:
Stage 6: Determine the weight of each of the criteria:
Stage 7: Calculate a weighted average of the values assigned to each alternative: This step allows normalization of the relative importance into weights summing to 1.
Stage 8: Make a provisional decision
Stage 9: Perform sensitivity analysis

G. PROMETHEE

It was developed by [95,96], this method uses pairwise comparison-based outranking to solve the problems. The characteristics of this method is similar to ELECTRE as both work on outranking methods. Here pairwise comparisons are converted to uni-criterion so that it can be calculated to compare to each other. PROMETHEE have the versions like ELECTRE PROMETHEE I use for partial ranking of alternatives, PROMETHEE II for complete ranking, PROMETHEE III for ranking based on interval, PROMETHEE IV for complete ranking, PROMETHEE V for problems with segmentation constraints and PROMETHEE VI for human brain representation [96,97]

H. Goal Programming(GP)

The e[105] proposed an extension to linear programming method and able to choose from an infinite number of alternatives. The measures are given by the goal or target value to achieved due to this the unwanted deviations are minimized. GP is used to perform three types of analysis.

1) To determine the required resources to achieve desired set of alternatives/objectives.
2) To determine degree of attainment of the goals with the available resources.
3) Providing the best satisfying solution under a varying amount of resources and priorities of the goals.

[106], applied goal programming method to solve DEA model and give the correct GP approach for the Li and [115] uses software for solving multi choice problem a real world problem by developing GP

I. TOPSIS

[121] proposed an alternative to the ELECTRE method and being widely used. This method is further extended by [122,123], and state that the best solution is the one which has shortest distance from the positive ideal solution and farthest from negative solution. This method has a tendency of increasing and decreasing utility. Therefore it is easy to define the ideal and negative ideal solutions. In this method various criteria are converted into non dimensional criteria as like ELECTRE method. It can be considered that for the benefits criteria the decision maker can have both maximum and minimum alternatives in reference to ideal solution. The TOPSIS works in the following way After defining n criteria and m alternatives, the normalized decision matrix is formed.

The normalized value rij is calculated from Equation (3), where fij is the i-th criterion value for alternative Aj (j = 1, . . . ,m and i = 1, . . . , n).[70]

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{m} f_{ij}^2}} \qquad (1)$$

To calculate v_{ij} in the decision matrix following equation is used.

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$v_{ij} = w_i \, r_{ij}$

The positive ideal A+ and negative ideal solution A - are derived as shown below, where I` and

I`` are positive and negative variables

$$A+ = \{v_1^+, \ldots, v_n^+\} = \{(MAX_j \, v_{ij} | i \in I`), ((MIN_j \, v_{ij} | i \in I``)\} \quad (2)$$

$$A^- = \{v_1^+, \ldots, v_n^+\} = \{(MIN_j \, v_{ij} | i \in I`), ((MAX_j \, v_{ij} | i \in I``)\} \quad (3)$$

From the n-dimensional Euclidean distance, D+j is calculated in (4) as the separation of every alternative from the ideal solution. The separation from the negative ideal solution follows in (5).

$$D_j^+ = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_i^+)^2} \quad (4)$$

$$D_j^+ = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_i^-)^2} \quad (5)$$

The relative closeness to the ideal solution of each alternative is calculated from:

$$C_j = \frac{D_j^-}{(D_j^+ + D_j^-)} \quad (6)$$

After sorting the Cj values, the maximum value corresponds to the best solution to the problem[123].

J. VIKOR

[138] proposed a method which is very much similar to TOPSIS, it also ranks and best alternative from a set of alternatives based on closeness to ideal solution. The inefficiency in TOPSIS being explained by VIKOR by ranking alternatives

K. WSM

[168] proposed this method first and it is being reused by [25], this method is also known as weighted linear combination or scoring methods and it is mostly known by Weighted Sum Model[25]. It is a simple method and it works on weighted average and score of alternatives. The SAW/WSM only deals with benefit criteria and applied to only single dimensional problems as it follows the intuitive process. WSM/SAW is easy applicable method; but the problems deals with qualitative and quantitative attributes it become difficult to handle it. Therefore it is mostly used with other methods. The steps involved in SAW is as follows.

1) prepare the comparison matrix according to Saaty (1-9) scale of pair wise comparisons. Form the weighted sum matrix and find the average of it find the consistency Index and consistency ratio.

2) Construct the matrix (m x n) type for alternatives and criteria.

Evaluate alternative by formula $A_i = \sum w_j x_{ij}$ the calculation continue till the consistency ratio reach to less than 0.1 then only indicates sufficient consistency [25]

L. WPM

[174 & 175] proposed a method similar to WSM the difference is that instead of addition in the model there is multiplication. In this method each alternative is compared by multiplying a number ratios to other alternative. This method suggest that the best alternative to the one which is better than or equal to other alternatives. WPM eliminates the unit of measurement that's why WPM is called as dimensionless analysis and therefore it can be used for single as well as multi-dimensional criteria method. Following formula gives the normalized matrix in order to compare the alternative Ak and AL [25,175,176].

$R(AK/AL) = \prod_{j=1}^{N} (a_{Kj} / a_{ij})^{w_j}$

N is number of criteria

a_{ij} – actual value of i-th alternative in terms of j-th criterion.

w_{ij} – weight

If the ratio of R(Ak / AL) ≥ 1, then Ak is more desirable than alternative. The best is one that is better than or equal to all the other alternatives [64-66].

M. Relevant MCDM and New Trend of MCDM

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During literature some different methods found that are the principal eigenvector technique [13], the weighted least square method (WLSM)[177], the logarithmic least square method (LLSM) or geometric mean method (GMM)[178], are used to calculate the weights.

The MCDM has the wide spectrum therefore the demerits of one method can be remedies by joining the other method with it, some combined methods are: DEMATEL initially proposed by [174] it is a simple pairwise comparison-based method and being mostly used by other MCDM methods. MACBETH [180] is a qualitative method used to compare the alternatives. Fuzzy AHP is Fuzzification of the AHP is widely used methods now. As it is found that the combination of two methods leads to better option than the single one. MAUT also find applications with combination of other MCDM methods. [183] uses MAUT,AHP and ELECTRE in combination for Marine Machienery system, [184] applied hybrid Delphi, MAUT, TOPSIS for selecting Green building credit, [41] uses Interval Evidential Reasoning (IER), Laplace Evidential Reasoning (LER), MAUT for Software requirement, [42] uses MAUT, Marco applied MAUT with mean value portfolio analysis to environmental and socio factor. There are many other application of MAUT with other MCDM method which gives better result. [193] prepared the biblometric performance indicators based on journals, authors on AHP and Topsis Technique find the most active area for AHP and TOPSIS i.e. supply chain management, sustainability research, risk management. [194] combined Goal Programming, AHP with TOPSIS for the selection of maintenance strategy in hydroelectric power plant. This combination gives the improvement of 77% in downtimes. [195] focused on performance of cellular mobile telephone service providers by using fuzzy extended ELECTRE to get the outranking of poor performers. [196] applied GIS and AHP to real world problem for the location of concentrating solar power (CSP) plants. [197] applied AHP integrated PROMETHEE and VIKOR methods for selection of military airport location in turkey, the criteria includes the requirement of airport plus the environmental and social effects. The results were compared with COPRA, MAIRCA and MABAC and found more suitable for location selection. [198] included attribute difference revision (ADR) to improve the learning performance of CBR method. [199] use text mining and case based reasoning (TM-CBR) for preparing the reference to designer for making the green building design and improve the effectiveness and adequacy of green building design. [200] combined Geographic Information Systems (GIS) with Analytic Hierarchy Process (AHP) method, TOPSIS method and ELECTRE TRI method for the comparative study for the location of the photovoltaic farms in spain. The comparison reveals that the results are not identical but there are some similarity between these methods. [201] study the reverse logistics which is the important part of green supply chain management as to minimize the waste at end of life. The study focused on the barriers and ranking of both barriers and solution of reverse logistics in electronics industries. Fuzzy AHP and TOPSIS used to get the weights of each barriers and TOPSIS uses get the final ranking

III.CHARACTERISTICS OF MCDM

The mentioned MCDM methods are used for solving many problems but not all suggested for solving any multi-criteria decision problem. MCDM uses quantitative and qualitative data for evaluation, but some methods uses only quantitative and some only qualitative. Weighted method shows the quantitative information and the result occurred in ranking form. Evaluation, using graphics for evaluation gives the qualitative and quantitative information and gives result in visual form. Outranking Methods shows the quantitative information and gives result in ranking form some time it gives incomplete ranking. Analytical hierarchy process (AHP) shows the qualitative information with low transparency and gives result in ranking form. Permutation method shows the qualitative information with low transparency and gives result in ranking form.

A. Strength and Weakness of MCDM Methods

It is being found that there are various types of information like information on criteria, alternatives ways being categorized and present the classification based on input data [20,21]. MCDM gives a systematic and transparent approach to enhance objectivity which gives result that can be preferred for analysis [22]. The elements of MCDM summarized are as follows:

1) Aggregation algorithms: There are number of MCDM methods and it gives various outcomes, to get the solution which is given by most of the methods can be considered as the final but the selection of proper method is really no the straight path.

2) Compensatory methods: The complete accumulation methods which allow for trade-offs between good and poor performance on different criterion, e.g. the poor performance on water quality could be compensated with good performance on investment cost. This things are debatable and have many criteria to relate with the performance. The mathematical calculation of MCDM can give better decision for one criteria and poor for another criteria this is an obligatory thing.

3) Elicitation process: some methods uses the way of idiosyncratic information i.e. weights and preference is not trifling and is likely to influence the results.

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4) Incomparable options: The aim of all MCDM is to reduce incomparability, and to reduce the problems to single-criterion problems for which an optimal solution exists completely. This result in selecting the best option with value e.g. A is better than B by 0.45 value
5) Scaling effects: certain MCDM methods works on scale which gives evaluation which is unacceptable.
6) Problem structuring: in some case results could be manipulated by omission or addition of some relevant criteria or options.
7) Additional required information: some MCDM methods need additional information to get the better result.
8) Uncertainty: The results can be changed if the number of decimals places are increase or decrease

TABLE III MCDM APPLICATIONS

MCDM Method	Merits	Demerits	Applications	References used
Multi-attribute utility analysis (MAUT) Churchman, C.W., Ackoff, R.L. and Arnoff, E.L. (1957)	• Takes uncertainty into account; • Can represent the uncertainty directly to decision model • It has a strong form of decision making Simple to method • Easy calculations. • The mechanism of the method is straight forward	Needs a lot of input; preferences need to be precise.	• Public Sector like, new airport, forest land use • Power Plant related selection. • Supplier selection • Economics, finance, actuarial, water • Management • energy management • agriculture • E commerce • Truck load condition. • Motion simulator. Global manufacturing (canbolt Chelst Garg 2007) Social problem Land use Natural resource management Technical socio-cultural for eight countries(Ananda and hearth 2005) Watering system(kailiponi 2010) Soil contamination (zabeo)	[24-43]
Analytic Hierarchy Process (AHP) Saaty, T. L. (1977).	• Easy to use; • handle the multiple measures and perspectives • scalable; • hierarchy • structure can easily adjust to fit • many sized problems; not data intensive.	Problems due to interdependence between criteria and alternatives; can lead to inconsistencies between judgment and ranking criteria; rank reversal.	• Supply chain Management. • Transportation • Resource management • Health Technology • corporate policy and strategy. • public policy, • Industrial robots • Selection of Techno-Entrepreneurship Projects • political strategy, and planning. • Fisheries • Infrastructure. • Water resource management	[44-60]
Case-Based Reasoning (CBR)	• Not data intensive; • can adapt to changes in environment.	Sensitive to inconsistent data; requires many cases.	• Health • Insurance • Identifying knowledge leader.	[61-70]

Roger Schank, 1982).		Gives good result for computer and health based application	• Human anatomy. • Banking • Businesses • Phishing detection • Construction • Environment • Energy management	
Data Envelopment Analysis (DEA) M.J.Farrell (1957)	Capable of handling multiple inputs and outputs; efficiency can be analyzed and quantified.	Does not deal with imprecise data; assumes that all input and output are exactly known.	• Industrial waste control • Economics and eco efficiency • Energy Efficiency • Renewable and sustainable energy • Energy performance • Environmental efficiency. • agriculture, retail, and business problems.	[71-86]
Simple Multi-Attribute Rating Technique (SMART) Edwards, W.; Barron, F. H. (1994).	Simple; allows for any type of weight assignment technique; less effort by decision makers.	Procedure may not be convenient considering the framework.	• Environmental, • construction, • transportation and logistics, military, • manufacturing and assembly problems.	[93,94,14,2,3]
ELECTRE Roy Bernard (1968)	Takes uncertainty and vagueness into account.	outranking causes the strengths and weaknesses of the alternatives to not be directly identified.	• Water resource management • Infrastructure • Water and waste water main. • Supplier selection • Energy, economics, environmental, • water management, and transportation problems.	[87-92,2]
PROMETHEE Brans & Vinek (1985)	Easy to use; does not require assumption	Does not provide a clear method by which to assign weights.	• Environmental, hydrology, • Water management, • waste water system • transportation • bridges. • sustainability, • portfolio selection • chemistry, logistics • manufacturing and assembly, energy, agriculture.	[95-104]
Goal Programming (GP) Charnes (1955)	Capable of handling large-scale problems; can produce infinite alternatives.	It's ability to weight coefficients; typically needs to be used in combination with other	• Energy Plan • Production planning, scheduling, • Waste water treatment plant. • water reservoir management • Transportation • Infrastructure	[105-120]

		MCDM methods to weight coefficients. Not suitable for multi choice problem.	• Financial & portfolio selection. • Agriculture • health care • real life problem. • Renewable Energy • Forest management. • Supplier Selection	
Technique for Order Preferences by Similarity to Ideal Solutions (TOPSIS) Hwang & Yoon (1981)	Has a simple process; easy to use and program; the number of steps remains the same regardless of the number of attributes.	Its use of Euclidean Distance does not consider the correlation of attributes; difficult to weight and keep consistency of judgment.	• Supply chain management and logistics. • Blastic Pattern selection in mine. • Air Conditioning system. • engineering, manufacturing. • Shelter for human being, • water resources management. • Sustainability. • Bridges • Financial performance • systems, business and marketing, • environmental, human resources.	[121-137]
VIKOR (VlseKriterijumska Optimizacija I Kompromisno) (Opricovic 1998)	Easy to use It is a comprises solution		• Sustainability • Renewable energy • Management • Manufacturing fields • Construction • Risk and financial management. • Water resource planning. • Tourism • Health • Supplier selection • Human resource management.	[138-167]
Simple Additive Weighting (SAW) Churchman, C. W. and R. L. Ackoff (1954)	Ability to compensate among criteria; calculation is simple intuitive to decision makers;	It do not always reflect the real situation; Result are not logical.	• Water management, • Bridges • Transportation. • Food • Human resource management. • Thermal • business, and • financial management.	[168-173]

IV. CONCLUSIONS

Decision Making is an essential technique and it is found that the application of these techniques are increasing. It offered number of suitable tactics for exhibiting decision aiding. MCDM method have the capability to marked different contradictory interest and solve it more precisely which is not possible with the optimizations models. The number of papers and books were reviewed to get all the MCDM in one umbrella and to find the application of these methods. The table 2 shows the application of the MCDM method and reveals the area of research where MCDM can be applied with the method more suitable for it. The review gets the latest trend of using the benefits of other methods with another one to get the proper decision. The study get that the integrated methods give better performance than the individual ones. The study is limited to find most MCDM methods and their applications. The study can be continued in future with focus on one applications one method and with integration of other methods. One can study the sub areas of the field shown in application. The review tried to give the better understanding of MCDM techniques. This will help researcher to practice in the integrated or hybrid technique to solve the various problems

V. ACKNOWLEDGMENT

The heading of the Acknowledgment section and the References section must not be numbered.
Causal Productions wishes to acknowledge Michael Shell and other contributors for developing and maintaining the IEEE LaTeX style files which have been used in the preparation of this template. To see the list of contributors, please refer to the top of file IEEETran.cls in the IEEE LaTeX distribution.

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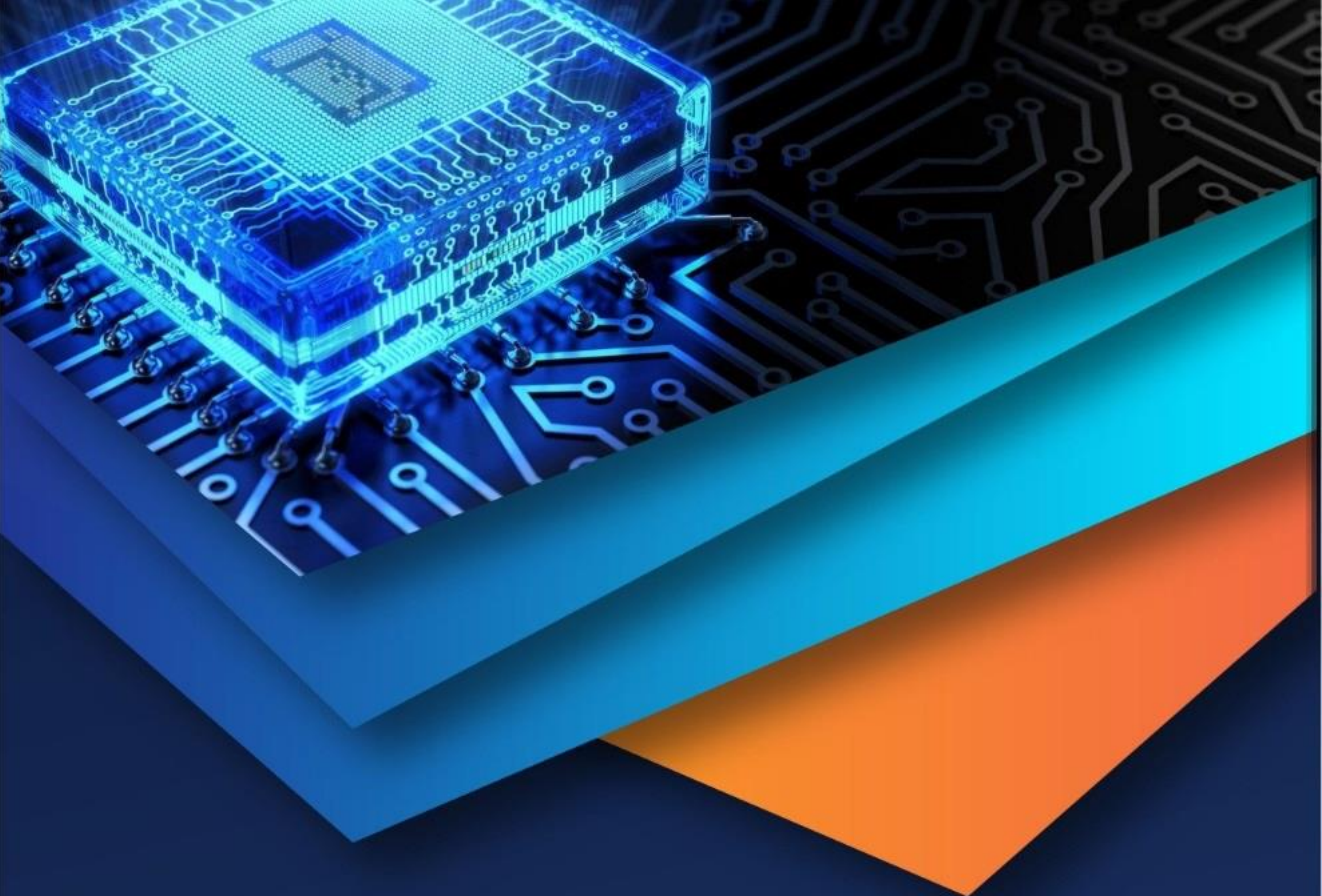

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