Multi Attribute Decision-making: A Survey

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ABSTRACT:
In Decision-making domain, selection of best alternative is a complex problem based on someconflicting criteria. Multi Criteria Decision-Making (MCDM) makes it possible to find the best alternatives amongst all alternatives and to find the optimum solution. MCDM can be used across a wide range of application areas. The aim of the survey is mainly focused on different types of MCDM approach, which are robust and also optimal, to solve different real life problems. Analytical Hierarchical Process(AHP), Weighted Product Method(WPM), Ranking Organization method for Enrichment Evaluation (PROMETHEE), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Simple Additive Weighting(SAW), Elimination EtChoix Traduisant la REalite(ELECTRE), are various types of MCDM methods that we have discussed in this paper. This survey article contains various types of MCDM method and their applications on various domains and discussion about the advantage and disadvantage of each method.

KEYWORDS: Multi criteria Decision-Making (MCDM), fuzzy set theory, FTOPSIS, AHP,FAHP, best choice.

1. INTRODUCTION

Making judgments in today's complex world have grown increasingly challenging, and can only be handled by focusing on a certain attribute, often known as a criterion for a specific problem.So, in multi-criteria problems, where comparisons, ranking, and selection may be done between various attributes as well as multiple alternatives with the support of decision makers, MCDM approaches come in useful.Decision-making is a cognitive progression in which the finestpossibility among the possibilities is logically chosen. It is made up of a collection of criteria and options. Each criterion has a weighted value that can be determined by a decision-maker or expert panel. The decision can be made after weighing the weighted value of various criteria. MCDM model has numerous elements depending on the type of problem, and the following diagram represents the most commonly seen elements-

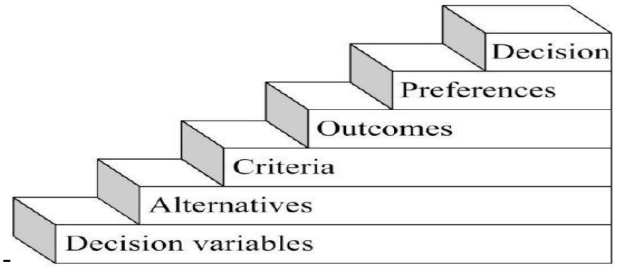

Fig 1.1 MCDM Model's elements

Multi-Attribute Decision Making (MADM) and Multi-Objective Decision Making (MODM) are two kinds of MCDM. When numerous criteria are involved in MCDM, determining the best optimal decision among the choices is difficult. There are several ways to solve a problem.One way is to elect the finestalternate out of a collection of replacements and additional way is to choose out of a small set of good substitutions [1].Choosing the finestalternate is undoubtedly a multifaceted task where the problem is serene of dissimilar criteria. The

purposeof this survey article is to facilitate the decision-makers when several choices are available to solve a problem. MCDM problem can be expressed as

$$\mathbf{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array}$$

$$W = [w_1 \quad w_2 \quad \cdots \quad w_n]$$

A comparison matrix is denoted by D. Where A_1, A_2, ... Am are the available choices from which the decision maker must choose the best one. The list of criteria is C_1, C_2, ..., C_n. The performance of alternatives is evaluated using these standards. The rating of alternatives generated from a comparison of alternative A_i and each criteria is represented by C_j. $W_j$represents the weight of each benchmark C_j.

Sometimes the information presented to decision-makers is partial or inaccurate. The impression of ambiguity can be created by the human mind. As a result, problem solving is quite tough in this situation. To address this issue, fuzzy set theory is introduced, as well as the MCDM, which may solve unclear circumstances. This is referred to as Fuzzy Multi-Criteria Decision Making (FMCDM) (FMCDM). Zadeh created the fuzzy set theory in 1965 to support vagueness linked with ambiguity or impression, which is relevant to human cognition [2]. A fuzzy MCDM modelconsists of several criteria, alternatives and weight of each criteria, which can be represented in the term of linguistic values and expressed by fuzzy numbers to help of a committee of decision-makers. Most of FMCDM problems, the final rating of alternatives are still in fuzzy numbers. De-fuzzification is required to convert from fuzzy value to crisp value for decision-making.

There are several types of MCDM and FMCDM methods available that are used to solve the decision-making problems and this survey article is mainly based on understanding the MCDM and how to solve this problem by providing the various MCDM methods. As the application area of MCDM method is very large, there are lots of work that have been proposed in MCDM domain and different type of MCDM methods is applied for the selection of the optimal choice in different field. We have tried to sum up some of them.Each MCDM approach has its own distinct features and qualities. Combining two or more strategies can result in a hybrid strategy that can be utilised to solve complex decision-making challenges. Some of the application areas of MCDM & FMCDM methods are location planning [3], Supply chain management [4][5], E commerce[6], Software Industry[7], Financial[8], Airlines[9] etc. There is some example of hybrid approach in MCDM, such as AHP and Fuzzy TOPSIS [10],Fuzzy AHP and DEA [11] etc.

This article is organized as follows. We have discussedthe different types of MCDM methodsin section 2.Section 3 containsthe applications of MCDM methods. Section 4contains the findings and the conclusion is given in section 5.

2. METHODS OF MCDM

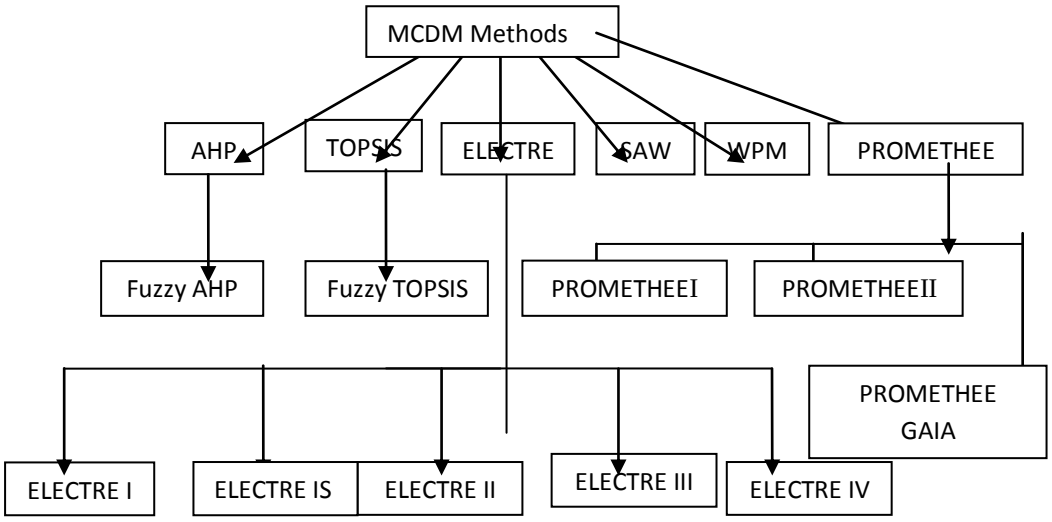

Fig 2.1. Hierarchical representation of MCDM Methods

Attributes can be classified in two different types, qualitative and quantitative. These above mentioned MCDM methods canbe applied to both data types. The fundamental goal of these techniques is to find the finest solution and indicate the greatestalternate. The hierarchical structure of various MCDM methods is shownin figure 2.1. These methods have been discussed in following section as follows-

2.1 ANALYTIC HIERARCHY PROCESS (AHP)

AHP was originally proposed by Prof. Thomas L.Saaty(1980). It was created primarily to pact with complex decision-making glitchesconnectingmanifold kinds of conflicting criteria and choices. This strategy relieves decision-makers of some of their responsibilities. The purpose of AHP is to assess the final ranking, which is determined by comparing alternatives and criteria pairwise. AHP is a simple method because it does not necessitate the creation of a complicated expert system containing the decision-knowledge. maker's. Computations made by the AHP are always supported by the decision-maker.

In AHP, every individual evaluation is very simple that can be easily deduced by a user, but when the number of standards andreplacementsupsurge, then it requires a large number of evaluations. Indeed, as the number of criteria and alternatives increases, the numeral of pairwise contrastsupsurgesintensely. For an example, suppose a problem consist of 10 criteria and 4 alternatives. So the number of comparisons required to build a weight vector become $(4 \times 3)\ /2 = 6$ and number of pairwise comparisons required to build the score matrix becomes$4 \times\ (10 \times 9)\ /2 = 180$.

Steps of AHP

The following are the major steps in the AHP process.

Step 1Construct the comparison matrix by making pairwise comparisons between the objects.

A Comparison matrix represents all pairwise comparisons. Each object has a score that may be determined using the comparison scale and is provided by the decision-maker. Actual judgement values occupy the upper triangular matrix, whereas reciprocal values fill lower triangular matrix. Assume$A$ is a $m \times m$ comparison matrix, where with $'m'$ being the numeral of conditions.Each entry a_{ij} of the matrix Asignifies the relevance of the ith criterion corresponds to the jth criterion. Each pair of a_{ij} and a_{ji} are satisfying the following constraint,

$a_{ij}\ .a_{ji}\ = 1$ (1)

Step 2.Build the Normalized and Weighted Normalized matrices.

After building the comparison matrix, it is required to be normalized by making the totality of individualcolumn equal to 1. Suppose A_1 is regularised matrix and each entry of that matrix,$\bar{a}_{ij}$ is calculated as

$\bar{a}_{ij}\ = \frac{a_{ij}}{\sum_{k=1}^{m} a_{kj}}$(2)

Lastly, the $'w'$(Criteria Weight Vector) is calculated by taking the average of each row of A_1 i.e.

$w_i = \frac{\sum_{k=1}^{m} \bar{a}_{ik}}{m}$(3)

Step 3.Reckoning of the Option Score matrix:

The Option Score matrix$B$ is a $m \times n$ real matrix,wherever$'m'$ is a set of measures and $'n'$ is a set of replacements. Each entry b_{ij} of Bindicates the score of ith option with respect to jth criteria. For each criterion a pair-wise comparison matrix $B^i$is built $(i = 1, \ldots, m)$. $B^i$is a $n \times n$real matrix, where $n$is the number of alternatives. The same procedure which is described above is applied to eachB^i.After evaluating each B^i, finally score matrix S is obtained.

Step 4.Ranking the Options

After computing the weight vector w and score matrix S, global score of vector v is obtained by multiplying S and w.

$v = S.w$(4)

Each entry v_i of v is represented by the global score which is obtained after applying AHP. Finally the largest entry of v is considered the best option and the option ranking is completed by collation the comprehension scores in diminishing order.

Step 5. Checking the uniformity

Inconsistency may occur during the pairwise comparison computation. As a result, it's critical to double-check consistency during pairwise comparisons. The procedure for ensuring consistency is as follows:
i. Calculate the Principle Eigen value(λ_{max}),which is calculated by adding the artefact of each element of the Eigen vector and the sum of the decision matrix's columns..
ii. Calculate the Consistency Index(CI) as follows,

$$CI=\frac{\lambda_{max}\ -\mathrm{n}}{n-1} \quad (5)$$

Where n is a number of objects.
iii.Calculate the consistency ratio(CR),which is obtained from the following equation,

$$CR=\frac{CI}{RI} \quad (6)$$

Where RI stands for Random Consistency Index.
The worth of current discrepancy is adequate if the assessment of Consistency Ratio is fewer than or equal to 10%. If the Consistency Ratio is superior than 10%, the slantedfindings in the decision matrix must be revised in order to obtain a new value of inconsistency, which will be tested again.

2.2 SIMPLE ADDITIVE WEIGHTING(SAW)

One sort of MCDM problem is multi-attribute decision-making (MADM). MADM models are picker models that are used to evaluate, rank, and choose the most apposite option from a set of options [12]. It is a straightforward method for determining the ultimate score of choices. SAW (Fishburn,1967) consists of primarily two steps: first, each alternative's final score is evaluated, and then they are ranked. The following is a description of the method.

$P_i = \sum_{j=1}^{k} w_j \,.r_{ij}\ ;\ i = 1,2,\ldots\ldots,m$[7]

where r_{ij} is the normalized value of decision matrix, that can computed as follows,
for profit attribute

$$\mathrm{r_{ij}} = {\mathrm{d_{ij}}}\Big/{\mathrm{d_j^{Max}}}\ ;\ \mathrm{d_j^{Max}} = \max_{1\le i\le m} \mathrm{d_{ij}}\ \ ;\ \mathrm{j} = 1,2,\ldots\ldots,\mathrm{k}[8]$$

for cost attribute

$$\mathrm{r_{ij}} = {\mathrm{d_j^{Min}}}\Big/{\mathrm{d_{ij}}};\ \ \mathrm{d_j^{Min}} = \min_{1\le i\le m} \mathrm{d_{ij}}\ \ ;\ \mathrm{j} = 1,2,\ldots\ldots,\mathrm{k}[9]$$

2.3 WEIGHTED PRODUCT METHOD(WPM)

WPM is a procedure that is comparable to SAW. The sole difference between SAW and WPM is that instead of doing a summation operation to calculate the rank in SAW, WPM (Miller and Starr, 1969) does a multiplication operation to calculate the rankings. The approach for calculating the normalised value of an option in WPM is the same as in SAW.

2.4 TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION (TOPSIS)

It's alternative outstanding MCDM problem-solving methodology, created by Hwang and Yoon in 1981 and subsequently developed by Yoon in 1987 and Hwang, Lai, and Liu in 1993. The TOPSIS principle is to choose the option that is closest to the positive ideal solution while being the furthest away from the undesirableidyllic solution.The constructive ideal explanation, A+, is made up of the best presentation values. A-, the negative ideal, is made up of the nastiestenactment numbers. The TOPSIS approach is carried out as follows:
Step1: Compute the normalized decision
Step2:Compute the weighted normalized decision matrix V
Step 3: Find the positive ideal solution (PIS) A^+ and negative ideal solution (NIS) A^-
Where J is a set of benefit attributes and J' is a set of cost attributes.
Step 4: Compute the separation measures using the m-dimensional Euclidean distance.

Step 5: Determine the relative closest to the ideal solution. The relative closeness of the alternative A_i with respect to A^+ is defined asfollows:
Step 6: Rank the alternatives in descending order with respect to C_i.

2.5 ELIMINATION ETCHOIX TRADUISANT LA REALITE(ELECTRE)

ELECTRE was founded in 1966 by Benayoun, Roy, and Sussmann. ELECTRE I, ELECTRE IS, ELECTRE II, ELECTRE III, ELECTRE IV, and ELECTRE TRI are some of the variations of the ELECTRE method that have been presented. For the MCDM, this strategy is efficient and effective. The ELECTRE method's main principle is built on the concept of outranking by comparing alternatives pair by pair under each criterion. The ELECTRE method has two steps:

1. Building the outranking relation
2. Exploitation of the outranking relation

The ELECTRE approach is used to eliminate some of the problem's unacceptable choices. After eliminating unsuitable options, another MCDA is performed to choose the best one. The key benefit of employing the ELECTRE approach before applying another MCDA with a limited range of choices is that it saves a lot of time. According to the type of decision-making problem, the degree of complexity, and information quality, the ELECTRE approach differs from one version to the next. There are two sets of parameters in the ELECTRE method: I the significance co-efficient, and ii) veto thresholds.

The basic ELECTRE concept is introduced, followed by expansions of ELECTRE I, ELECTRE IS, ELECTRE II, ELECTRE III, ELECTRE IV, and ELECTRE TRI introduce veto thresholds and pseudo criteria, which are the core applications of the ELECTRE approach for MCDM.

2.6 PREFERENCE RANKING ORGANIZATION METHOD FOR ENRICHMENT EVALUATION (PROMETHEE)

Professor Jean Pierre Brans first introduced PROMETHEE in 1982. It uses the mutual comparison of each alternative pair for each criterion and is based on the premise of the out ranking approach. There are two steps in this process:

Step 1. The first step is to assign a preference function

The evaluation matrix that represents the performance of each alternative under each criteria serves as the starting point for this step. Compare the options pair-by-pair under each criteria using the data from the evaluation matrix. A function called the preference function is used to express the outcomes. The preference function has a range of 0 to 1, with 0 indicating no difference and 1 indicating a significant difference between the pair.

Step 2. Calculatesthe outranking degree of the options

Multiply the preferences by the weights of the criterion and add the single value to get the global preference matrix. The total of the rows in a global preference matrix shows an option's strength (dominance), while the sum of the columns represents how much an alternative is dominated by the others (sub dominance). Subtract the sub dominance value of the dominance value to get the rank of the alternatives.

The weights of the criteria are not provided by the PROMETHEE technique. The weights of the criteria and the preference function are provided by the decision-makers. PROMETHEE I, PROMETHEE II, and PROMETHEE GAIA are some of the PROMETHEE methods introduced.

TABLE 1. MCDM methods with its advantages and disadvantages

Sl. No	MCDM Methods	Description	Advantages	Disadvantages
1	AHP	It compares numerous alternatives pair by pair for a variety of criteria.	1. Straightforward, adaptable, and advantageous. 2.Always checks inconsistency. 3. The problem is organised into a hierarchical structure that aids in the achievement of the goal.	1.To find the goal, it needs alarge number of pairwise comparisons. 2.Ranking evaluation is in irregular manner. 3.Inconsistancy obligatory by 1 to 9 scale.

			4.It gives a clear idea about the importance of each criteria. 5.Perform pairwise comparison between the attributes.	4.Subjective evaluation. 5. For a high number of criteria, this method is ineffective.
2.	TOPSIS	Choose the option that is closest to the positive ideal solution and the furthest away from the negative ideal solution.	1. Decision making is simple using both cost and profit criteria. 2.Evaluate the rank of each alternative. 3.Easily programmable and simple computation process 4.Good computational efficiency.	1.only independent criteria are allowed. 2.Normalization is required for criteria evaluation. 3.Criteria are monotonically decreasing or Increasingin nature.
3.	Simple Additive Weighting(SAW)	Provides a pair-by-pair comparison of multiple options for a variety of criteria. Then calculate the score for each option It is calculated using a weighted average.	1.It is a simple technique and most often used in MCMD. 2.Consistency is measured.	It is only efficient when criteria evaluation is maximized.
4.	Weighted Product model(WPM)	Compare the weights and ratios of each criterion to compare the options.	1. Any unit of measurement can be removed. 2. It is used to represent relative values.	No support for calculating weights.
5.	Data Envelopment Analysis (DAE) (Afshari, 2010)	The DEA is used to locate he problem's efficiency when several inputs and outputs are combined.	1. It is possible to manage several inputs and outputs. 2. It is not necessary to have a relationship between the inputs and outputs. 3. Direct comparisons are made against peers. 4. The units of inputs and outputs can be significantly varied.	1. Errors in measurement might have serious consequences. 2. It is impossible to quantify absolute efficiency. 3. There are no statistical tests that can be used. 4. Large problems can be difficult to solve.
6.	ELECTRE	It builds the outranking relation then explore the relation. This method discards some alternative which is not acceptable.	1.Outranking is used	1. It takes a long time. 2. It is a difficult decision-making process that necessitates a large amount of primary data.
.7.	PROMETHEE	Choose the best option by comparing each alternative pair against each other for each criterion. In this method, the decision maker's preference function is employed to indicate the performance of each criteria of each alternative.	1.Group level decision making is supported	1. Does not give any weighting information for criterion as a guideline, but assumes that the decision makers will be able to provide the weights of the criteria correctly. 2. The method by which preference ranking data is handled is intricate and difficult to explain to non-experts.

2.7 FUZZY SET THEORY IN MULTI CRITERIA DECISION MAKING(MCDM) PROBLEM

In MCDM problem,constructing pairwise comparison between the objects is dealing with the judgement of decision-maker. Sometimes the information provided to the decision-maker is incomplete or

imprecise and some problem dealing with the uncertainties and vagueness. Human thought or perception cannot be judged by the form of exact numerical value. To support this problem, fuzzy set theory was introduced into a decision making domain where the decision maker can give their opinion in the form of linguistic term rather than exact numerical value.

2.7.1 FUZZY SET THEORY

The fuzzy sets are represented by linguistic terms that construct one or more linguistic variables, i.e., the linguistic variables' various states are defined in a discourse universe represented by these linguistic terms[13].

A fuzzy set 'C 'can be represented as,

$C = \{(x, \mu_c(x)) \mid x \in X\}$

where $\mu_c(x)$ is called the Membership Function(MF) for the fuzzy set C.The Universe of Discourse (X) is represented as linguistic values. Each element of Xhas membership grade ranging from 0 and1.

Fuzzy set and its MF can be represented as different way, such as Triangular, Trapezoidal,

Sigmoidal, Gaussian, etc.

Fuzzy set theory can be applied to different types MCDM methods for supporting the uncertainties and vagueness. It is compact with the various types of MCDM methods and it helps to increase the performance of this method. Fuzzy Analytical Hierarchical Process (FAHP), Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (FTOPSIS), Fuzzy Simple Additive Weighting (FSAW), Fuzzy Weighted Product Method (FWPM), and others are examples of FMCDM methods.

3 APPLICATIONS OF FMCDM METHODS

In day-to-day life FMCDM methods are used in various fields. It reduces the complexity of decision-making, problem and helps to provide flexible decision-making. Some of FMCDM methods such as FAHP, FSAW, FWAP has the capability of consistency checking. It removes the inconsistency while making the judgement by decision-makers. Some of FMCDM methods and its application are discussed in this article.

Some application area of FAHP is describing in Table.2 i.e. A suitable bridge construction[14], Evaluation Of The Best Technical Institutions[15], Contractor Selection[16], Evaluating Tourism Islands[17].

TABLE 2. Application of Fuzzy AHP

Author & year	**Variable, Parameter**		**Methodology**	**Finding (Best Alternatives)**
	Criteria	**Alternatives**		
Pan, et al.14]	1.Quality 2.Cost 3 .Safety 4.Duration 5.Shape	3 alternatives method 1.Full-span Precast & Launching Method 2.Advance Shoring Method 3.Incremental Launching Method	Fuzzy AHP	Advancing Shoring Method is the most appropriate alternative
Chatterjee &. Mukherjee[15]	1.Campus Infrastructure. 2,Faculty. 3. Student 4. Academic Ambience 6.Teaching Learning Process 7.Supplementary Process	3 alternatives of college. 1.BCREC 2.BCET 3.DIATM	Fuzzy AHP	Find the Best Technical Institutions. BCREC is the select as bestTechnical Institution

Alias, Maizura, Noor,Selamat , Saman & Abdullah [16]	1.financial:C1 2.performance:C2 3.Staff:C3 4.Equipment:C4	4 alternatives of contractor 1.A1 2.A2 3.A3 4.A4	Fuzzy AHP (FAHP)	Select the best contractor A1>A3>A2>A4 Contractor A1 is the best preferred choices by decision maker
Maizura Noor, Amalina, Sabri, Hitam, Ali & smail[17]	1.Attraction:D1 2.Environment:D2 3. Accomodation:D3 4.Transportation:D4 5.Restaurant:D5 6.Other Facilities:D6 7.Activity:D7 8.Entertainment:D8 9.Residents Attitudes:D9 10.Souvenir:D10	3 Domain experts	Fuzzy AHP (FAHP)	Find the best criteria of social attributes performance for tourism island.Attraction is the most important criteria for selection island Evaluation.

Sub criteria[14]Toughness, AppropriatenessImpairment cost, Edifice cost, Circulation conflict, Site circumstance, Constructability, Climatesituation, Scenery, Geometry,Ecologicalprotection.

Sub criteria[15]: Refuge, Conveyance/canteen/Internet, Power hold-up, Sanctuary, Teacher/Student ratio, Prerequisite/Knowledge of Faculty, Faculty preservation, Admittance, Academic Outcome, Placement, Classroom, Laboratory, Library, Syllabus coverage, Tutorial/ counteractiveUsage of Advance Teaching Aid, Alumni, Co-curricular activity, Cultural activity, seminar/ Workshop.

Sub criteria[16]: Asset:C1-2,Liability:C1-2,Current:C2-1,Previous:C2-2,Experience:C31,Qualification:C3-2.

Sub criteria[17]: Unspoiled Nature, Unspoiled Forest, Colourful Fish, Beautiful Scenery, Traditional Fishermen Village, Marvellous Coral Reef, Nice Beaches, Waterfall. The first three important criteria are attractive, atmosphere andlodging. The primary three significant sub-dimensions are unchangednature, beautiful scenery and marvellous coral reef.

Some implementation areasof FTOPSISmethod describe in Table3. These fields consist Manufacturing System[18], RiskImitation Evaluation in Multi-Target Tracing System[19],Supplier Selection[13][20], Location planning[3][21][22], Stock Marketing[23] etc.

TABLE 3. Application of Fuzzy TOPSIS

Author & year	**Variable, Parameter**		**Methodology**	**Finding (Best Alternatives)**
	Criteria	**Alternatives**		
Karsak[18]	1.Capital as well as operating Cost 2.Required floor space 3.Product flexibility 4.volume flexibility 5.Quality Improvement 6.Work In Progress(WIP)	8FSM alternatives. 1.FMS_1 2.FMS_2 3.FMS_3 4.FMS_4 5.FMS_5 6.FMS_6 7.FMS_7 8.FMS_8	Fuzzy TOPSIS (FTOPSIS)	FMS_3>FMS_8>FMS_2 FMS_4>FMS_7> FMS_5 > FMS_1 > FMS_6 FMS_3 is the best FSM alternatives
Wang, Huan, Qin, Yan & Bai [19]	1.Alter ratio of goal velocity: D_1 2. Alter ratio of Objective radial velocity: D_2 3. Alter ratio of	5 alternatives of target 1.Target1 2.Target2 3.Target3 4.Target4	Fuzzy TOPSIS (FTOPSIS)	To find which target Underwater Unmanned vehicle (UUV) should attack first.

	objective directional angle: D_3 4.Objective orientation itinerant velocity:D_4 5. Outright value of objective velocity amongst guesstimate and expectancy:D_5 6. Complete value of directional angle amongst objective and UUV: D_6 7. Complete assessment of depth amongst objective and UUV:D_7 8. Outright value of aloofness amongst target and UUV:D_8 9. Likelihood to be nautical vessels:D_9	5.Target5		Target1> Target3> Target5> Target4> Target2 UVV must outbreak Target1 foremost
Sevkli, Zaim, Turkyılmaz & Satır[13]	1. Distribution enactment 2. Feature enactment 3.Price/Cost 4.Finncial forte 5.Management and essential strength	3 Supplier alternatives 1.A 2.B 3.C	Fuzzy TOPSIS	Select the best provide counterfeiting parts for Propeller sluice for the light besides hefty viable vehicles C>A>B C is selected as best supplier
Awasthi , Chauhan & Goyal[3]	1.Approachability(C1) 2.Sanctuary (C2) 3.Connectivity to multimodal conveyance (C3) 4.Expenses (C4) 5.Conservational impression (C5) 6.Immediacy to clienteles (C6) 7.Juxtaposition to dealers (C7) 8.Reserve obtainability (C8) 9.Conformance to Defensible freight guidelines (C9) 10.Likelihood of extension (C10) 11.Quality of service (C11)	3 Location choices 1.A1 is positioned external the city adjacent to a thoroughfare while locations. 2.A2 is situated inside the city on the fringes exclusive the city neighbouring to highways and to the customer locations 3. A3 is placed in the city centre far from thoroughfares.	Fuzzy TOPSIS (FTOPSIS)	Assortment of impending whereabouts for metropolitan dispersal centres A1>A3>A2 A1 is select as the unsurpassed locality for urban distribution centres

Madi & Tap[23]	1. Market Assessment(RM billion):C1 2) Stock Transaction Capacity (million units), :C2 3) Stock Interchange Worth(RM million):C3	3 substitutions of Speculation Boards on Bursa Malaysia 1.The Main Board: A1 2. The Subsequent Board:A2 3.The MESDAQ Market:A3	Fuzzy TOPSIS (FTOPSIS)	Handpicked the most preferable speculation boards by integrating operational risks . Main Board is the best suitable choice MESDAQ is the second choice and Second Board is the last choice.
Boran[21]	1.Expansion possibility: C1 2. Obtainability of attainment Material:C2 3.Unrestricted considerations:C3, 4.Remoteness to market:C4 5. labour cost:C5	4 Alternatives of candidate. 1.A_1 2.A_2 3.A_3 4.A_4	Fuzzy preference relation, Fuzzy TOPSIS(FTOPSIS)	select The best location for building a new plant A_2 has been selected as best location .
Ashrafzadeh[22]	1.Labor budgets 2.Conveyance expenses 3.Management costs 4.Terrestrial cost 5.Accomplished labour 6Availability of labour force.7.Terrestrial obtainability 8.Environment 9.Actuality of manners of conveyance 10.Telecommunication systems.11.Quality and dependability of modes of transportation 12. Superiority and steadfastness of conveniences 13. Juxtaposition to Customers 14. Propinquity to dealers or creators 15. Principal eras and sensitivity	5 Alternatives Locations 1. Isfahan:A_1 2. Arak:A_2 3. Rasht:A_3 4. Urmia:A_4 5. Tabriz:A_5	Fuzzy TOPSIS	Selecting the best location for new warehouse $A_1 > A_2$ $A_5 > A_4 > A_3$ Isfahan(A_1) select as best location for new warehouse
Yayla , Yildiz & Özbek[20]	1.Quality 2.Delivery Time 3.Cost 4.Flexibility 5.Geographic Location	3 Alternatives of supplier 1.Supplier1:A1 1.Supplier2:A2 1.Supplier3:A3	Fuzzy TOPSIS (FTOPSIS)	Hand-picked the finest contractor A1> A3 > A2 Supplier 1(A1) as best supplier

Various types of application field of Fuzzy SAWmethod are describe in table4. Some applications of this method are Personnel Selection problem[24], Optimal Robots and Manipulators Selection[25], Project Manager Selection[26] etc.

TABLE 4. Application of Fuzzy SAW

Author & year	**Variable, Parameter**		**Methodology**	**Finding (Best Alternatives)**
	Criteria	**Alternatives**		
Afshari, Mojahed & Yusuff[24]	1. Knack to exertion in diverse commercial units:C1 2. Former familiarity: C2 3. Team player:C3 4. Eloquence in a Foreign language:C4 5. Deliberate Discerning:C5 6.Verbalised communication skills:C6 7. Computer Skills:C7	5 Personal alternatives 1.P1 2. P2 3.P3 4.P4 5.P5	Simple Additive Weighting (SAW)	Select the best personnel who have passed examination in a Telecom company P3>P2>P5>P1>P4 P3 is select as best personnel
Bai & Wang[25]	1. Axes:C1 2. Payload (kg):C2 3.Repeatability (mm):C3 4.Accuracy (mm):C4 5:System cost (US$):C5 6:Bulk (kg):C6 7: Max Gesticulation Speed (rad/s):C7 8.Mounting technique (average, good, super):C8 9.Power debauchery (kW):C9 10.H-Reach (mm):C10 11 V-Reach(mm):C11 12.Connexion space (m3):C12	20 .Alternatives of Robot A,B,C,D,E,F,G, H,I,J,K,L,M,N, O,P,QR,S,T	Fuzzy simple additive weighting (FSAW)	Select the optimum robot scheme from a hefty cluster of robot candidates.The top 10 optimal robot is: D > C > P > J > B > E > O > N > I > Q.
Afshari, Yusuff & Derayatifar[26]	1.Basic Requirements 2.Project Management Skills 3.Management Skills 4.Interpersonal Skills	3 Project manager alternatives.(candidate) 1.P1 2.P2 3.P3	Fuzzy Simple Additive Weighting(FSAW)	Selecting project manager in MAPNA Company P2>P3>P1 Candidate P2 Select as best project manager

Sub criteria[26]: Bygone knowledge, Edification, .Communiqué skills, Computer talents, Period Administration, Price Controlling, .Resource Organisation, Superiority Organisation, Arrangement, .Consolidating, Regulations, Delinquent solving, Judgement making, Team development.

3.1 MULTI CRITERIA GROUP DECISION MAKING (MCGDM) AND MULTI ATTRIBUTE DECISION-MAKING(MADM)

In multi-criteria environment, sometime it is quite difficult for single decision-maker to give his/her appraisal for different domain such as banking, stock market etc. One decision maker can't give sufficient

information due to insufficient knowledge or experience. This problem can be solved by the group policymaking (GDM), where a certain group of decision-makers are present and they can give their judgements on some problem. Sometime the problem contains uncertainties and vagueness, therefore the judgements of decision makers go in the method of dialectal term rather than exact numerical values[27]. In multi-criteria environment the GDM is called Multi Criteria Group Decision-making (MCGDM).

MADM is a one type of MCDM problem. It is dealing with the selection problem, where the numbers of alternatives are chosen supported on a set of attributes. It is a discrete method and dealing with the finite number of alternatives. Table5 describe the some application area of MCGDM and MADM.

TABLE 5. Application of Multi Criteria Group Decision-making (MCGDM)

Author & year	**Variable, Parameter**		**Methodology**	**Finding (Best Alternatives)**
	Criteria	**Alternatives**		
Saghafian & Hejazi[28]	1.Publications and investigates (C1) 2. Instruction skills (C2) 3.Hands-on knowledges in trades and corporations (C3) 4.Former understandings in teaching (C4) (5) Teaching restraint (C5)	Name of three eligible candidates 1.A1 2.A2 3.A3	Multi Criteria Group Decision Making(MCGDM), Fuzzy TOPSIS (FTOPSIS)	Finding the best candidate for teaching in an University A2>A3>A1 A2 is the best candidate
Wang ,Chen & Chen [29]	1. effectiveness of contractor (C1) 2. Connexion familiarity (C2) 3. Technological competence (C3) 4. Conformance superiority (C4) 5. Skirmish resolution (C5)	5 suitable Material Supplier 1.A1 2.A2 3.A3 4.A4 5.A5	Group Fuzzy Multi-criteria Decision Making, Fuzzy TOPSIS (FTOPSIS)	Select a suitable material supplier for purchasing martial of new product. A2>A3>A1>A4>A5 A2 is the best alternatives
Wang & SKao[]30	1.Debt to total possessions ratio 2.Working principal to entire possessions ratio 3.Rapid ratio 4.Cash flow ratio 5.Working capital to current assets ratio.6.Accounts payable turnover 7. accounts receivable Turnover 8. Fixed assets turnover 9. Net income(loss) turnover 10.Gross profit ratio.	3 companies 1.A_1 2.A_2 3.A_3	Fuzzy multi-criteria group decision making (FMCGDM), fuzzy TOPSIS (FTOPSIS)	$A_2>A_1>A_3$ A_2 has best beneficial performance.

	11.Manoeuvre profit ratio 12.Net revenue ratio			
Jiang & Liu [27]	1.Financial measurements:y_1 2.Customers:y_2 3.Iinternal business process:y_3 4. Learning and growth:y_4	Four commercial banks 1.x_1 1.x_2 1.x_3 1.x_4	Multi-Criteria Group Decision Making (MCGDM), Balanced scorecard (BSC),linguistic 2-tuples	Select the best commercial bank $x_4 > x_1 > x > x_2 > x_3$ x_4 is selected as best commercial bank.
Wimatsari, Putra, Buana[28]	1. GPA (Grade Point Average):C1 2. Measure of revenue parents by the numeral of dependents:C2 3. The Tradition of Electrical Power:C4 4. Student Happenings:C5	8 Students where Attainment Scholarship is 5 students and Underprivileged grant is 3 students 1.001 2.002 3.003 4.004 5.005 6.006 7.007 8.008	Fuzzy Multi Attribute Decision Making (FMADM), Fuzzy TOPSIS (FTOPSIS)	Student selection for achievement scholarship and Underprivileged scholarship. 5 Candidates who achieve scholarship and rank is006>005>001>008>003 3 Candidates who achieve Underprivileged scholarship and rank is 004>002>007

Two or more methods can be combined with MCDM domain for evaluating the best result. So hybridization of methods is possible for solving a decision-making problem. Some application area of hybridization method is discussed in table6. Sustainable city logistics planning[10] problem are solved by the combined method of AHP and fuzzy TOPSIS, is a beautiful example of hybridization between MCDM methods.

TABLE 6. Application of Combinational and others FMCDM methods

Author & year	Variable, Parameter		**Methodology**	**Finding (Best Alternatives)**
	Criteria	Alternatives		
Chang & .Tseng [32]	1.Cost:x_1 2.Speed:X_2 3.Strength:x_3 4.Lubrication system:x_4 5.Coolant pump system:x_5	16 configuration alternatives A_1 to A_{16}	Fuzzy TOPSIS (FTOPSIS) , Fuzzy quality function deployment (QFD)	Select a the best configuration alternative of CNC lathe machine. A_4 is chosen as best alternative
Zhuofu, Wei-min & Jun-zu; Bin[33]	1.Project Characteristics 2.Owners' Needs & Preferences 3.Project	Comprehensive evaluation value 1.Outmoded technique (DBB) 2. Design-build	Entropy method, Fuzzy compr-ehension evaluation	Choose the proper project conveyance arrangement for a large- scale aquatic

	Circumstances.	scheme (DB) 3. edifice organisation at peril technique (CM at-Risk)		quantity project CM at-Risk>DB> DBB CM at-Risk is chosen as best project distribution technique.
Apak & Vayvay[34]	1. M1 decision Management System 2. M2 Intelligent text mining 3.M3 risk management	3 Intelligent Business System (IBS) alternatives 1.A1 2. A2 3.A3	Fuzzy AHP, Fuzzy TOPSIS	Evaluating a proper IBS of IT department A3>A1>A2 A2 select as best IBS.
Santos[35]	1.Attributes Revenue:C1 2. Percentage of bills late more than 30 days:C2 3.Regularity of payment bills:C3 4.Total weight carried:C4 5.Amount of invoice by customer:C5 6.Amount of Transport invoice:C6	10 customers Alternatives A_n n=1 To 10.	Fuzzy Rule-Based Systems Fuzzy TOPSIS (FTOPSIS),Fuzzy Flexible TOPSIS (FFTOPSIS)	CRM (Customer Relationship Management) systems in a transport company. A2 is select as best customer.
Awasthi & Chauhan[10]	1.Technical 2.Social 3.Economic 4.Enviornment	4 sustainable city logistics initiative 1.Vehicle sizing restrictions:A1 2.Congestionchargi ng schemes:A2 3.Urban distribution centre:A3 4.Admittance Effectiveness Limitations:A4	AHP & Fuzzy TOPSIS	Select the best sustainable city logistics initiative A4 > A2 > A1 > A3. A4 (Timing Limitations) is select as the best justifiable city logistics inventiveness.
Nagar[36]	1. Purchasing cost:C1 2. Founding cost (machine –floor requirements, etc.):C2 3.Functioning cost:C3 4.Reliability:C4 5.Operational flexibility:C5 6.Productivity:C6 7. Risks (safety):C7 8. Supplier's Environmental behaviors:C8	5 Maintenance alternatives 1. Predictive maintenance:.A_1 2. Breakdown maintenance:A_2 3. Routine maintenance:A_3 4.Preventive Maintenance:A_4 5.Corrective maintenance:A_5	Multiple-Criteria Decision Making(MCDM),Fuzzy sets	picking the greatest appropriate maintenance approach for Air caster. $A_1>A_2>A_4>A_3>A_5$. A_1,is select as the best maintenance alternative for Air caster.

Hicdurmaz[7]	1.People 2.Process 3.Tecnical	4 type of Software Life Cycle Model (SLCM) 1. Cascade Model 2. V Model 3. Spiral Model 4. Evolutionary Prototyping	Fuzzy AHP, Fuzzy TOPSIS	assortment of appropriate software life cycle model (SLCM) of software development progression. Evolutionary Prototyping > V Model > Spiral > Waterfall. Evolutionary Proto-Typing model select as best software life cycle model of software development process

Evaluation attributes[33]: Venture scale(A1), Project intricacy(A2), Profundity of the enterprise article(A3), Gradation of engrossment after indenture award(A4), Fee control(A5), Agenda control(A6), Peril distribution(A7), Occurrence of native edifice market(A8), Law and local regulation(A9).

Sub criteria[34]: Optimization model(C1), Time series exploration(C2), Controlled text examination(C3), Numeric data breakdown(C4,), Foretelling model(C5), Clustering(C6), Classification(C7), Profiling(C8), Hyper linking(C9), System(C10), Prediction(C11).

Ranking evolution[35] of each alternative after applying 3 different methods 1.Fuzzy Rule Based System: A2> A1> A6> A8 > A7 >A3 A4 >A10 >A5 >A9, 2. Fuzzy TOPSIS A2> A1> A3> A6 > A7 >A8 A5 >A4 >A10 >A9, 3. Fuzzy F-TOPSISA2> A1> A6> A5 > A3 >A10 A7 >A4 >A8 >A9

Sub criteria[10]: Logistical competence (C1), Flexibility(C2) , Convenience(C3),Facility quality(C4), Loading influence(C5), Customer attention(C6), Deliverance of public space(C7), Energy upkeep(C8), Trip efficiency(C9), Incomes(C10), Volume of consignment handled(C11), Accidents(C12), Costs:(C13), Cramming (C14), Air pollution(C15), Noise(C16)

Sub criteria[7]: Ease of administration, User participation and Opinion, Cost, Intricacy, Critically, Suppleness, Reusability, Doc, and software quality, Testing and amalgamation, .Focus on design and architecture, Formal reviews, Requirement stability.

4 FINDINGS

MCDM has certainly become one of the furthermost supreme techniques in the policymaking field. Approaches of MCDM are designed perfectly to choose the best option for a complex decision-making, problem based on criteria evaluation and ranking the criteria. Though it is very much difficult to sum up all the different techniques in MCDM world, but our main motto behind this paper is to give an initial outline to a novice researcher in this area and to show the various application domains of MCDM methods such as FAHP, FTOPSIS, FSAW which we have discussed in this survey article.

Following section of this paper contains the results of this survey.

From our survey we have found wide variations of application domain on which Fuzzy MCDM techniques were applied such as Manufacturing System, Supply chain management, Location planning, Stock Marketing, Construction, Evaluation Of The Best Technical Institutions, Contractor Selection, Evaluating Tourism Islands, Robotics, E commerce, Software Industries, Project Manager Selection, Quality Management etc. We are putting a table too for better understanding,

TABLE. 7 Domain-wise Applications of MCDM methods

Sl no	**Commercial**	**Industrial**	**Environmental estimation**	**Performance rating**
1	To find the most preferable investment boards by incorporating operational risks.	To hand-picked the optimal technique for bridge construction.	Find the finest standards of social qualities enactment for tourism island.	To pursuit measures in the evolution of the best technical institution.
2	To find the finest automaton scheme from a huge group of robot entrants.	Contractor assortment, in selecting the finest contractor who is able to deliver better service.	To find the best potential locations for urban distribution centres.	To find which target Underwater Unmanned vehicle (UUV) should attack first.
3	To evaluate financial performance of different airline companies.	To find the best Flexible Manufacturing System (FMS) in industries.	To find the best location for building a new plant	To find the best personnel who are suitable In a Telecom company.
4	To evaluate banking performance of commercial banks.	To find the best supplier to deliver counterfeiting parts for Propeller shaft for the light and substantial viable vehicles	To find the best suitable location for building a new warehouse.	To Find the best candidate for teaching in an University.
5	To select the best configuration alternative of a lathe machine.	Find the best supplier in the garment industry.	To find the best sustainable city logistics initiative.	Student selection for achievement scholarship and underprivileged scholarship.
6	To evaluating an Intelligent Business System of IT department.	To hand-picked the best project manager in a certain corporation.		To hand-picked the unsurpassed customer in a transport company.
7		To Select the suitable material supplier for purchasing martial of new product.		
8		To find a proper project delivery system for a large-scale water supply project.		
9		To find the most appropriate maintenance approach for air caster.		
10		To select the appropriate Software Life Cycle Model (SLCM) of software development process.		
contr	6	10	5	6

This table describes the application fields of the FMCDM techniques and also gives us the clear essence about generalized the domains in which these techniques can be applied. We have divided the generalized domains into 4 parts. Under these domains we have also listed respective domain works. From the survey we have listed 6, 10 5 and 6 applications under commercial, industrial, environmental estimation and performance rating respectively. Though it will be wrong to say that FMCDM methods are mostly used in industrial sectors, but from our short survey we have found a number of applications in the industrial area than any other areas. From this above table we can easily conclude that the application areas of these methods are numerous. In most of these decision making problems, a fuzzy approach to MCDM is applied according to the complexity and the difficulty of the problem and due to its capability of handling uncertain situations and as it proves to be the best determination for the decision makers.

TABLE. 8 FMCDM methods and their respective number of occurrences

Sl. no	**MCDM methods**	**allowance**
1	FAHP	4
2	FTOPSIS	8
3	FSAW	3
4	Combinational	7
5	FMCGDM	5

Table 8 gives the most widely used fuzzy MCDM techniques in MCDM problems and they are also ranked according to their usage and applicability in various domains. The allowable number shows their number of occurrences in different problems in this survey.

For better understanding we have also plotted a graph indicating respective usages of different Fuzzy MCDM techniques as follows

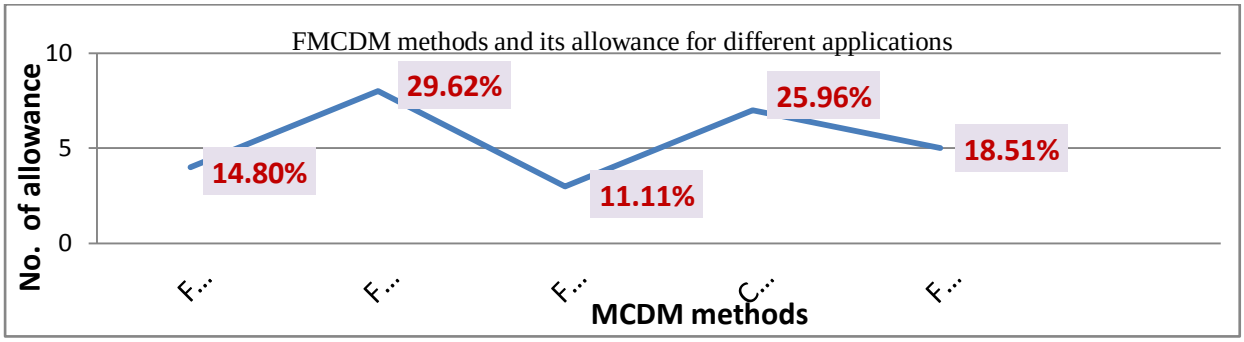

Fig 3.1 FMCDM methods and its allowance for different applications

Most widely used Fuzzy MCDM techniques only are taken into consideration. This is basically the graphical representation of the table no 8. The Fuzzy MCDM techniques include Fuzzy AHP(FAHP), Fuzzy TOPSIS(FTOPSIS), Fuzzy SAW(FSAW), Fuzzy Combinational techniques and Fuzzy MCGDM(FMCGDM) techniques.

From the above figure we can say that FTOPSIS and Fuzzy combinational techniques come among the most widely used FMCDM techniques in order to be used in some domain, though it will be unfair to judge the usefulness of these techniques only in a small scale as we have done that based on our survey. In between these techniques, there also many techniques which include some alterations in classical techniques and those alterations are new variations of those techniques which are actually altered for gaining better result and according to the problem analysis. We are enlisting also some of the papers where these modified approaches have been shown.

S. Saghafian and S.R Hejazi[28] proposed a modified Fuzzy TOPSIS procedure in which they have implemented a new approach for measuring distance using the fuzzy comparison function instead of simple vertex method. W. Zhuo, etal.[33] have used a new weight evaluation technique "entropy weight method" which modifies the experts subjective weight and give the comprehensive weight, instead of using the attribute weight setting method. Some of the papers listed in this article also show the combinational methods for better result. A. Awasthi and S.S. Chauhan[10] previously used the simple Fuzzy TOPSIS method for location planning, but for better evaluation later they have proposed a combinational approach towards city logistic planning.

Many other MCDM methods are also around such as Fuzzy BCC, FSROWA, Fuzzy SBM, COPRAS-G, VIKOR, Fuzzy DEMATEL, Grey theory, Data envelopment investigation (DAE), Aggregated Indices Randomization method (AIRM), Goal Programming etc. But as the world of MCDM is too vast to be restricted to a survey, we have only taken the methods under MADM which are vastly using methods.

5 CONCLUSIONS

This paper is actually meant for outlining the research opportunities in MCDM and also their respective features that can be taken for solving domain problem when multiple choices are available for decision making. Paper mainly aims at finding the importance of MCDM methods in various fields. We also conclude that

FMCDM is the best to be applied in various domains for selecting the best alternatives among set of alternatives based on multiple criteria where vagueness and uncertainty involved and as they can be applied can be applied on both quantitative and qualitative data items. Various applications include domain such as Location planning, IT industry, Banking, Marketing, Supply chain management and other multi criteria domain etc. This survey is not biased towards any certain problem domain and mainly lists various fields of action so that a novice in this field can have the basic application ideas. Methods of FMCDM have been selected based on the problem type and its domain.

In recent years, combining different methods i.e. building hybrid methods has become very commondue to advancing technologies and increasing complexity. The combination of multiple methods handles and fulfils the deficiencies that can be seen in certain methods. These hybrid methods can be extremely successful in their applications, but only if their strengths and weaknesses are properly assessed. That is why we have also shown respective advantages and disadvantages of certain MCDM methods in our paper.

Lastly we conclude that MCDM techniques mixed with fuzzy are able to handle some the most complex decision making problems and the research area as well as application area of MCDM techniques is huge. So the future scope in this field is immense.

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