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A Survey on Multi Criteria Decision Making Methods and Its Applications

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Abstract Multi Criteria Decision Making (MCDM) provides strong decision making in domains where selection of best alternative is highly complex. This survey paper reviews the main streams of consideration in multi criteria decision making theory and practice in detail. The main purpose is to identify various applications and the approaches, and to suggest approaches which are most robustly and effectively useable to identify best alternative. This survey work also addresses the problem in fuzzy multi criteria decision making techniques. Multi criteria decision making have been applied in many domains. MCDM method helps to choose the best alternatives where many criteria have come into existence, the best one can be obtained by analyzing the different scope for the criteria, weights for the criteria and the choose the optimum ones using any multi criteria decision making techniques. This survey provides the comprehensive developments of various methods of FMCDM and its applications.

Keywords: *multi criteria decision making, fuzzy, MCDM, TOPSIS, best choice, decision making*

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1. Introduction

In our day today life, so many decisions are being made from various criteria's, so the decision can be made by providing weights to different criteria's and all the weights are obtain from expert groups. It is important to determine the structure of the problem and explicitly evaluate multi criteria. For example, in building a nuclear power plant, certain decisions have been taken based on different criteria. There are not only very complex issues involving multi criteria, some criteria may have effect toward some problem, but over all to have an optimum solution, all the alternatives must have common criteria which clearly lead to more informed and better decisions.

Multi Criteria Decision Making is pertaining to structure and solve decision and planning problems involving multiple criteria. The main objective of this survey is to support decision makers where there are huge choices exist for a problem to be solved. Typically, it is necessary to use decision maker's desire to differentiate between solutions [1] where there is no unique optimal solution for these problems. Solving the problem can be interpreted in different ways. It could correspond to choose the "best" alternative from a set of alternatives (where "best" can be interpreted as "the most preferred alternative" of a decision maker). Another interpretation of "solving" is to choose a small set of good alternatives, or grouping alternatives into different preference sets. An extreme interpretation is used to find all "efficient" or "non-dominated" alternatives.

The problem becomes more complex when many criteria exist for the alternatives. A unique optimal solution for an MCDM problem can be obtained without the desired information incorporation. An optimal solution's idea is often put back by the set of non-dominated solutions. A non-dominated solution has the property that without sacrificing at least one criterion it is not possible to move away from it to any other solution. Therefore, the decision maker can easily able to choose a solution from the non-dominated set. Otherwise, the decision maker could not do worse in any of them and could do better in terms of all the criteria. However, the set of non-dominated solutions is too large to present to the decision maker for their final choice.

This survey on multi criteria decision understands the need of MCDM, many works have been proposed in determining the best optimal solution for a problem using different methods in it, and each of the MCDM method has its uniqueness. Many applications uses MCDM in determining the flaws in the system, these flaws can be managed by using appropriate method for solving the problem.

The rest of the paper organized as follows, in section 2 discuss about the prior research on MCDM methods and its applications and section 3describes the research opportunities and section 4 concludes the paper.

2. Prior Research

In spite of incomplete information fuzzy logic allows decision making with estimated values. It should be noted

that a decision may be incorrect and can be later improved when additional information is available. Of course, a complete lack of information will not support any decision making using any form of logic. For complex problems, conventional methods (non-fuzzy) are usually depend on mathematical approximations (E.g. linearization of nonlinear problems), which leads to poor performance and very expensive. Under such circumstances, fuzzy systems often outperform conventional MCDM methods. Many works have been done in various fields like banking, general purpose, student and teacher performances, water resource location and many. In this case the alternatives and criteria have been collected and the evaluation of the criteria has been done to choose the best alternatives. MCDM structures complex problems by considering multi criteria explicitly, which leads to more informed and better decisions.

2.1. Methods of MCDM

MCDM methods have been applied to different applications and find the best solution to choose the best alternative. The Figure 1 depicts the hierarchical view of MCDM methods and its types. The widely used MCDM methods have been described in following headings.

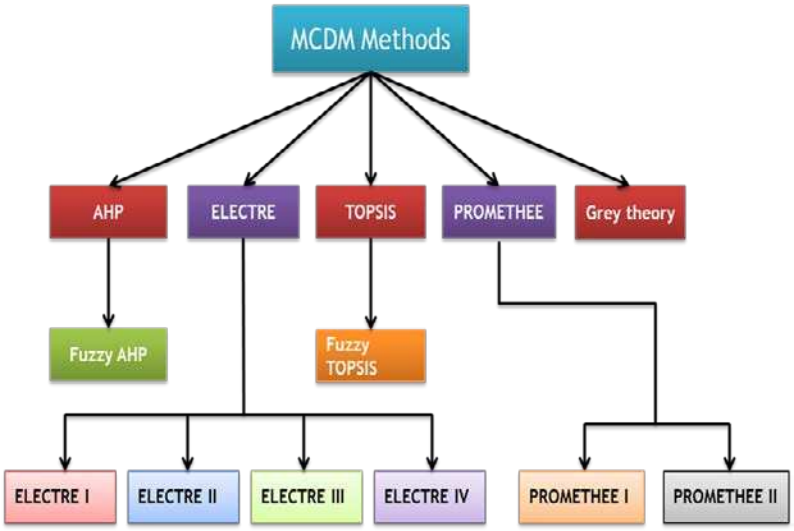


Figure 1. Hierarchical structure of MCDM Methods

2.1.1. Analytic Hierarchy Process

The basic idea of AHP is to capture experts' knowledge of phenomena under study. Using the concepts of fuzzy set theory and hierarchical structure analysis a systematic approach is followed for alternative selection and justification problem. Decision-makers usually find that it is more confident to give interval judgments than fixed value judgments. When a user preference is not defined explicitly due to fuzzy nature this method can be applied. AHP includes the opinions of experts and multi criteria evaluation; it is not capable of reflecting human's vague thoughts. The classical AHP considers the definite judgments of decision makers, thus the fuzzy set theory makes the comparison process more flexible and capable to explain experts' preferences. The Analytic Hierarchy Process (AHP) decomposes a difficult MCDM problem into a systematic hierarchy procedure [2]. The final step in the AHP method deals with the structure of an m*n matrix (where m is the number of alternatives and n is the number of criteria's). Using the relative importance of the alternatives a matrix is constructed in terms of each criterion. Analytic Hierarchy Process (AHP) is based on priority theory. It deals with the complex problems which involve the consideration of multi criteria/alternatives simultaneously.

2.1.2. Fuzzy Analytic Hierarchy Process

Fuzzification of Analytic Hierarchy Process (Fuzzy AHP) is used in conventional market surveys, etc. AHP, several products and alternatives are evaluated, by means of pairwise comparisons, the weight of each item evaluation and the evaluation values for each product and alternatives are found for each item evaluation, but the result of pairwise comparisons are not 0,1, but rather the degree is given by a numerical value [3]. In fuzzy AHP, the weight is expressed by necessary measure or possibility measure, and in addition, the conventional condition that the total of various weights 1 can be relaxed.

2.1.3. TOPSIS

The TOPSIS method assumes that each criterion has a tendency of monotonically increasing or decreasing utility which leads to easily define the positive and the negative ideal solutions. To evaluate the relative closeness of the alternatives to the ideal solution Euclidean distance approach is proposed. A series of comparisons of these relative distances will provide the preference order of the alternatives. The TOPSIS method first converts the various criteria dimensions into non-dimensional criteria similar to ELECTRE method [4] The concept of TOPSIS is that the chosen alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS). This method is used for ranking purpose and to get the best performance in multi criteria decision making. FUZZY TOPSIS method is used to evaluate the criteria in each region and then all the criteria have been ranked based on the region.

2.1.4. ELECTRE

ELECTRE (Elimination EtChoix Traduisant la REalite´) is one of the MCDM methods and this method allows decision makers to select the best choice with utmost advantage and least conflict in the function of various

criteria. The ELECTRE method is used for choosing the best action from a given set of actions and was later referred to as ELECTRE I. Different versions of ELECTRE have been developed including ELECTRE I, II, III, IV and TRI. All methods are based on the same fundamental concepts but differ both operationally and according to the type of the decision problem [5]. Specifically, ELECTRE I is intended for selection problems, ELECTRE TRI for assignment problems and ELECTRE II, III and IV for ranking problems. The main idea is the proper utilization of "outranking relations". ELECTRE creates the possibility to model a decision process by using coordination indices. These indices are concordance and discordance matrices. The decision maker uses concordance and discordance indices to analyze outranking relations among different alternatives and to choose the best alternative using the crisp data.

2.1.5. Grey Theory

Grey Theory has a high mathematical analysis of the systems which are partly known and partly unknown and is defined as "insufficient data" and "weak knowledge". When the decision-making process is not obvious Grey Theory examines the interactional analysis, there exist a great number of input data and it is distinct and insufficient. In the recent years, many decision making problems uses Grey Theory methodology in a successful manner [6].

Above listed MCDM methods have been applied widely to find best alternative when choices and criteria are high. These methods have been selected according to nature of the decision making. For selection of best ELECTRE have been applied, for ranking TOPSIS have been applied which chooses the best and Grey theory have been applied to chose the best where complete data is not available. The next section discusses about applications of these Fuzzy MCDM methods.

Apart from the MCDM methods which are listed, many other MCDM methods are available which have been listed below with its purpose, advantages and disadvantages. The suitability of each method and problem in which it can be applied has been described in Table 1. The merits and demerits of various MCDM methods have been described in Table 1 as follows.

Table 1. MCDM methods with its merits and demerits

Sl. No	MCDM Methods	Description	Advantages	Disadvantages
1.	Analytic hierarchy process (AHP)	It also includes pair wise comparison of different alternatives for different criterion.	1. Flexible, intuitive and checks inconsistencies 2. Since problem is constructed into a hierarchical structure, the importance of each element becomes clear. 3. No bias in decision making	1. Irregularities in ranking 2. Additive aggregation is used. So important information may be lost. 3. More number of pair wise comparisons are needed
2	Analytic Network Process(ANP)	AHP builds the decision problem from arrangement of different goals, criteria and alternatives and pair wise comparison of the criteria to obtain the best alternative	1. Independence among elements is not required. 2. Prediction is accurate because priorities are improved by feedback.	1. Time consuming 2. Uncertainty – not supported 3. Hard to convince decision making
3.	Data envelopment analysis (DAE)	DAE is a method where it is used to find the efficiency of combination of multi inputs and multi outputs of the problem.	1. Multiple inputs and outputs can be handled. 2. Relation between inputs and outputs are not necessary. 3. Comparisons are directly against peers 4.Inputs and outputs can have very different units	1.Measurement error can cause significant problems 2. Absolute efficiency cannot be measured. 3. Statistical tests are not applicable. 4. Large problems can be demanding.
4.	Aggregated Indices Randomization method (AIRM)	This method solves the complex problem where uncertainty occurs which has incomplete information for the problem to be solved.	1. Non-numeric, non-exact and non-complete expert information can be used to solve multi criteria decision making problems. 2. Transparent mathematical foundation assures exactness and reliability of results.	It aims only at complex objects multi-criteria estimation under uncertainty.
5.	Weighted Product model(WPM)	Alternatives are being compared with the other by the weights and ratio of one for each criterion.	1. Can remove any unit of measure. 2. Relative values are used rather than actual ones.	No solution with equal weight of DMs
6.	Weighted Sum Model (WSM)	It is used for evaluating a number of alternatives in accordance to the different criteria which are expressed in the same unit.	Strong in a single dimensional problems	Difficulty emerges on multi-dimensional problems
7.	Goal Programming	Goal programming is a division where it has more than one objective which conflicts with each other, and by arranging the goals or target have to be achieved by minimizing the irrelevant information.	1. Handles large numbers of variables, constraints and objectives. 2. Simplicity and ease of use	1. Setting of appropriate weights. 2. Solutions are not pair to efficient.
8.	ELECTRE	It is used to select the best choice with maximum advantage and least conflict in the function of various criteria	Outranking is used	Time consuming
9.	Grey analysis	This methods deal with all incomplete data and to overcome the deficiencies of other methods.	Perfect information has a unique solution	Does not provide optimal solution.

Table 1 has described advantages and disadvantages of each of the MCDM method. The next section describes various applications of Fuzzy MCDM methods from the literature.

2.2. Applications of FMCDM

FMCDM is used in various domains such as banking, performance elevation, decision making in different organization, safety assessment, multi choice general purpose problems, and etc. This section discuss about the various FMCDMS methods and its application domains.

2.2.1. Fuzzy MCDM Applications

Fuzzy occurs in various business organizations when multiple choices are available to take the best decision. For example for supplier selection for an organization is one of the multi criteria decision making problem which includes both quantitative and qualitative factors [7]. In order to choose the best supplier it is essential to make a trade-off between these tangible and intangible factors some of which may conflict. The process of determining the suitable suppliers, who are capable of providing the right quality product or services at the right price at the right time and in the right quantities to the buyers, is one of the most critical activities for establishing an effective supply chain. To solve this various FMCDM methods such as TOPSIS, ELECTRE and AHP have been applied. ELECTRE is used to reach close to the positive and get move off from negative points.

Safety issues are really at the core of marine engineering. In marine engineering the safety comes on, how the crew members understand the urge of risk and how the members effectively manage it is very important [8]. For this purpose fuzzy techniques such as TOPSIS, ELECTRE, and AHP have been applied to find best safety measures. Fuzzy MCDM methods also have been applied in areas such as location planning [9], revision of OWA operator problems [10] etc., which are described in Table 2.

Table 2. FMCDM applications in business domain

Application	Alternatives	Criteria	Problem	Techniques	Best alternative
Location planning for urban distribution centers under uncertainty [9]	3 Different Areas A1 A2 A3	1.Accessibility 2.Security 3.Connectivity to multimodal transport 4. Costs 5.Environmental impact 6. Proximity to customers 7. Proximity to suppliers 8. Resource availability	Location planning for urban distribution centers is vital in saving distribution costs and minimizing traffic congestion arising from goods movement in urban areas.	TOPSIS	A1 >A3 >A2. A1 is the best area
Revising the OWA operator problems under uncertainty (A case study) [11]	1. Sahand 2. Shahriar 3. Kalghan 4.Germichai 5. Givi 6. Taleghan 7. Talvar 8. Galabar 9. Sanghsiah 10. Soral 11. Siazakh 12. Bijar	1.Allocation of water to prior usages 2.Number of beneficiaries 3.Supporting other projects 4.Benefit/cost 5.Range of environmental impacts 6.Publicparticipation 7.Jobcreation	In finding the most robust alternative among these seven criteria	FSROWA Fuzzy-Stochastic-Revised Ordered Weighted Averaging (FSROWA) method is applied.	Germ chai project is the most preferred project
Enhancing information delivery in extended enterprise networks [27]	P1, P2, P3, P4, P5 (information receivers)	1. partner's price range 2. partner's interest to information 3. partner's product range	To find the best supplier for mold and die manufacturing concern, the product price range, the information receiver's interest and the product range are often considered by enterprises.	FMCDS	P2
Evaluating anti-armor weapon using ranking fuzzy numbers [28]	1. Dragon 2. Milan and 3. Sword (weapon systems)	1. basic capability 2. fight capability 3.logisticmaintenance 4. electronic system	Fuzzy multi criteria decision support procedure is applied to non-quantitative factors where decision making is complex.	Fuzzy multi attribute decision making	Sword
Evaluation suppliers in supply chain management [7]	1.Suppiler 1 2.Suppiler 2 3.Suppiler 3 4.Suppiler 4 5.Suppiler 5	1.Urgent delivery 2.On time delivery 3.Ordering cost 4.Warranty period 5.Product price 6.Financial stability 7.Delivery lead time 8.Accessibility 9.Reliability 10.Transportation cost 11.Rejection of defective product 12.Cost of support service 13.Testability	Supplier selection, the process of determining the suitable suppliers who are able to provide the buyer with the right quality products and/or services at the right price, at the right time and in the right quantities.	TOPSIS	Supplier 3

A fuzzy multi-criteria decision making model for supplier selection [12]	1.Saudi Arabian for Packaging Industry (SAPIN), 2.Arabian Can Industry (ACI), 3. ZA Turkish Supplier 4. Al-Watonga for Containers Manufacturing (CMC)	1.unit price and payment terms 2.delivery terms 3.supplier factory capacity 4.shipping method 5.lead time 6.location of can supplier 7.technical specifications 8.Services and communications with the supplier 9.compensationfor waste 10,major customers with the same business 11.certificate of Supplier	For the selection of cans supplier/Suppliers at Nitrides Factory in Amman-Jordan to demonstrate the proposed model.	1.Modified fuzzy DEMATEL model, 2.A modified TOPSIS model	SAPIN
Examine the use and application of MCDM techniques in safety assessment [29]	3 DIFFERENT COMPNANY 1.C1 2.C2 3.C3	1.Cost-control 2.Detailed information about the crewmembers and their behavior 3.availability of presenting data per ship 4.comparsion with industry 5. Planning, preview and scenarios of risk management.	To enhance safety by mitigating risks and increasing the reliability of a system.	1.TOPSIS 2.ELECTRE 3.AHP	C2
Multi-criteria decision making approach based on immune co-evolutionary algorithm with application to garment matching problem [13]	65 trousers with the same color, style and material for female are studied	waist girth (W), hip girth (H), and trousers length (L)	To solve the large scale garment matching problem where Size fitting problem is a main obstacle to large scale garment sales and online sales because it is difficult to find the fit garments by the general size information	co-evolutionary immune algorithm for the MCDM model	The product which satisfies the “CUSTOMER SATISFACTION and SERVICE QUALITY “ the most
An incident information management framework based on data integration, data mining, and multi-criteria decision making [14]	1.Beijing 2.Tianjin 3.Hebei 4.Chongqing 5.Xinjiang(31 provinces)	1.Percentage of areas covered to total areas 2. Percentage of areas affected to total areas (Drought Flood Hailstorm Frost)	A case study on agro meteorological disasters that occurred in China between 1997 and 2001. This case study demonstrates that the combination of data mining and MCDM methods can provide objective and comprehensive assessments of incident risks.	TOWA operator, cluster analysis, grey relational analysis, and TOPSIS	Chongqing
Assessment of health-care waste treatment alternatives using fuzzy multi-criteria decision making approaches [15]	1.Incineration 2. Steam sterilization 3.Microwave 4. Landfill	1.Economic 2.Environmental 3.Technical 4.Social	The objective of this research is to propose multi-criteria decision making techniques for conducting an analysis based on multi-level hierarchical structure and fuzzy logic for the evaluation of HCW treatment alternatives.	fuzzy MCDM methodology, hierarchical distance-based fuzzy MCDM algorithm	Landfill
Comparative analysis of multi-criteria decision making methodologies and implementation of a warehouse location selection problem [6]	1. Warehouse A 2. Warehouse B 3. Warehouse C 4. Warehouse D	1.Unit price 2.Stock holding capacity 3.Average Distance to shops 4.Average distance to main suppliers 5.Movement Flexibility	To compare the MCDM methods and implementation of a warehouse location selection problem	AHP, TOPSIS, ELECTRE and Grey Theory	WAREHOUSE
Health- Safety and Environmental Risk Assessment of Refineries Using of Multi Criteria Decision Making Method [16]	Power plant 1. location 1 2. location 2 3. location 3 4. location 4	1.environment of the power plant, 2.health-safety risks, 3.technological risks, 4.the affected environment risks	To find the best location for the implementation of the power plant using the AHP	AHP	Location 3

Mathematical analysis of fuel cell strategic technologies development solutions in the automotive industry [17]	1.Professional manpower on industrial & semi-industrial scale 2.Professional manpower on laboratory scale 3.Know-how on industrial & semi-industrial scale 4.Know-how on laboratory scale 5.Hardware on industrial & semi-industrial scale 6.Hardware on laboratory scale	1. Power density 2. Efficiency system of fuel cells 3. Fuel type (Including the effect on fuel cells operation, process stages, availability, cost, safety and environment considerations) 4. Life time and preserving fuel cells 5. Operational heat, start-up period, reaction period and response of fuel cells 6. Security and confidence	The analysis of fuel cell strategic technology in the automotive industry using TOPSIS	TOPSIS	Professional manpower on laboratory scale

*[12] - Unit price and payment terms (C1), delivery terms (C2), supplier factory capacity (C3), shipping method (C4), lead time (C5), location of can supplier (C6), technical specifications (C7), certifications (Regular and International) (C8), services and communications with the supplier (C9), compensation for waste (C10), printing complies to design and color (C11), easy open and spoon leveling (C12), testing methods for packaging materials and available tests from supplier (C13), variation of dimensions (C14), stretch wrapping and clean separators, pallet size and height (C15), major customers with the same business (C16), certificate of supplier materials (C17), SAPIN - Saudi Arabian Packaging Industry, ACI - Arabian Can Industry, CMC - Containers Manufacturing.

*[14] - Incident information management framework consists of three major components. The first component is a high-level data integration module in which heterogeneous data sources are integrated and presented in a uniform format. The second component is a data mining module that uses data mining methods to identify useful patterns and presents a process to provide differentiated services for pre-incident and post-incident information management. The third component is a multi-criteria decision-making (MCDM) module that utilizes MCDM methods to assess the current situation, find the satisfactory solutions, and take appropriate responses in a timely manner

*[15] -Sub criteria: Economic: Capital cost, Operating cost, Environmental: Solid residuals and environmental impacts, Water residuals and environmental impacts, Air residuals and environmental impacts, Release with health effects. Technical: Reliability, Volume reduction, Need for skilled operators, Occupational hazards occurrence impact, Treatment effectiveness, Level of automation, Occupational hazards occurrence frequency. Social: Adaptability to environmental policy, Land requirement, Public acceptance obstacles

Table 2 describes some the application of Fuzzy MCDM in various disciplines. In some applications uncertainty in decision making arises, so fuzzy multi criteria decision making is chosen to solve this issue. The criteria used in urban distribution centers such as security, accessibility, cost, and environment [9]. The sensitivity analysis is performed to determine the influence of criteria and weights on location planning is applied to find the suitable locations. The selection of location for placing the watershed which is using the new method FSROWA is introduced to combine the Fuzzy and Stochastic features into a revised OWA operator, for choosing the effective place for the location of the water shed [10]. To search the best place for urban Centre distribution all the places are ranked based on criteria.

The co-evolutionary immune algorithm for the multi-criteria decision making (MCDM) model, is used for the model to solve the large scale garment matching problem. Size fitting problem is a main obstacle to large scale garment sales and online sales because it is difficult to find the fit garments by the general size information. This study regards the fit garment matching problem as a MCDM model with the constraints of size satisfaction. An immune co-evolutionary algorithm is used to search the fit garments from the candidate garments in the stock [33]. Health-care waste (HCW) management is a high priority environmental, public and health concern in developing countries. The management and treatment of HCW are gaining more attention with the rising awareness. The proposed decision approaches enable the decision-makers to use linguistic terms, and thus, reduce their cognitive burden in the evaluation process. By using MCDM, the evaluation of multi-level hierarchical structure and fuzzy logic for HCW treatment can be obtained [15].

An effective incident information management system deals with several challenges. Decision makers have to detect variance and extract useful knowledge. Different services to satisfy the requirements of different incident management phases. Multi-criteria decision-making assess the current situation, finds the satisfactory solutions, and takes appropriate responses in a timely manner [14].To compare the performance of different MCDM methods such as AHP, TOPSIS, ELECTRE (I, II, IS, III, IV and A), Grey theory a case study on warehouse selection have been selected and different characteristic of each method is discussed [6].

AHP method is used in the analysis of the health - safety and environmental risk assessment of refineries for the location of the power plant, the risk factor such as health-safety risk, technology risk, etc., have been considered [16]. To select best strategic technology for the fuel cell in the automotive industry TOPSIS have been applied [17].

From all these works, different methods have been used for different applications where each of the method has its own characteristics in finding the best alternatives. The applications which are developed to solve multi choice problems and FMCDS methods which are chosen provides better performance in cases such as supplier chain management in business applications, safety assessment in marine engineering, watershed location and urban distribution centers in public sectors.

2.2.2. FMCDM in Banking

To process the mortgage or loan applications banks have a fixed set of criteria. After going through the criteria the decisions are made rigidly by the bank officers. This process can be made easier and more efficient using fuzzy logic. Nowadays, banks are increasingly turning to intelligent banking solutions like artificial intelligence to screen out many loan applications to make the final recommendation and approval. Banks can save valuable man-hours and dedicate the resources to other productive one by means of using these approaches. Therefore, it improves the bank processes efficiency and lowers the operating cost for the bank. Table 3 describes some of the bank applications which describe FMCDS.

Table 3. FMCDM applications in banking domain

Application	Alternatives	Criteria	Problem	Techniques	Best alternative
Banking performance based on Balanced Scorecard.[18]	Three banks 1.C Bank, 2.S Bank, and 3.U Bank	1. Finance 2. Customer 3.Internal Process 4. Learning and Growth	To rank the banking performance and improve the gaps with three banks as an empirical example.	The three MCDM analytical tools of 1. SAW, 2. TOPSIS, 3. VIKOR	‘‘U Bank”
Fuzzy performance evaluation in Turkish Banking Sector using Analytic Hierarchy Process and TOPSIS.[19]	The largest five commercial banks of Turkish Banking sector are examined and these banks are evaluated in terms of several financial and non-financial indicators	**Financial criteria:** 1. Asset quality 2. Capital adequacy 3. Liquidity 4. Profitability 5. Income and expenditure **Non Financial criteria:** 1.Pricing 2.Marketing 3.Productivity 4.Delivery services	To maintain the performance of the banking system since the economy is changing rapidly.	1.Fuzzy sets and fuzzy numbers 2.FAHP 3.TOPSIS	Customer satisfaction and Service quality have been evaluated for commercial banks.
The impact of 3D e-readiness on e-banking development in Iran: A fuzzy AHP Analysis. [30]	1. Human resource readiness 2. Top management readiness 3. Strategy readiness 4. Structure readiness 5. Technology readiness	1. organizational e-readiness 2. industry e- 3. macro environmental e-readiness	New information technologies and emerging business forces have triggered a new wave of financial innovation– electronic banking (e-banking).	Fuzzy AHP	Top management readiness and strategy readiness

Table 3 describes the various applications of Fuzzy MCDM in banking sector. However, intelligent banking systems has seen its usefulness enhanced with breakthroughs in technology such as fuzzy logic, there is still a need of human interpretation that must be used in dealing with sensitive transactions. It is a still a long way before intelligent banking system can do away with human interaction at all levels. Fuzzy logic allows a computer to reach a decision based on a myriad of factors with different levels of importance [21]. Rather than a yes or no answer, fuzzy logic application reaches a decision based on the weight given to the factors. The artificial intelligence in the application will compare all the potential results both positive and negative before coming to a final conclusion. Fuzzy logic applications using artificial intelligence often make use of neural networks to process the task.

Banking is the sector where fuzzy may occur many times, to overcome this fuzzy MCDM is applied. The fuzzy multi criteria decision making is very much useful in banking application and the performance evaluation of banks has important results for creditors, investors and stakeholder’s since it determines banks’ capabilities to compete in the sector and has a critical importance for the development of the sector [19].

The threat for E-Banking is identifying any phishing websites in real-time is really a complex and dynamic problem involving many factors and criteria [22]. The banking and financial industry is transforming itself in unpredictable ways powered in an important way by advances in information technology. Methods like TOPSIS, AHP, FAHP, FBCC and FSBM have been applied in e-banking.

In credit limit allocation model for banks all the criteria have been identified and each criteria assign weight by the experts group, and then criteria have been grouped in region wise [23]. The FUZZY TOPSIS method is used to evaluate the criteria in each region and then all the criteria have been ranked. Liner programming assigns credit risk concentration limits to the regional heads such that the total value of capital from all location (TVCA) becomes maximum.

The studied works gives an overview of applications of FMCDM where the different methods have been applied and used. Fuzzy is a technique which is widely used where uncertainty occurs, where the judgment of the result is not clear and optimal, the fuzzy weights have been assigned to each criterion and they have been evaluated. In banking sector FMCDM is used to overcome the uncertainty which was the drawback of the system. It is also being used in E- Banking where users often tend to have problem or dilemma in selecting the links where there is a threat of hacking the passwords through spam mails and hence fuzzy have been applied to identify the phishing web sites and links. The below sections explains about the performance evaluation of MCDM applications.

2.2.3. Fuzzy MCDM in Performance Evaluation

Not only general domains, the Fuzzy MCDM methods also applied to evaluate the performance of organization. Table 4 describes FMCDM methods to evaluate the performance of organizations. By applying COPRAS-G

method the performance of a teacher has been computed. This method is adapted to utilize numerical scores in the form of interval marking. Common methodologies reported in past research can handle quantitative numerical score. These methods cannot consider interval making assigned to a particular item whereas COPRAS-G method overcomes this drawback [24].

In Evaluation of training performance of administrative instructors fuzzy set theory is applied to measurement the performance. AHP is applied to obtain criteria weight and for ranking TOPSIS is applied. To evaluate decision alternatives involving subjective judgments made by a group of decision makers, fuzzy MCDM approach is used. A linguistic rating method is used for making absolute judgments and a pair-wise comparison process is used to help individual decision makers to make comparative judgments [4].

Table 4. FMCDM in Performance evaluation

Application	Alternatives	Criteria	Problem	Techniques	Best alternative
Application of MCDM approaches on teachers' performance evaluation and appraisal	5 teachers' T1 T2 T3 T4 T5	1.Interaction with students 2.Time taken for Problem solving (decision making) 3.Depth of knowledge in own field 4.Dedication, Punctuality and involvement 5.Pedagogy of teaching	To find the best teachers using MCDM technique. The performance and appraisal of each teacher are done separately.	COPRAS-G	T3
Training Performance Evaluation of Administration Sciences Instructors by Fuzzy MCDM Approach [4]	4 Instructor Instructor A Instructor B Instructor C Instructor D	1.Teaching style, 2.Individual features and social relation, 3.Knowledge level, 4. Observance of educational regulations 5.Educational tools.	To find the best trainee and the performance of the administrative science instructors	FMCDM	Instructor A
Power customer satisfaction and profitability analysis using MCDM [26]	A1, A2 A3 A4	cost, reliability, availability, maintainability and power quality	To investigate appropriate tools (MCDM) aiding decision makers to achieve their goals.	Analytic Hierarchy Process (AHP)	A2
Multi-criteria decision-making method based on interval-valued intuitionist fuzzy sets. [27]	1. A car company; 2. A food company; 3. A computer company; 4. An arms company.	1.The risk analysis; 2. The growth analysis; 3. The environmental impact analysis	To find the best company for investment of money in the 4 company using the interval valued intuitionist fuzzy sets.	interval-valued intuitionist fuzzy information	A2 >A4 >A3 >A1

*[26] - Alternative 1 (A1): Corresponds to the actual state of the electric power system under study, Alternative 2 (A2): Faults detectors are installed at each substation; consequently the time to fault research is reduced. Alternative 3 (A3): To alternative 2 (A2), are added remote control switches on outgoing MV lines to reduce the number of customers concerned by a failure. Alternative 4 (A4): Some overhead circuits are undergrounded and sections of the aging cables are replaced by new ones (are concerned the sections with a number of joints exceeding the threshold value).

The performance evaluation is used to measure the performance of the employee in the organization. Evaluations are utilized to determine whether the employee meets the certain criteria and to recommend appropriate follow-up actions. During the evaluation of performance uncertainty occurs, so MCDM approach is applied to measure the performance issues. In Teachers performance evolution many alternatives and criteria are applied to analyze the performance of teachers and best teacher is identified using COPRAS-G. In the same way to analyze the training administrative instructor's performance various criteria such as the knowledge level, problem solving skills and cognitive abilities have been considered [4].

Consumer demands for electrical energy are increasingly growing, because this energy is present in all the fields of human activity. The alternatives are technical and the organizational measures often taken in planning and operation phases of electrical power systems is to investigate appropriate tools (multi-criteria decision making methods) aiding decision makers to achieve the goals like customer satisfaction and profit making [26]. Multi-criteria decision-making method based on interval-valued intuitionist fuzzy sets which is used for determining the best company(a car company, a food company, a computer company, an arms company) to invest the money to obtain more profit [16].

3. Findings of Survey

Multi criteria decision making and its applications have been discussed in this survey. The multi criteria decision making is one of the powerful tool for obtaining the best choice for a complex decision making situations using various methods such as Fuzzy AHP, ELECTRE, TOPSIS, Grey theory etc. The evaluation of the criteria and ranking the criteria to find the best alternative have been found using MCDM techniques. The outcome of this survey has been described below.

3.1 MCDM is the Powerful Technique for Decision Making

The MCDM is used in many application such as performance evaluation, warehouse location, supplier selection, supply chain management, Assessment of health-care waste treatment, Banking performance, e-banking, teachers' performance and in various multi choice selection process. The decision making in all these application is efficient and best alternative have been found. Table 5 describes about various applications of MCDM techniques.

Table 5. Application of MCDM

MCDM Applications		
Banking performance	Performance mgmt.	Selection process
Business performance	Partner selection	Risk mgmt.
Automotive industry	Environment assessment	Mold and Die Industry
Education	Health care	Marine egg.
Financial investment decisions	Financial ratios and business performance	Manufacturing systems
Demand forecasting	Material selection	Bioinformatics

The performance of the MCDM is very high in the business organization which is used to solve the complexity of the problem. MCDM is used in all real world application such as warehouse location, environment assessment. The performance of the organization is developed by better solution which can be obtained by MCDM. In the business, the collections of relevant information have been done, to provide the better solution for the problem. The relevant information is very useful in the making the decision in the complex problem which occurs in the organization. The methods of MCDM are unique in there characteristic, which can be used in the certain problem that suits there characteristic. For example, the TOPSIS method, that has chosen the best alternative based on a maximization of the distance from the negative ideal point and minimization of the distance from the positive ideal point. Grey theory methods, examines the interactional analysis when the decision-making process is not clear, there are a great number of input data and it is discrete and insufficient data.

3.2. Fuzzy MCDM Application and Fuzzy MCDM Methods

The fuzzy multi criteria techniques have been applied in various fields such as Banking sectors, issues such as urban distribution centers, water shed allocation, safety assessment, and performance evolution of business organizations. The statistical report for the some of the areas in which multi criteria decision making is used is described in Table 6.

Table 6. Domain Vs. FMCDS application

S.No.	Banking	Business	Environment assessment	Performance evaluation
1	To evaluate Banking performance based on Balanced Scorecard	To find the best supplier for mold and die manufacturing concern in the enterprises	Location planning for urban distribution centers	To find the best teachers using MCDM technique. The performance and appraisal of each teacher are
2	To analysis performance of the banking system during economy is changing rapidly	Finding the best supplier who is able to provide the right quality products and/or services at the right price with the right quantities and at the right time.	In finding the most robust alternative among these seven criteria for water planet location	To find the best trainee and the performance of the administrative science instructors
3	To detect the phishing mails	Supplier selection, in selecting the best suppliers who are able to provide the buyer with the right quality products	To enhance safety by mitigating risks and increasing the reliability of a system.	To find the best company for investment of money in the 4 company using the interval valued intuitionist fuzzy sets.
4	New information technologies and emerging business forces in banking	For the selection of cans supplier/Suppliers at Nitrides Factory in Amman-Jordan	Evaluation of HCW treatment alternatives	to investigate Appropriate tools (multi-criteria decision making methods) aiding decision makers to achieve these goals
5	Data envelopment analysis (DEA) mainly utilizes envelopment technology to replace production function in microeconomics	-	Implementation of a warehouse location selection problem	-
6	-	-	To find the best location for the implementation of the power plant using the AHP	-
Contr.	5	4	6	4

Table 6 describes the analysis report of the multi criteria techniques which is widely used in various applications. Table 6, also describes the clear essence of the domains in which MCDM is applied. Most of the multi criteria based problems fuzzy MCDM approach is applied due to its capability of solving uncertainty issues and it gives the best determination for the decision makers, so that MCDM method is used in many domains. Each MCDM method is chosen according to difficulty of the problem. Table 7 describes about most widely applied methods in multi criteria decision making and these methods are ranked based on its applicability and usage in various domains.

Table 7. MCDM Methods and its usage

S. No	MCDM Methods	Contributions
1	FMCDM	5
2	TOPSIS	9
3	FAHP	6
4	VIKOR	2
5	ELECTRE	5
6	Others	3

A graph is plotted to indicate the usage of MCDM methods in the various applications in the survey work. Most widely applied methods in decision making problem such as TOPSIS, ELECTRE, FAHP, FMCDM, VIKOR and there are others methods such fuzzy DEMATEL,

FSROWA, Fuzzy BCC, Fuzzy SBM etc have been applied in few works.

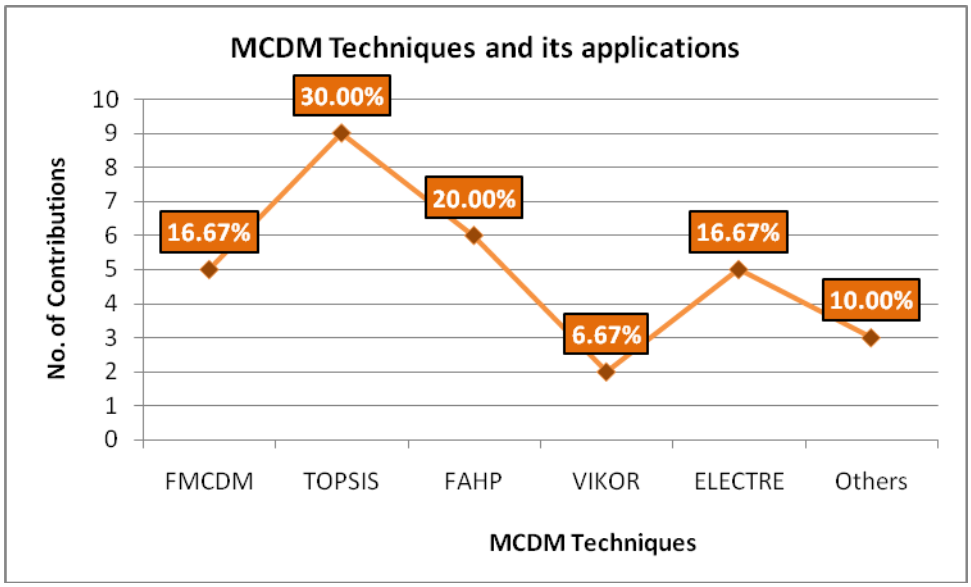


Figure 2. MCDM methods and its contributions

From the Figure 2 it known that TOPSIS method is applied mostly in many applications. The next is FMCDM method that has been used in the fuzzy application for solving the uncertainty. A Fuzzy MCDM is an approach for evaluating decision alternatives involving subjective judgments made by a group of decision makers. A pair-wise comparison process is used to help individual decision makers to make comparative judgments, and a linguistic rating method is used for making absolute judgments. The other methods are Fuzzy BCC, Fuzzy SBM, FSROWA and COPRAS-G. This survey outlines research opportunities in MCDM, the features of MCMD can be applied to any domain when multiple choices are available for decision making. The next sub section discuss the difference between fuzzy AHP methods,

3.3. Comparison of AHP and Fuzzy AHP

Analytic hierarchy process AHP is a method used for ranking purpose in selecting the best one when the decision maker has multiple criteria. This method helps the decision makers to select a better alternative from all by satisfying the minimal score to rank each decision alternative based on how well each alternative meets them. Fuzzy AHP, where it helps the human to make quantitative predictions as they are not well versed, but they are equally better in making quantitative forecasting. The uncertainty occurs during the judgments where in turn in consistency arises in between the alternatives.

Fuzzy pair wise comparisons states that there are many criteria's but if any criteria has a less important among all then it can be weighed as zero unlike other methods. Though that criterion is handled for the decision making process, if it has no importance when compared to all others. In the classic AHP method, deterministic values and operations do not permits such a situation "having zero weighed", but if a criterion is evaluated as less than all of the others, then the numerical weight of the criteria will be near to zero. Fuzzy AHP can merely ignore the criteria that have less importance whereas the classic AHP where it will be given with so weight. This can also be an advantage for fuzzy-AHP presenting additional information for decision maker that there is no difference between the existence and nonexistence of such a criterion. Therefore, the decision maker can focus on more important criteria.

Classical and fuzzy methods are not the rivals with each other at same conditions. The important point is that if the information / evaluations are certain, classical method should be chosen; if the information / evaluations are not certain, fuzzy method should be chosen. In recent years, because of the uniqueness of information and decision makers, probable deviation should be integrated to the decision making processes, and because of that for each decision making method, a fuzzy version is developed. Fuzzy AHP method is a natural result of this necessity. Linguistic and subjective evaluations take place in questionnaire form. Each linguistic variable has its own numerical value in the predefined scale. In classical AHP these numerical values are exact numbers whereas in fuzzy AHP method they are intervals between two numbers.

3.4. Comparison of ELECTRE, TOPSIS and GREY THEORY

TOPSIS method selects the best alternative by minimizing the distance from the positive ideal point and maximizing the distance from the negative ideal point, was not only applied to areas such as performance evaluation but also applied to problems such as selection of production processes and flexible manufacturing systems, within the operation management scope. Similarly, ELECTRE methods (ELECTRE I, IS, II, III, IV, A) selects the best alternative by means of all alternatives pairwise comparison; within the decision problems, especially has been applied to solve the issues present in environmental valuation and environmental management.

Grey Theory has a high mathematical analysis of the systems which are partly known and partly unknown and is defined as "insufficient data" and "weak knowledge". When the decision-making process is not obvious Grey Theory examines the interactional analysis, there exist a

great number of input data and it is distinct and insufficient. In the recent years [6], many decision making problems such as financial performance evaluation, supplier selection facility layout selection, demand forecasting and material selection uses Grey Theory methodology in a successful manner.

3.4.1. The Main Process

Using different calculation methods, decision making methodologies are separated from each others. The steps required separating from other decision making methods and the important solution algorithm are named as the core process [6].

TOPSIS:

In TOPSIS methodology, the distance calculation from the positive ideal and the negative ideal solutions of each alternative draws attention. The algorithm for TOPSIS method is as follows,

Step 1: By using the alternatives m and criteria n we calculate the normalized values (R_{ij})

$$R_{ij} = \frac{Aij}{\sqrt{\sum_{i=1}^{m} A_{ij}^2}} \quad i = 1,2,3...m, j = 1,2,...n \tag{1}$$

Step 2: The normalized values can be obtained by giving weights to the criteria (V_{ij})

$$V_{ij} = W_j * A_{ij}, i = 1,2,3...m, j = 1,2,...n \tag{2}$$

Step 3: The best performance (s^+) and worst perform (s^+) for every ideal alternative is determined.

$$s^+ = \left\{v_{1j}, v_{2j}, v_{3j} \ldots, v_{mj}\right\} = \left\{\max v_{ij} \, for \forall j \in n\right\} \tag{3}$$

$$s^- = \left\{v_{1j}, v_{2j}, v_{3j} \ldots, v_{mj}\right\} = \left\{\min v_{1j} \, for \forall j \in n\right\} \tag{4}$$

Step 4: For all the criteria, every alternatives distance to the best alternatives (D_i^+) using (3) and worst alternative (D_i^-) using (4)

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - s_j^+)^2} \quad for \quad i = 1,2,...m \tag{5}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - s_j^-)^2} \, for \quad i = 1,2,..m \tag{6}$$

Step 5: The positive ideal solution (C_i) is calculated using (5) and (6).

$$C_i = \frac{D_i^-}{D_i^- + D_i^+} \quad i = 1,2,...m \quad and \quad 0 \le C_i \le 1$$

The biggest (C_i) value is chosen as best selection and solution for the MDCM problem is obtained through TOPSIS.

ELECTRE:

While ELECTRE I and ELECTRE II methods are differs from the other methods through the determination of concordance and discordance matrices for each criterion and alternative pair. ELECTRE III method differs from the other methods and it is based on the principle of fuzzy logic and uses the preference and indifference thresholds while determining the concordance and discordance indexes. The algorithm for the ELECTRE I method is given as,

The first two steps are same as TOPSIS. The weighed normalized values are calculated using the equation (1) and (2).

The C_{kl} concordance matrix elements is calculated,

$$C_{kl} = \sum_{j \in C_{kl}} W_j \, .$$

The D_{kl} discordance matrix element is calculated,

$$D_{kl} = \frac{\max\left\{V_{kj} - V_{ij}\right\} j \in D_{kl}}{\max\left\{\left|V_{kj} - V_{ij}\right|\right\} j \in V_j}$$

Concordance threshold (C_{avr}) and discordance threshold (D_{avr}) is calculated.

The last step, according to the condition $C_{kl} \ge C_{avr}$ and $D_{kl} \ge D_{avr}$ is calculated and the best alternative is selected.

GREY THEORY:

Step 1: The data set are created based on the criteria $C_0 = \{C_1, C_2, C_3, \cdots\}$

Step 2: $C_i = \{C_{i1}, C_{i2}, C_{i3}, \cdots\}$ comparison data is determined which shows the performance values of each alternatives against the criteria, where i=1,2,3..k, where k defines the alternative number.

The maximum performance indicator of the criteria is calculated as follows,

$$V_i(l) = \frac{V_i(l) - \min V_i(l)}{\max V_i(l) - \min V_i(l)} \tag{7}$$

The minimum performance indicator of the criteria is calculated.

$$V_i(l) = \frac{\max V_i(l) - V_i(l)}{\max V_i(l) - \min V_i(l)} \tag{8}$$

The optimum value performance indicator of the criteria is calculated

$$V_i(l) = 1 - \frac{\left|V_i(l) - U_i\right|}{\max\left|V_i(l) - U_i\right|} \tag{9}$$

The normalized data is calculated from equations (7), (8) and (9).

Step 3: The distance between data sets are calculated using $\Delta i = \left(\left|d_{01} - d_{i1}\right|, \left|d_{02} - d_{i2}\right| \ldots\ldots \left|d_{0m} - d_{im}\right|\right)$ with global maximum ($\Delta_{\max}$) and global minimum ($\Delta_{\min}$).

Step 4: Each data point in difference set is changed into Grey Relational Coefficient. Grey Relational Coefficient of the data point "j" in difference set "i" is calculated using the formula:

$$C_i \gamma_i(j) = \frac{\Delta_{\min} + \xi \Delta_{\max}}{\Delta_i(j) + \xi \Delta_{\max}}$$

$\Delta i(j)$, Δ_i is the j. value in the difference set. Coefficient n is a value between 0 and 1, and is used to decrease the

effect of Δ_{max}, which is the extreme value in the data set. This coefficient is taken as 0.5 in most problems.

Step 6: The grey relational grade of alternative (i) is calculated:

$$r_i = \sum_{n=1}^{m} \left(\gamma_i(n) * w(n) \right)$$

The criteria are ranked according to their grey relational grade, the priority ranking is obtained and best alternative is selected.

3.4.2. Number of Outranking Relationship and its Type

Many number of pair wise comparison matrix exist which leads to a disadvantage of AHP and the opportunity of carrying out the methodology is prevented when the number of alternative and criteria are huge. ELECTRE I and TOPSIS methodologies needless input is compared with AHP and the necessity of pairwise comparison is eliminated.

3.4.3. The Consistency Control

One of the most important advantages of AHP is the limitation of consistency. In methods like TOPSIS, ELECTRE I and ELECTRE II the consistency is not controlled. Furthermore, since it is necessary to make pairwise comparisons in all the levels of hierarchy, as the number of alternatives and criteria gets increased, it gets harder to perform AHP for more complex problems. On the other hand, AHP can be easily performed without regarding the applied data evaluation of alternatives based on criteria either is qualitative or quantitative. Based on its simplicity in perception and its usage TOPSIS method gets attention. For a problem with huge number of alternatives and criteria's, TOPSIS and ELECTRE methods can be performed easily.

4. Research Directions in MCDM

To provide the decision-maker with the ability to look into the future, and to make the best possible decision based on past and present information and future predictions is the true goal in integrated decision-making system. In the case of sustainable development, to predict in advance the risk and vulnerability of populations and infrastructure to hazards, both natural and man-induced. This requires that data be transformed into knowledge, and the consequences of information use, as well as decision-making and participatory processes, be analyzed carefully. The use of fuzzy will give only an approximate solution for problem is the conclusion obtained from the survey works. The use of fuzzy is to analyze the quantitative and qualitative data for any application. The different methods under FMCDM help us to perform may subtasks between where evaluation and ranking are done by different methods. Each method has its own uniqueness. This is how fuzzy in analyzing an application. In previous works the mapping of information has been done where what information is needed for which users, for e.g., Government needs a lots of information when compared to other users like customers, management etc, so the further work can be enhanced by sending information to the users via correct medium and right time. The work to be done is to customize the correct information, where a student as a customer can get enough information regarding the educational loans. The visualization is mainly used to attract the users to get accessed often.

Fuzzy MCDM methods can be applied for information delivery in banking sector. In banking, loads of information's are obtained for various users like customers, government, management etc. so it's essential to deliver the correct information to the users in the way they want, each users might have they own perception of information to be delivered to them, so in banking the various needs of the users can be obtained by having many interviews from different users, making them to fill certain applications and questionnaire where they might able to capture the needs of each individual type of users, by this way the need of information delivery in banking can be improved to provide a better performance to them by customizing the information. Here comes the uncertainty in the information delivery for the user. For each user the information varies and content of the information also varies. Finding the best user and delivering right information and in user preferred channel should be delivered. The level of information also varies where different users need different information and the level of security also varies. This uncertainty problem can be solved by using FMCDM methods, which is used to provide the right information to right user in right time.

5. Conclusion

This survey finds opportunities in multi criteria decision making where decision making involves multiple choices. Fuzzy multi criteria decision making is used in many applications like Banking, performance evaluation, safety assessment and other multi criteria domains. FMCDM is applied to domains in which we need to evaluate more alternatives and multiple criteria and from that select the best alternative. According to the problem and its domain the MCDM methods have been selected. Very limited work has been applied using multi criteria decision making. This survey is concerned for banking where uncertainty occurs often in decision making. Fuzzy based MCDM is suitable for approximate problem spaces. Thus FMCDM can be applied to analyze quantitative and qualitative data of any application to arrive the solution. As it is known already there are many methods under MCDM each having its own scope of performance, the method have to be chosen in such a way for different problems that have to be solved.

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