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RESEARCH ARTICLE

A COMPREHENSIVE LITERATURE REVIEW OF MCDM TECHNIQUES ELECTRE, PROMETHEE, VIKOR AND TOPSIS APPLICATIONS IN BUSINESS COMPETITIVE ENVIRONMENT

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ABSTRACT

Purpose: The purpose of this paper is to introduce and provide an overview of the Multi Criteria Decision Making techniques PROMETHEE, ELECTRE, VIKOR and TOPSIS and suggest further scope and direction of research in this emerging field.
Design/Methodology/Approach: The work relies on step wise method, case studies, application and other literature related to MCDM techniques PROMETHEE, ELECTRE, VIKOR and TOPSIS. Literature has been segregated to understand various issues and work related to MCDM techniques PROMETHEE, ELECTRE, VIKOR and TOPSIS. A detailed review is used to sort out the literature and develop the research direction of the study. The review is focussed on development and improvement of MCDM techniques PROMETHEE, ELECTRE, VIKOR and TOPSIS including all those research which is relevant to the implementation of these methods in various sectors including energy, transportation etc. A literature seems to be a valid approach, as a necessary step in structuring a research field.
Findings: The objectives of this paper are to identify major research work conducted on MCDM techniques PROMETHEE, ELECTRE, VIKOR and TOPSIS and to classify them to identify gaps in literature and opportunities for future research. The paper has provided an integrative framework for study, improvement and implementation of MCDM techniques PROMETHEE, ELECTRE, VIKOR and TOPSIS. The findings also identify a number of issue that need to be addressed.
Research limitations/Implications – Implication of the work is that the knowledge of the research gap can to be used to focus efforts on key areas so as to ensure speedy and comprehensive implementation of MCDM techniques PROMETHEE, ELECTRE, VIKOR and TOPSIS.
Practical implications: The paper may prove to be a very useful source of information to decision makers in various fields to select the best alternatives/solution and in implementation of MCDM techniques.
Originality/Value: This paper provides some of the very first insights into development and implementation of MCDM techniques PROMETHEE, ELECTRE, VIKOR and TOPSIS. This methodological review will provide better understanding of the current state of the research in the discipline.

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INTRODUCTION

Multi-criteria decision-making MCDM) is one of the most widely used decision methodologies in the sciences, business, government and engineering worlds. MCDM methods can help to improve the quality of decisions by making the decision-making process more explicit, rational, and efficient. Multi-criteria decision making MCDM) is regarded as a main part of modern decision science and operational research, which contains multiple decision criteria and multiple decision alternatives. Fast-changing technologies on the product front cautioned the need for an equally fast response from the manufacturing industries. The selection decisions are complex, as decision making is more challenging today.

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In these situations Multi-criteria decision-making MCDM) techniques have been widely used in various fields.

Objectives and methodology of the paper

The objectives of this paper are to identify and report the major research work conducted on MCDM techniques PROMETHEE, ELECTRE, VIKOR and TOPSIS. The review of extant literature helps to identify gaps in literature and provide opportunities for future research. A literature review seems to be a valid approach, as a necessary step in structuring a research field and forms an integral part of any research Esterby-Smith *et al*., 2002). This helps to identify the conceptual content of the field and guides towards theory development Meredith, 1993). Multi-criteria decision-making MCDM) is one of the most emerging field and only few

reviews have been made over the years to examine the various aspects of MCDM related research. A number of existing reviews explore the MCDM literature for the development of various MCDM techniques and their methodology. In this work, we have examined existing studies from several perspectives, i.e. methodology and development of MCDM techniques PROMETHEE, ELECTRE, VIKOR and TOPSIS, use of these methods in literature and case studies, development of hybrid methods. Our review focuses on most recent research work in this fast growing field of Multi-criteria decision-making MCDM). The distribution of research publications from 1995 to 2015 is shown in figure 1. The results shows that approximately 80 percent work involving MCDM techniques PROMETHEE, ELECTRE, VIKOR and TOPSIS has been in the last seven years 2009-2015. which indicates the need of research, suggesting a field with a great scope for future study.

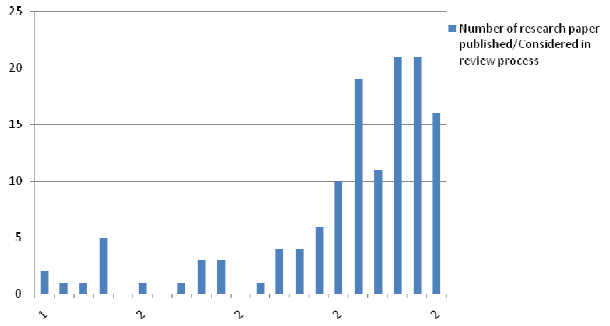

Figure 1. Number of research paper published/ considered in review process

ELECTRE definition

ELECTRE model is an outranking model or method to deal with Multi Criteria Decision Making MCDM) situations in which a finite set of alternatives should be ranked from the best to the worst. Various researchers defined ELECTRE in different words. Some of them are given in Table1.

PROMETHEE definition

The PROMETHEE is a multi criteria decision-making method developed by Brans, Vincke, and Mareschal 1986). It compares each pair of alternatives for each criterion and grades the alternativesin the 0–1 interval. Various researchers defined ELECTRE in different words. Some of them are given in Table2.

VIKOR definition

This method focuses on ranking and selecting from a set ofalternatives, and determines compromise solutions for a problemwith conflicting criteria, which can help the decision makers toreach a final decision. Here, the compromise solution is a feasiblesolution which is the closest to the ideal solution, and a compromisemeans an agreement established by mutual concessions Opricovic & Tzeng, 2007).

TOPSIS definition

The TOPSIS technique for order performance by similarity to ideal solution) was first developed by Hwang & Yoon 1981). According to this technique, the best alternative would be the one that is nearest to the positive-ideal solution and farthest from the negative ideal solution Ertugrul&Karakasoglu, 2007).

Development of research work on MCMD techniques Many researchers have worked on further development of methods/techniques ELECTRE, PROMETHEE, VIKOR and TOPSIS to improve the quality of results obtained by them or to make them more efficient in various ways and developed further improved forms of these methods. ELECTRE has been further developed to ELECTRE II, ELECTRE III, ELECTRE V, ELECTRE TRI and PROMETHEE has PROMETHEE I, PROMETHEE II and improved PROMETHEE as its modified forms. VIKOR and TOPSIS are also modified in the form of fuzzy VIKOR and fuzzy TOPSIS.

Table 1. ELECTRE definition

S. No.	ELECTRE definition as reported in the literature	Researcher(s)
1.	The ELECTRE III model is a highly developed multicriteria analysis model, which takes into account the preference, indifference and veto thresholds, as well as with the importance coefficients.	Agis Papadopoulos *et al*. (2006)
2.	The ELECTRE III method, in which the criteria of the set of decisional alternativesare compared by means of a binary relationship, defined as 'outranking relationship',are more 'flexible' than the ones based on a multi-objective approach.	M. Beccali *et al*.(2003)
3.	In ELECTRE methods, the construction of an outranking relation amounts at validating or invalidating, for anypair of alternatives (a; b), the assertion ''a is at least as good as b''.	Vincent Mousseau *et al*. (2003)
4.	ELECTRE method provides a different approach. This method concentrates the analysis on the dominance relationsamong the alternatives. That is, this method is based on the study of outranking relations, exploitingnotions of concordance.	Adiel Teixeira de Almeida (2006)
5.	ELECTRE III relies upon the construction and the exploitation of theoutranking relations.	Christos Giannoulis *et al*. (2010)
6.	ELECTRE method is composed of a pair-wise comparison of alternativesbased on evaluated information provided by the decisionmaker. This method is concerned with concordance, discordance,and outranking relationships.	Ming-Che Wu *et al*. (2011)
7.	ELECTRE III is a multi-criteria decision-making method thatreflects the decision maker's preferences and it can be applied when aset of alternatives must be ranked according to a set of criteriaconflicting each other or when just the preferred has to be selected.The method is based upon pseudo-criteria.	Antonella Certa *et al*. (2013)
8.	ELECTRE is a multi-criteria decision-ma king procedure that can be applied when a set of alternatives must be ranked according to a set of criteria reflecting the decision maker's preferences.	Giuseppe Aiello *et al*. (2013)

Table 2. PROMETHEE definition

S. No.	PROMETHEE definition as reported in the literature	Researcher(s)
1.	The PROMETHEE belongs to the family of outranking methods as it seeks to enrich the dominance relation thereby trading less credibility for a greater number of comparable pairs of actions.	Luis C. Dias *et al*. (1996)
2.	It is well adapted to problems where a finite number of alternatives are to be ranked considering several, sometimes conflicting criteria. The evaluation Tableis the starting point of this method.	Amir Albadvi *et al*. (2007)
3.	As an outranking technique PROMETHEE quantifies a ranking of alternatives through the pair wise comparison (differences) between their criteria values.	Malcolm J. Beynon *et al*. (2008)
4.	The PROMETHEE method can handle data that are known with a reasonable degree of accuracy and have fixed numerical values. It is a ranking method quite simple in conception and application compared to other methods for multi criteria analysis.	Li Wei-xiang *et al*. (2010)
5.	The PROMETHEE method belongs to the outranking family (Vincke, 1992). The actions are first pair-wise compared on each criterion according to the decision-maker's preferences, resulting to local scores.	Alessio Ishizaka *et al*. (2011)
6.	It belongs to the methods of partial aggregation, or also called outranking methods, and was partly designed as a reaction to the complete aggregation (MAUT) methods.	Laurence Turcksin *et al*. (2011)
7.	PROMETHEE method is the most known and widely applied outranking methods for pair wise comparison of the alternatives in each separate criterion.	S. Vinodh *et al*. (2012)
8.	The PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) uses the outranking methodology to rank alternatives. The central idea of the PROMETHEE is to compare alternatives in pairs regarding criteria firstly one by one then comprehensively.	Xiaohan Yu *et al*. (2012)
9.	In PROMETHEE, the preference structure for each criterion is based on pair wise comparisons. The deviation between theevaluations of two alternatives on a particular criterion is considered.	Golam Kabir *et al*. (2014)

Table 3. VIKOR definition

S. No.	VIKOR definition as reported in the literature	Researcher(s)
1.	The VIKOR method is an effective tool in multi-criteria decision making, particularly in situations where the decision-maker is unable to indicate preferences among decisions that may result in diverse outcomes.	Lisa Y. Chen *et al*. (2008)
2.	The basic concept of VIKOR technique lies in defining the positiveand negative ideal points, which was first put forth by Opricovic(1998) and Opricovic and Tzeng (2004). The VIKOR method is based on the compromise programming of MCDM.	Ming-Shin Kuo *et al*. (2011)
3.	VIKOR focuses on ranking and sorting a set ofalternatives against various, or possibly conflicting and non-commensurable,decision criteria assuming that compromising isaccepTableto resolve conflicts.	Ali Shemshadi *et al*. (2011)
4.	The VIKOR method was developed to solve multi-criteria decisionmaking problems with conflicting and non-commensurable(different units) criteria, assuming that compromising is acceptablefor conflict resolution, the decision maker wants a solutionthat is the closest to the ideal, and the alternatives are evaluatedaccording to all established criteria.	G. NilayYücenur *et al*. (2012)
5.	The VIKOR method introduces the multi-criteria ranking index based on the particular measure of closeness to the ideal solution(Opricovic, 1998). This ranking index is an aggregation of all criteria,the relative importance of the criteria, and a balance betweentotal and individual satisfaction.	Hu-Chen Liu *et al*. (2012)
6.	The basic concept of VIKOR method lies in defining the positive and negative ideal points, which was first put forth byOpricovic and Tzeng. The VIKOR method is based on the compromise idea of MCDM.	Yanbing Ju *et al*. (2013)
7.	The VIKOR method was introduced as one applicable technique to be implemented within MCDM problem and it wasdeveloped as a multi criteria decision making method to solve a discrete decision making problem with non-commensurable(different units) and conflicting criteria.	Nian Zhang *et al*. (2013)
8.	The VIKOR method was developed for the multi-criteria optimisationof complex systems. It determines the compromise rankinglist and the compromise solution.	Wan-Yu Chiu *et al*. (2013)
9.	VIKOR is used to solve discrete decision problems with conflicting criteria which can help the decision makersto optimize complex systems to get a final solution.	Kamran Rezaie *et al*. (2014)

Table 4.TOPSIS definition

Sn. No.	TOPSIS definition as reported in the literature	Researcher(s)
1.	Themethod is based on the concept that the chosen alternative shouldhave the shortest distance from the positive-ideal solution (i.e.,achieving the minimal gaps in each criterion) and the longest distancefrom the negative-ideal solution (i.e., achieving the maximallevels in each criterion).	Chia-Chi Sun (2010)
2.	TOPSIS method is based on choosing the best alternative, whichhas the shortest distance from the positive-ideal solution and thelongest distance from the negative-ideal solution.	Fatemeh Torfi *et al*. (2010)
3.	TOPSIS has been shown to be one of the best MADM methods inaddressing the rank reversal issue, which is the change in the rankingof alternatives when a non-optimal alternative is introduced.	MadjidTavana *et al*. (2011)
4.	TOPSISis a multiple criteria method to identify solutions from a finite setof alternatives and initially proposed by Chen and Hwang (1992).The underlying logic of TOPSIS proposed by Hwang and Yoon(1981) is to define the ideal solution and negative ideal solution.	GulcinBuyukozkan *et al*. (2012)
5.	This method is a unique technique toidentify the ranking of all alternatives considered. In the TOPSISmethod, the decision making matrix and weight vector are determinedas crisp values and a positive ideal solution (PIS) and a negativeideal solution (NIS) are obtained from the decision matrix.	H.H. Goh *et al*. (2013)
6.	Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) is a multi-attribute decision-making method, and uses to resolve multi-objective and multi-program decision problem. the basic idea is: the basic for estimation will be decided by constructing positive ideal solution and negative ideal solution of evaluationindicators and compare with the close and away degree of the ideal solution.	Jingfei YU *et al*. (2013)
7.	The primary concept of TOPSIS approach is that the most preferred alternative should not only have the shortest distancefrom the positive ideal solution (PIS), but also have the farthest distance from the negative ideal solution (NIS).	S. Vinodh *et al*. (2014)
8.	The TOPSIS method was proposed by Hwang and Yoon as amulti criteria decision making method to identify a solution froma finite set of points. The chosen points are the 'shortest' point'sin distance from the positive ideal and the 'farthest' points in distance from the negative ideal solution.	Osman Taylan *et al*. (2014)
9.	Basic concept of this approach is to select the alternatives on the basis of shortest geometric distance from the positive ideal solution and longest geometric distance from the negative ideal solution.	Mohit Tyagi *et al*. (2014)

Table 5. Development in ELECTRE

Sn. No.	Topic of research paper	Work done	Researcher(s)
1.	Choosing realistic values of indifference, preference and veto thresholds for use with environmental criteria within ELECTRE	A new, more comprehensive approach for specifying realistic limits for p, *q* and u, within the context of an environmental appraisal, where both criterion error/uncertainty and human sensitivity to differing levels of the criterion are taken into account.	Martin Rogers, Michael Bruen (1998)
2.	A new method for group decision support based on ELECTREIII methodology	N individual rankings and N corresponding valued preference functions are taken, and the natural heuristic provided by ELECTRE methodology for obtaining a fuzzy binary relation representing the collective preference is used.	Juan Carlos Leyva-Lopez, Eduardo Fernandez-Gonzalez (2003)
3.	Valued outranking relations in ELECTRE providing manageable disaggregation procedures	A slight adaptation of the valued outranking relation is used in the ELECTRE III and ELECTRE TRI. This modification is used to preserve the original discordance concept.	Vincent Mousseau, Luis Dias (2004)
4.	Ranking irregularities when evaluating alternatives by using some ELECTRE methods	some computational are done on ELECTRE II and III methods and these tests revealed that sometimes these methods might change the indication of the best alternative and this phenomena is known as rank reversals.	XiaotingWanga, EvangelosTriantaphylloub (2008)
5.	ELECTRE methods with interaction between criteria: An extension of the concordance index	An extension of the comprehensive (overall) concordance index of ELECTRE methods is presented, which takes the interaction between criteria into account. Three types of interaction have been considered: mutual strengthening, mutual weakening, and antagonistic.	Jose Rui Figueira, Salvatore Greco, Bernard Roy (2009)
6.	Design a new mixed expert decision aiding system using fuzzy ELECTRE III method for vendor selection	A fuzzy version of ELECTRE III method is proposed for ranking the alternatives based on their outranking relations and by considering the existing uncertainty in their performances. This way the final ranking is resulted from an independent fuzzy system, which has considered the existing uncertainty in the evaluations not once but twice.	Gholam Ali Montazer, HamedQahriSaremi, Maryam Ramezan (2009)
7.	The ELECTRE multicriteria analysis approach based on Atanassov'sintuitionistic fuzzy sets	a new method, the IF ELECTRE method is developed for solving MCDM problems with A-IFS information. This methodcan be also applied to situations with missing information orimperfect data.	Ming-Che Wu, Ting-Yu Chen (2011)
8.	Extension of Fuzzy ELECTRE based on VIKOR method	ELECTRE I is a simple method but is not efficient in ranking, so a combination of ELECTRE and VIKOR method is proposed with respect to relationship between them, to solve this problem.	A. Zandi, E. Roghanian (2013)
9.	Hesitant fuzzy ELECTRE II approach: A new way to handle multi-criteria decision making problems	HF-ELECTRE II approach is proposed that combines the idea of HFSs with the ELECTRE II method, to efficiently handle different opinions of group members that are frequently encountered when handling the MCDM problems. The approach formulated by defining the concepts of hesitant fuzzy concordanceand discordance sets and by constructing the strong and weak outranking relations, which are employed to decide the ranking for a set of alternatives.	Na Chen, Zeshui Xu (2015)
10.	An extension of ELECTRE to multi-criteria decision-makingproblems with multi-hesitant fuzzy sets	Some outranking relations for MHFNs, which are based on traditional ELECTRE methods, are introduced, and several properties are analyzed. For ranking alternatives an outranking approach is proposed to multi-criteria decision-making (MCDM) problems similar to ELECTRE III, where weights and data are in the form of MHFNs.	Juan-juan Peng, Jian-qiang Wang, Jing Wang, Li-Jun Yang, Xiao-hong Chen (2015)
11.	ELECTRE-III-H: An outranking based decision aiding method for hierarchically structured criteria	The analysis of the criteria is done according to the subsets defined in the hierarchy, and following the precedence relations in a bottom up approach. To deal with this type of hierarchical structures, an extension of the ELECTRE-III method, called ELECTRE-III-H, is proposed.	Luis Del Vasto-Terrientes, Aida Valls, Roman Slowinski, Piotr Zielniewicz (2015)
12.	Multiple Criteria Hierarchy Process for ELECTRE Tri methods	Proposed methodology to deal with hierarchical structure of criteria in decision problems by Multiple Criteria Hierarchy Process (MCHP). Applied MCHP to the ELECTRE-Tri methods. and extended ELECTRE Tri-B, ELECTRE Tri-C and ELECTRE Tri-nC methods. Adapted MCHP concept to the case where interaction among evaluation criteria has eitherstrengthening, or weakening, or antagonistic effect. Presented an extension of the Simos–Roy–Figueira (SRF) method to determine the weights of criteria in case they are hierarchically structured.	Salvatore Corrente,Salvatore Greco, Roman Słowi ´nski (2016)
13.	ELECTRE Methods in PrioritizedMCDM Environment	Considered special case of MCDM with prioritisation among criteria, called Prioritised MCDM. reformulate the expressions of concordance and discordanceindices based on fuzzy measures and digraphs respectively, so as to obtain generalized forms ofthe two indices which were key points to extend application of traditional ELECTRE methods.	XiaohanYua*, SuojuanZhanga, XianglinLiaoa, XiuliQia (2017)
14.	Supporting performance appraisal in ELECTRE based stepwise benchmarking model	Proposed a way to enhance the accuracy of input data in ELECTRE based stepwise benchmarking model For this purpose, devised a new module in stepwise benchmarking model, which translates the sequence of descriptive, non-numerical decision maker's assertions into scoring parameters. Model was implemented among European Union member states in the field of digital connectivity.	MarijanaPetrovic, NatašaBojković 2017
15.	A robust ranking method extending ELECTRE III to hierarchy ofinteracting criteria, imprecise weights and stochastic analysis	Suggested to apply Multiple Criteria Hierarchy Process MCHP to the ELECTRE III ranking method adapted to handle three types of interaction effects between criteria: mutual-weakening, mutual-strengthening and antagonistic effect. Also involved MCHP an imprecise elicitation of criteria weights, generalizing a technique called the SRF method. In order to explore the plurality of rankings obtained by the ELECTRE III method for possible sets of criteria weights, applied the Stochastic Multiobjective Acceptability Analysis (SMAA) that permits to draw robust conclusions in terms of rankings and preference relations at each level of the hierarchy of criteria.	Salvatore Correntea,Jos_e Rui Figueirab, Salvatore Grecoa,c, Roman Slowinski 2017

ELECTRE

Many of the researchers worked on ELECTRE method and its various aspects. Some of the major work done in the field of development of ELECTRE inchoosing realistic values of indifference, preference and veto thresholds within ELECTRE, a disaggregation approach for ELECTRE, ranking irregularities in ELECTRE method, ELECTRE methods with interaction between criteria, fuzzy ELECTRE III method, ELECTRE approach based on Atanassov's intuitionistic fuzzy sets, Extension of Fuzzy ELECTRE based on VIKOR method, Hesitant fuzzy ELECTRE II approach, extension of ELECTREwith multi-hesitant fuzzy sets, ELECTRE-III-H etc. This work done is summarized in Table 5.

PROMETHEE

Some major work done in the field of development of PROMETHEE is extension of the PROMETHEE frameworkcalled ``PROMETHEE I'', extension of PROMETHEE to deal with fuzzy inputdata, multiplicative PROMETHEE, PROMETHEE-MD-2T-I and II, PROSLP, prioritizedPROMETHEE etc. This work is summarized in Table 6.

VIKOR

VIKOR method is further developed and used in various other forms like extended VIKOR, extension of VIKOR method in intuitionistic fuzzy environment, with linguistic information and with hesitant fuzzy element, Induced aggregation operators

Table 6. Development in PROMETHEE

Sn. No.	Topic of research paper	Work done	Researcher(s)
1.	An interval version of PROMETHEE for the comparison of building products' design with ill-defined data on environmental quality	An extension of the PROMETHEE framework called ``PROMETHEE I'' has been introduced to cope with interval criteria introduced for the evaluation of the environmental quality of building products through LCA.	J.F. Le Teno, B. Mareschal (1998)
2.	An extension of the PROMETHEE method for decision making in fuzzy environment: Ranking of alternative energy exploitation projects	Multi criteria analysis by the PROMETHEE Method is extended to deal with fuzzy input data. This approach introduces new information into the decision making process resulting in a more realistic ranking where the imprecision of the data is taken into consideration.	M. Goumas, V. Lygerou (2000)
3.	A multiplicative version of Promethee II applied to multi objective optimization problems	A modified version of Promethee method, called multiplicative Promethee, is proposed to solve non convex problems. The multiplicative Promethee got much better results than the original Promethee II, being capable of solving convex and nonconvex problems, with continuous and discontinuous Pareto fronts.	R.O. Parreiras, J.A. Vasconcelos (2007)
4.	PROMETHEE-MD-2T method for project selection	Two multi criteria 2-tuple group decision methods called ''Preference Ranking Organisation Method for Enrichment Evaluation Multi Decision maker 2-Tuple-I and II'' (PROMETHEE-MD-2T-I and II) are used. They are able to integrate inside their procedure both quantitative and qualitative information in an uncertain context.	N. Halouani, H. Chabchoub, J.-M. Martel (2009)
5.	A single-layer perceptron with PROMETHEE methods using novel preference indices	A novel single-layer perceptron method PROSLP is presented called for addressing multi-criteria classification problems. Based on the original preference index in the PROMETHEE methods, a new overall preference index is proposed by balancing between total and individual satisfaction.	Yi-Chung Hu (2010)
6.	An extension of the Promethee II method based on generalizedfuzzy numbers	A new extension of Promethee II method based on generalized fuzzy numbers is presented.The proposed method considers the difference between each point in two interval numbersbased on the a-cut of generalized fuzzy numbers, simultaneously, the defuzzified values, the heightand the spreads of generalized fuzzy numbers, achieves the ranking order of every alternative.	Li Wei-xiang, Li Bang-yi (2010)
7.	A combined approach for equipment selection: F-PROMETHEE method and zero–one goal programming	Combined approach of F-PROMETHEE and ZOGP is proposed. Combined F-PROMETHEE and ZOGP approach endeavours to minimize the overall deviations in the objective function given the various goals and objectives.	Burcu Yilmaz, MetinDagdeviren (2011)
8.	Prioritized Multi-Criteria Decision Making Based on the Idea of PROMETHEE	A new prioritized multi-criteria decision making (MCDM) method is developed based on the idea of PROMETHEE aiming to overcome the drawbacks of existing methods. After comparing alternatives in pairs, an intuitionistic preference relation is innovatively constructed, which a significant combination of decision is making technology and fuzzy theory.	Xiaohan Yu, Zeshui Xu, Ying Ma (2013)
9.	An extension of PROMETHEE to interval clustering	Suggested that multicriteria clustering techniques aim to detect groups of alternatives evaluated on multiple criteria with similar profiles focus on the particular case of interval clustering. For this purpose, developed a model based on the PROMETHEE I outranking method and the FlowSort sorting procedure. The performance of the proposed model was evaluated on real-world datasets regarding the convergence, the stability and the quality of the clustering. This analysis has pointed out some promising results on the basis of performances of the proposed model.	R. Sarrazin, Y. De Smet J. Rosenfeld 2017
10.	Multi-criteria decision analysis for sub-watersheds ranking via the PROMETHEE method	PROMETHEE II method ranking of nine sub-watersheds delineated in the Topciderska river watershed, Serbia, was performed by using ArcGIS software. The criteria used for determining the order of the most vulnerable sub-watersheds are land cover, rainfall, soil erodibility as well as topography. s. The results of the PROMETHEE II method and the ArcGIS application represent the valuable information for watershed management planning and implementation of soil erosion and torrent control measure.	TijanaVulević, Nada Dragović 2017
11.	A fuzzy logic basedPROMETHEE method for material selection problems	Presented a fuzzy PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) method based on trapezoidal fuzzy interval numbers that can be applied to the selection of materials for an automotive instrument panel. Also, the relationships between the compared methods and the proposed scenarios for fuzzy PROMETHEE were evaluated via the Spearman's correlation coefficient. The objectivewas to select the most suitable material.	Muhammet Gul, ErkanCelik, Alev Taskin Gumus 2017
12.	Social sustainability assessment of small hydropower with hesitant PROMETHEE method	Suggested application of PROMETHEE outranking method using hesitant fuzzy linguistic term set (HFLTS). HFLTS was introduced to describe the uncertainty of information. Then, the Analytical Network Process (ANP) method was adopted to measure the correlation between indicators. Moreover, the PROMETHEE method employed to rank the social sustainability of each alternative. Finally, public recognition is discovered as the key indicator by comparative analysis and discussion.	Yunna Wu, Kaifeng Chen, Yang Wang (2017)

in the VIKOR method, interval 2-tuple linguistic VIKOR method, extended VIKOR method based on prospect theory etc. This development is summarized in Table7.

Hybrid methods/techniques

MCDM techniques often combined with other techniques in order to get more accurate results or sometimes to solve a particular class of problems and cases. These combined forms of multi criteria decision making techniques are termed as Hybrid methods/techniques. Some of very often used and developed hybrid MCDM techniques are AHP-ELECTRE, AHP-PROMETHEE, AHP-VIKOR, AHP-TOPSIS, similarly other methods with AHP or ANP are combined to form hybrid MCDM methods/techniques. Hybrid MCDM methods/techniques used in literature are summarized in Table 8, 9, 10, 11 for ELECTRE, PROMETHEE, VIKOR and TOPSIS.

Table 7. Development in VIKOR

Sn. No.	Topic of research paper	Work done	Researcher(s)
1.	Extended VIKOR method in comparisonwith outranking methods	The VIKOR method is extended with a stability analysis determining the weight stability intervals and withtrade-offs analysis.	SerafimOpricovic, Gwo-HshiungTzeng (2007)
2.	Extension of VIKOR method in intuitionistic fuzzy environment for robot selection	VIKORmethod is extended in intuitionistic fuzzy environment, aiming at solving multiple-criteria decision makingproblems in which the weights of criteria and ratings of alternatives are taken as triangular intuitionisticfuzzy set.	Kavita Devi (2011)
3.	Extension of VIKOR method for multi-criteria group decision makingproblem with linguistic information	A new method is proposed to solve multi-criteria group decision making problems inwhich both the criteria values and criteria weights take the form of linguistic informationbased on the traditional idea of VIKOR method. The linguistic criteria weights givenby all decision makers are transformed into trapezoidal fuzzy numbers, and then aggregatedand defuzzified to crisp values.	Yanbing Ju, Aihua Wang(2013)
4.	Extension of VIKOR method for decision making problem based onhesitant fuzzy set	Hesitant fuzzy set is very useful in avoidingsuch issues in which each criterion can be described as a hesitant fuzzy set defined in terms of the opinions of decision makers.Therefore,the concept of VIKOR method and TOPSIS method is extended to develop a methodology for solving MADM problemswith hesitant fuzzy element.	Nian Zhang, Guiwu Wei (2013)
5.	Induced aggregation operators in the VIKOR method and itsapplication in material selection	A new distanceaggregation operator called the induced ordered weighted averaging standardized distance(IOWASD) operator is developed. The main advantage of the IOWA-based VIKOR (IOWA-VIKOR) isthat it is able to reflect the complex attitudinal character of the decision maker by usingorder inducing variables and provide much more complete information for decision making.	Hu-Chen Liu, Ling-Xiang Mao, Zhi-Ying Zhang, Ping Li(2013)
6.	Material selection using an interval 2-tuple linguistic VIKOR methodconsidering subjective and objective weights	An interval 2-tuple linguistic VIKOR (ITL-VIKOR) method is presented for solving the material selection problemunder uncertain and incomplete information environment.The method has exactcharacteristic and can avoid information distortion and losing in the linguistic information processing.	Hu-Chen Liu, Long Liu, Jing Wu(2013)
7.	An extended VIKOR method based on prospect theory for multiple attribute decision making under interval type-2 fuzzy environment	TheVIKOR method is extended based on theprospect theory to accommodate interval type-2 fuzzy circumstances. A new distancemeasure for IT2FS is proposed, whichcomes as a sound alternative when being compared with the existing intervaltype-2 fuzzy distance measures. Then, a decision model integrating VIKOR method and prospect theory isproposed.	Jindong Qin, Xinwang Liu, WitoldPedrycz(2015)
8.	A state of the art literature review of VIKOR and its fuzzy extensions on applications	Conducted a state-of-the-art literature review to categorize, analyze and interpret the current research on VIKOR applications. Also discussed the extensions of VIKOR applied in fuzzy environments.	MuhammetGul ,ErkanCelik ,NezirAydinb (2016)
9.	Intuitionistic fuzzy multi-attribute group decision-making with an application to plant location selection based on a new extended VIKOR method	Presented a new decision method for multi-attribute group decision-making(MAGDM) problems in general and plant location selection (PLS) problem in particular,with intuitionistic fuzzy information captured through trapezoidal intuitionistic fuzzy numbers(TrIFNs). Extended the classical VIKOR method to solve MAGDM problems under intuitionisticfuzzy environment based on the TrIFN	Pankaj Gupta, Mukesh Kumar Mehlawat (2016)
10.	Extended VIKOR method for multiple criteria decision-making with linguistichesitant fuzzy information	Suggested that linguistic hesitant fuzzy set (LHFS), a special hesitant fuzzy set (HFS) defined onlinguistic term set (LTS), not only can express decision makers' (DMs') qualitative preferences, butcan reflect their uncertainty and hesitancy. Developed a new LHF-VIKOR (linguistic hesitantfuzzy VlsekriterijumskaOptimizacija I KompromisnoResenje) method for solving multiple criteria decision-making (MCDM) problems with LHFSs.	Shu-ping Wan, Fang-fang Yuan, Jiu-ying Dong (2017)
11.	An extended stochastic VIKOR model with decision maker's attitude towards risk	Proposed a risk-based stochastic VIKOR (RB-VIKOR) model that accounts for differences inthe risk attitudes of the decision makers (DMs) when ranking stochastic alternatives. Presented a case study inthe banking industry to illustrate how differences in the risk attitudes of the DMs condition therankings obtained. Moreover,compared results with those derived from a stochastic superefficiencydata envelopment analysis (DEA) model to demonstrate the applicability and efficencyof RB-VIKOR	MadjidTavana , Debora Di Caprio , Francisco J. Santos-Arteaga (2017)
12.	Evaluating service quality of airline industry using hybrid best worstmethod and VIKOR	Showed application of VIKOR (VlseKriterijuska Optimizacija I KomoromisnoResenje) methodology is used to rank the best airline with respectto these attributes. Tangibility, Reliability, security and safety and Ticket pricing are found to be mostimportant attributes of service quality and further analysis using VIKOR methodology suggests that airline 2 is performing well on these attributes among the five airlines taken for study.	Himanshu Gupta (2017)

Table 8. Hybrid Methods of ELECTRE

Sn. No.	Topic of research paper	Hybrid Method	Researcher(s)
1.	Determining the weights of criteria in the ELECTRE type methods with a revised Simos' procedure	ELECTRE with revised Simos' procedure	Jos_eFigueira, Bernard Roy (2002)
2.	Multi-objective approach to facility layout problem by genetic search algorithm and Electre method	Genetic search algorithm with Electre method	G. Aiello, M. Enea, G. Galante (2006)
3.	Multicriteria decision model for outsourcing contracts selection based on utility function and ELECTRE method	Utility function with ELECTRE method	Adiel Teixeira de Almeida (2007)
4.	A new application of ELECTRE III and revised Simos' procedure for group material selection under weighting uncertainty	ELECTRE III with revised Simos' procedure	A. Shanian, A.S. Milani, C. Carson, R.C. Abeyaratne (2008)
5.	A multi criteria model for risk sorting of natural gas pipelines based on ELECTRE TRI integrating Utility Theory	ELECTRE TRI with Utility Theory	Anderson J. Brito, Adiel Teixeira de Almeida, Caroline M.M. Mota (2010)
6.	An integrated fuzzy AHP–ELECTRE methodology for environmental impact assessment	Fuzzy AHP with ELECTRE	Tolga Kaya, CengizKahraman (2011)
7.	Multicriteria group decision making with ELECTRE III method based on interval-valued intuitionistic fuzzy information	TheELECTREIIImethodwiththeinterval-valuedintuitionisticfuzzynumber	ShideSadatHashemia,SeyedHosseinRazaviHajiagha (2015)
8.	Integrated framework for preference modeling and robustness analysis for outranking-based multiple criteria sorting with ELECTRE and PROMETHEE	ELECTRE with PROMETHEE	MiłoszKadziński, Krzysztof Ciomek(2016)
9.	A comparative analysis of operational performance of Cellular Mobile Telephone Service Providers in the Delhi working area using an approach of fuzzy ELECTRE	FUZZY ELECTRE	Pravin Kumar, Rajesh K. Singh, Karishma Kharab (2017)
10.	Supplier selection using ANP and ELECTRE II in interval 2-tuple linguistic environment	ANP AND ELECTRE II	Shu-ping Wan a , Gai-li Xu a , Jiu-ying Dong c (2017)

Table 9. Hybrid Methods of PROMETHEE

Sn. No.	Topic of research paper	Hybrid Method	Researcher(s)
1.	PROMETHEE and AHP: The design of operational synergies in multicriteria analysis. Strengthening PROMETHEE with ideas of AHP	PROMETHEE with AHP	Cathy Macharis, Johan Springael, Klaas De Brucker, Alain Verbeke (2004)
2.	A combined approach for equipment selection: F-PROMETHEE method and zero–one goal programming	F-PROMETHEE method with zero–one goal programming	Burcu Yilmaz, MetinDagdeviren (2011)
3.	A combined AHP-PROMETHEE approach for selecting the most appropriate policy scenario to stimulate a clean vehicle fleet	AHP with PROMETHEE	Laurence Turcksina, AnnaliaBernardinia, Cathy Macharisa (2011)
4.	Material selection using PROMETHEE combined with analytic network process under hybrid environment	PROMETHEE with analytic network process	An-Hua Peng, Xing-Ming Xiao (2013)
5.	Power substation location selection using fuzzy analytic hierarchy process and PROMETHEE: A case study from Bangladesh	Fuzzy analytic hierarchy process with PROMETHEE	Golam Kabir, Razia Sultana Sumi (2014)
6.	The SMAA-PROMETHEE method	SMAA with PROMETHEE	Salvatore Corrente, Jose Rui Figueira, Salvatore Greco (2014)
7.	Selecting ''The Best'' ERP system for SMEs using a combination of ANP and PROMETHEE methods	ANP with PROMETHEE	HuseyinSelcukKilic, Selim Zaim, DursunDelen (2015)
8.	A ranking method based on DEA and PROMETHEE II	DEA with PROMETHEE II	Maryam Bagherikahvarin, Yves De Smet (2016)
9.	Evaluating outsourcing risks in thepharmaceutical supply chain: Case of a multi-criteria combined fuzzy AHP-PROMETHEE approach	FUZZY AHP with PROMETHEE	A. El Mokrini,N. Kafa A. Berrado(2016)
10.	Urban Renewal Project Selection Using the Integration of AHP and PROMETHEE Approaches	AHP with PROMETHEE	Gul Polat, Atilla Damci, IliyadaDemirli (2016)
11.	An application of DEMATEL-ANP and PROMETHEE II approach for air traffic controllers' workload stress problem: A case of Mactan Civil Aviation Authority of the Philippines	DEMATEL with PROMETHEE II	Miriam F.Bongo, Kissy Mae S.Alimpangog, Jennifer F.Loar (2017)

Table 10. Hybrid Methods of VIKOR

Sn. No.	Topic of research paper	Hybrid Method	Researcher(s)
1.	Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: The case of Istanbul	VIKOR with AHP	Tolga Kaya, CengizKahraman (2010)
2.	Combining VIKOR with GRA techniques to evaluate service quality of airports under fuzzy environment	VIKOR with GRA techniques	Ming-Shin Kuo, Gin-ShuhLiang (2011)
3.	Fuzzy multiple criteria forestry decision making based on an integrated VIKOR and AHP approach	VIKOR with AHP approach	Tolga Kaya, CengizKahraman (2011)
4.	A new hybrid MCDM model combining DANP with VIKOR to improve e-store business	DANP with VIKOR	Wan-Yu Chiu, Gwo-HshiungTzeng, Han-Lin Li (2013)
5.	Evaluating performance of Iranian cement firms using an integrated fuzzy AHP–VIKOR method	AHP with VIKOR	Kamran Rezaie, Sara SaeidiRamiyani, Salman Nazari-Shirkouhi, Ali Badizadeh (2014)
6.	Evaluating suppliers to include green supplier development programs via fuzzy c-means and VIKOR methods	Fuzzy c-means with VIKOR	GulsenAkman (2014)
7.	Combining VIKOR-DANP model for glamor stock selection and stock performance improvement	VIKOR with DANP	Kao-Yi Shen, Min-Ren Yan, Gwo-HshiungTzeng(2014)
8.	A novel hybrid MCDM model based on fuzzy DEMATEL, fuzzy ANP and fuzzy VIKOR for city logistics concept selection	DEMATEL, fuzzy ANP and fuzzy VIKOR	SnezanaTadic, Slobodan Zecevic, MladenKrstic (2014)
9.	Application of VIKOR and fuzzy AHP for conservation priority assessment in coastal areas: Case of Khuzestan district, Iran	VIKOR with fuzzy AHP	ShararehPourebrahim, Mehrdad Hadipour, Mazlin Bin Mokhtar, ShahabaldinTaghavi (2014)
10.	Corrigendum to "Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: The case of Istanbul" [Energy 35(6) (2010) 2517e2527]	VIKOR with AHP	Mahdi Saeedpoor, Amin Vafadarnikjoo (2015)
11.	An integrated AHP and VIKOR for design concept evaluation based on rough number	AHP with VIKOR	Guo-Niu Zhu, Jie Hu, Jin Qi, Chao-Chen Gu, Ying-Hong Peng (2015)
12.	A novel approach for failure mode and effects analysis using combination weighting and fuzzy VIKOR method	combination weighting with fuzzy VIKOR	Hu-Chen Liua, Jian-Xin Youa, Xiao-Yue You, Meng-Meng Shana (2015)
13.	Multi-tier sustainable global supplier selection using a fuzzy AHP-VIKOR based approach	AHP with VIKOR	Anjali Awasthi, Kannan Govindan (2018)
14.	Optimizing discrete V obstacle parameters using a novel Entropy-VIKOR approach in a solar air flow channel	Hybrid Entropy ApproachImplementationwith VIKOR	AshutoshSharmaRanchanChauhan (2017)
15.	Erodibility prioritization of sub-watersheds using morphometric parameters analysis and its mapping: A comparison among TOPSIS, VIKOR, SAW, and CF multi-criteria decision making models	Erosion SuspectibIity of water	Alireza Arab America, Hamid RezaPourghasemi (2018)

Table 11. Hybrid Methods of TOPSIS

Sn. No.	Topic of research paper	Hybrid Method	Researcher(s)
1.	Weapon selection using the AHP and TOPSIS methods under fuzzy environment	AHP with TOPSIS	MetinDagdeviren, Serkan Yavuz, NevzatKılınc (2009)
2.	Project selection for oil-fields development by using the AHP and fuzzy TOPSIS methods	AHP with fuzzy TOPSIS	MortezaPakdinAmiri (2010)
3.	A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods	Fuzzy AHP with fuzzy TOPSIS	Chia-Chi Sun (2010)
4.	Group AHP-TOPSIS framework for human spaceflight mission planning at NASA	AHP with TOPSIS	MadjidTavana, Adel Hatami-Marbini (2011)
5.	An STEEP-fuzzy AHP-TOPSIS framework for evaluation and selection of thermal power plant location: A case study from India	STEEP-fuzzy AHP with TOPSIS	Devendra Choudhary, Ravi Shankar (2012)
6.	Emergency alternative evaluation under group decision makers: A method of incorporating DS/AHP with extended TOPSIS	DS/AHP with extended TOPSIS	Yanbing Ju, Aihua Wang (2012)
7.	Integrated Fuzzy AHP–TOPSIS for selecting the best plastic recycling method: A case study	Fuzzy AHP–TOPSIS	S. Vinodh, M. Prasanna, N. Hari Prakash (2014)
8.	Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies	Fuzzy AHP with fuzzy TOPSIS	Osman Taylana, Abdallah O. Bafail, Reda M.S. Abdulaala, Mohammed R. Kablia (2014)
9.	A Delphi-AHP-TOPSIS based framework for the prioritization of intellectual capital indicators: A SMEs perspective	Delphi-AHP-TOPSIS	Chandra Sekhara, Manoj Patwardhan, Vishal Vyas (2015)
10.	The new extension of TOPSIS method for multiple criteria decision making with hesitant Pythagorean fuzzy sets	TOPSIS with Pythagorean Fuzzy Sets.	DecuiLianga, ZeshuiXu (2017)
11.	An integrated fuzzy QFD and TOPSIS methodology for choosing the ideal gas fuel at WWTPs	TOPSIS with Fuzzy QFD	HalilAkbaşa, BilgeBilgen
12.	The application of the AHP-TOPSIS for evaluating ballast water treatment systems by ship operators	AHP with TOPSIS	HristosKarahalios (2017)
13.	An intelligent scheduling scheme for real-time traffic management using Cooperative Game Theory and AHP-TOPSIS methods for next generation telecommunication network	Game Theory, AHP with TOPSIS	TanuGoyal, SakshiKaushal (2017)
14.	An extended intuitionistic fuzzy TOPSIS method based on a new distance measure with an application to credit risk evaluation	Fuzzy Topsis	FengShen, XinsongMa, ZhiyongLi (2018)

Application of MCDM methods/techniques

MCDM methods/techniques ELECTRE, PROMETHEE, VIKOR and TOPSIS have found their application in various fields and sectors. As it a very fast growing research field, the work done on these methods/techniques and their implementation is widely seen in literature and many models on these basis are proposed to implement in industries and other sectors. Some of the application fields of MCDM methods/techniques are supplier selection, material selection, energy, site selection, process layout selection etc. Use of these MCDM methods/techniques in literature and other case studies is briefly described in Table15, 16, 17 and 18

DISCUSSION

This paper is an attempt to provide an overview of literature of Multi Criteria Decision making MCDM) techniques ELECTRE, PROMETHEE, VIKOR and TOPSIS.

A detailed literature survey is carried out and presented to highlight the present state of research work. We have focussed on the recent papers to review the development of MCDM techniques and their field of applications. This has helped us to identify the research gaps in this field. Future areas of research have been identified on the basis of literature gaps and applications and implementation of MCDM techniques.

Literature review of Multi Criteria Decision making MCDM) techniques ELECTRE, PROMETHEE, VIKOR and TOPSIS has been classified into three categories, development of methods/techniques, hybrid methods/techniques and the application/use of techniques in various fields. Extensive literature survey has been carried out to find the developments and application areas of Multi Criteria Decision making MCDM) techniques ELECTRE, PROMETHEE, VIKOR and TOPSIS. All three categories of literature review of all for MCDM techniques are briefly summarized in tabular form.

Table 15. Application of ELECTRE given in research literature

Sn. No.	Topic of research paper	Use/ Implementation/Country	Researcher(s)
1.	Application of ELECTRE III for the integrated management of municipal solid wastes in the Greater Athens Area	Management of municipal solid wastes in the Greater Athens Area	AvraamKaragiannidis, Nicolas Moussiopoulos (1997)
2.	DECISION MAKING IN ENERGY PLANNING: THE ELECTRE MULTI CRITERIA ANALYSIS APPROACH COMPARED TO A FUZZY-SETS METHODOLOGY	Energy planning, Italy	MARCO BECCALI, MAURIZIO CELLURA and DAVIDE ARDENTE (1998)
3.	Decision-making in energy planning: Application of the Electre method at regional level for the diffusion of renewable energy technology	Energy planning, island of Sardinia, Italy	M. Beccali, M. Cellura, M. Mistretta (2003)
4.	Multi-objective approach to facility layout problem by genetic search algorithm and Electre method	Layout design problem	G. Aiello, M. Enea, G. Galante (2006)
5.	Multicriteria decision model for outsourcing contracts selection based on utility function and ELECTRE method	Outsourcing contracts selection problem	Adiel Teixeira de Almeida (2007)
6.	Application of the multi-criteria analysis method Electre III for the optimisation of decentralised energy systems	Optimisation of decentralised energy systems, Greece	Agis Papadopoulos, AvraamKaragiannidis (2008)
7.	A new application of ELECTRE III and revised Simos' procedure for group material selection under weighting uncertainty	Material selection	A. Shanian a, A.S. Milani, C. Carson, R.C. Abeyaratne (2008)
8.	Bankruptcy prediction using ELECTRE- based single-layer perceptron	Bankruptcy analysis, Taiwan	Yi-Chung Hu (2009)
9.	Design a new mixed expert decision aiding system using fuzzy ELECTRE III method for vendor selection	vendor selection	G. A. Montazer, HamedQahriSaremi, Maryam Ramezani (2009)
10.	A Web-based decision support system with ELECTRE III for a personalised ranking of British universities	Personalised ranking of British universities, U.K.	Christos Giannoulis, Alessio Ishizaka (2010)
11.	A multi criteria model for risk sorting of natural gas pipelines based on ELECTRE TRI integrating Utility Theory	Risk sorting of natural gas pipelines, Brazil	Anderson J. Brito, Adiel Teixeira de Almeida, Caroline M.M. Mota (2010)
12.	Mathematical estimation for artificial lift systems selection based on ELECTRE model	Selection of artificial lift systems, Iran	M. Alemi, H. Jalalifar, G. R. Kamali, M. Kalbasiand PEDEC Research & Development (2011)
13.	ELECTRE III model for value engineering applications	Value engineering	M.M. Marzouk (2011)
14.	Application of Fuzzy AHP and ELECTRE to China Dry Port Location Selection	Dry Port Location Selection, China	Bian K.A. (2011)
15.	A fuzzy group Electre method for safety and health assessment in hazardous waste recycling facilities	Waste recycling	A. H. Marbini, M. Tavana, M. Moradi, F. Kangi
16.	A decision support system based on Electre III for safety analysis in a suburban road network	Safety analysis in a suburban road network, Italy	Fancello G., Carta M., and Fadda P. (2014)
17.	GIS-based photovoltaic solar farms site selection using ELECTRE-TRI: Evaluating the case for Torre Pacheco, Murcia, Southeast of Spain	Site selection, Spain	J. M. Sanchez-Lozano, C. H. Antunes, M. Socorro García-Cascales, Luis C. Dias (2014)
18.	Macro-site selection of wind/solar hybrid power station based on ELECTRE-II	Macro-site selection, China	Dong Jun, Feng Tian-tian, Yang Yi-sheng, Ma Yu (2014)
19.	Ranking projects of Logistics Platforms A methodology based on the ELECTRE multicriteria approach	Ranking of projects of Logistics Platforms	Juan Pablo Antuna, Rodrigo Alarcona (2014)

Table 16. Application of PROMETHEE in research literature

Sn. No.	Topic of research paper	Use/ Implementation/Country	Researcher(s)
1.	Water resources planning in the Middle East: application of the PROMETHEE V multicriteria method	Water resources planning	Maher F. Abu-Taleb, Bertrand Mareschal (1995)
2.	An interval version of PROMETHEE for the comparison of building products' design with ill-defined data on environmental quality	Comparison of building products' design	J.F. Le Teno, B. Mareschal (1998)
3.	An extension of the PROMETHEE method for decision making in fuzzy environment: Ranking of alternative energy exploitation projects	Ranking of alternative energy exploitation Projects, Greece	M. Goumas, V. Lygerou (2000)
4.	Formulating national information technology strategies: A preference ranking model using PROMETHEE method	Formulating national information technology strategies, Iran	Amir Albadvi (2004)
5.	Decision making in stock trading: An application of PROMETHEE	Stock trading	Amir Albadvi, S. Kamal Chaharsooghi, Akbar Esfahanipour (2007)
6.	The lean improvement of the chemical emissions of motor vehicles based on preference ranking: A PROMETHEE uncertainty analysis	Lean improvement of the chemical emissions of motor vehicles	Malcolm J. Beynona, Peter Wellsb (2008)
7.	PROMETHEE-MD-2T method for project selection	Project selection	N. Halouani, H. Chabchoub, J.M. Martel (2009)
8.	Selecting the best statistical distribution with PROMETHEE and GAIA	Selection of the best statistical distribution	Alessio Ishizaka, Philippe Nemery (2011)
9.	A combined approach for equipment selection: F-PROMETHEE method and zero–one goal programming	Equipment selection	Burcu Yilmaz, MetinDagdeviren (2011)
10.	Strategic decisions using the fuzzy PROMETHEE for IS outsourcing	IS outsourcing, Taiwan	Ying-Hsiu Chen, Tien-Chin Wang, Chao-Yen Wuc (2011)
11.	A combined AHP-PROMETHEE approach for selecting the most appropriate policy scenario to stimulate a clean vehicle fleet	Selection of the most appropriate policy, Belgium	Laurence Turcksina, AnnaliaBernardini, Cathy Macharis (2011)
12.	A PROMETHEE-based classification method using concordance and discordance relations and its application to bankruptcy prediction	Bankruptcy analysis	Yi-Chung Hu, Chiung-Jung Chen (2011)
13.	PROMETHEE based sustainable concept selection	Sustainable concept selection	S. Vinodh, R. JeyaGirubha (2012)
14.	A PROMETHEE-based approach to portfolio selection problems	Portfolio selection	Rudolf Vetschera, A.T. Almeida (2012)
15.	PROMETHEE II: A knowledge-driven method for copper exploration	Copper exploration, Iran	M. Abedi, S.AliTorabi, G. H. Norouzi, M. Hamzeh, G. R. Elyasi (2012)
16.	Material selection using PROMETHEE combined with analytic network process under hybrid environment	Material selection	An-Hua Peng, Xing-Ming Xiao (2013)
17.	Revised PROMETHEE II for Improving Efficiency in Emergency Response	Emergency Response, China	HongjuZhaoa, Yi Penga, Wei Lia (2013)
18.	Power substation location selection using fuzzy analytic hierarchy process and PROMETHEE: A case study from Bangladesh	Location selection, Bangladesh	Golam Kabir, Razia Sultana Sumi (2014)
19.	PROMETHEE technique to select the best radial basis functions for solving the 2-dimensional heat equations based on Hermite interpolation	Solving the 2-dimensional heat equations	Saeed Kazem, FarhadHadinejad (2015)
20.	Selecting ‘‘The Best’’ ERP system for SMEs using a combination of ANP and PROMETHEE methods	Selection of ERP system	HuseyinSelcukKilic, Selim Zaim, DursunDelen (2015)
21.	Competences-based Comparison and Ranking of Industrial Enterprises using PROMETHEE Method	Comparison and Ranking of Industrial Enterprises	Ivica Vezaa, StipoCelara, Ivan Peronja (2015)
22.	Unsupervised classification and multi-criteria decision analysis as chemometric tools for the assessment of sediment quality: A case study of the Danube and Sava River	Development of Evaluation Method for Sediment Quality in River	Dragan M.Crnković, Davor Z.Antanasijević (2016)
23.	The PROMETHEE multiple criteria decision making analysis for selecting the best membrane prepared from sulfonated poly(ether ketone)s and poly(ether sulfone)s for proton exchange membrane fuel cell	Selection of Best Membrane for fuel cell	Mohammad Ali Nikouei, Maryam Oroujzadeh (2017)
24.	A risk-based multi-objective model for optimal placement of sensors in water distribution system	Placement of water sensors in water distribution system.	SarehS.Naserizade, Mohammad RezaNikoo (2018)

Table 17. Application of VIKOR in research literature

Sn. No.	Topic of research paper	Use/ mplementation/Country	Researcher(s)
1.	Optimizing partners' choice in IS/IT outsourcing projects: The strategic decision of fuzzy VIKOR	IS/IT outsourcing projects	Lisa Y.Chen, Tien-ChinWang (2009)
2.	Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: The case of Istanbul	Energy planning, Istanbul	Tolga Kaya, CengizKahraman(2010)
3.	Group decision making process for supplier selection with VIKOR under fuzzy environment	Supplier selection	Amir Sanayei, S. Farid Mousavi, A. Yazdankhah (2010)
4.	A comprehensive VIKOR method for material selection	Material selection	A. Jahan, F. Mustapha, Md Y. Ismail, S.M. Sapuan, M. Bahraminasab (2011)
5.	Material selection for femoral component of total knee replacement using comprehensive VIKOR	Material selection	MarjanBahraminasab, Ali Jahan (2011)
6.	Combining VIKOR with GRA techniques to evaluate service quality of airports under fuzzy environment	Evaluate service quality of airports	Ming-Shin Kuo, Gin-ShuhLiang (2011)
7.	Deriving preference order of open pit mines equipment through MADM methods: Application of modified VIKOR method	Open pit mines equipment	Abbas AghajaniBazzazi, MortezaOsanloo, Behrooz Karimi (2011)
8.	Fuzzy multiple criteria forestry decision making based on an integrated VIKOR and AHP approach	Forestry, Turkey	Tolga Kaya, CengizKahraman (2011)
9.	A fuzzy VIKOR method for supplier selection based on entropy measure for objective weighting	Supplier selection	Ali Shemshadi, Hossein Shirazi, Mehran Toreihi, M.J. Tarokh (2011)
10.	Fuzzy VIKOR with an application to water resources planning	Water resources planning, Serbia	SerafimOpricovic (2011)
11.	Extension of VIKOR method in intuitionistic fuzzy environment for robot selection	Robot selection	Kavita Devi (2011)
12.	Multi-criteria decision-making in the selection of a renewable energy project in Spain: The Vikor method	Renewable energy, Spain	J.R. San Cristóbal (2011)
13.	Application of fuzzy VIKOR and environmental impact analysis for material selection of an automotive component	Material selection	R. JeyaGirubha, S. Vinodh (2012)
14.	Group decision making process for insurance company selection problem with extended VIKOR method under fuzzy environment	Insurance company selection	G. NilayYücenur, NihanÇetinDemirel (2012)
15.	Risk evaluation in failure mode and effects analysis with extended VIKOR method under fuzzy environment	Risk evaluation	Hu-Chen Liu, Long Liu, Nan Liu c, Ling-Xiang Mao (2012)
16.	Induced aggregation operators in the VIKOR method and its application in material selection	Material selection	Hu-Chen Liu, Ling-Xiang Mao, Zhi-Ying Zhang, Ping Li (2013)
17.	Fuzzy VIKOR approach for assessing the vulnerability of the water supply to climate change and variability in South Korea	Vulnerability of the water supply to climate change and variability, South Korea	Yeonjoo Kim, Eun-Sung Chung (2013)
18.	Material selection using an interval 2-tuple linguistic VIKOR method considering subjective and objective weights	Material selection	Hu-Chen Liu, Long Liu, Jing Wu (2013)
19.	A new hybrid MCDM model combining DANP with VIKOR to improve e-store business	E-store business	Wan-Yu Chiu, Gwo-HshiungTzeng, Han-Lin Li (2013)
20.	A fuzzy extension of VIKOR for target network selection in heterogeneous wireless environments	Network selection	A. Mehbodniya, F. Kaleem, K. K. Yen, F. Adachi (2013)
21.	Evaluating performance of Iranian cement firms using an integrated fuzzy AHP–VIKOR method	Performance Evaluation	Kamran Rezaie, Sara SaeidiRamiyani, Salman Nazari-Shirkouhi, Ali Badizadeh (2014)
22.	Fuzzy VIKOR method: A case study of the hospital service evaluation in Taiwan	Hospital service, Taiwan	Tsung-Han Chang (2014)
23.	A new flexible and reliable interval valued fuzzy VIKOR method based on uncertainty risk reduction in decision making process: An application for determining a suitable location for digging some pits for municipal wet waste landfill	Location selection, Iran	M.N. Mokhtarian, S. Sadi-nezhad, A. Makui (2014)
24.	Evaluating suppliers to include green supplier development programs via fuzzy c-means and VIKOR methods	Suppliers Evaluation	GulsenAkman (2014)
25.	Combining VIKOR-DANP model for glamor stock selection and stock performance improvement	Stock selection	Kao-Yi Shen, Min-Ren Yan, Gwo-HshiungTzeng(2014)
26.	Review-based measurement of customer satisfaction in mobile service: Sentiment analysis and VIKOR approach	Customer satisfaction measurement	Daekook Kang, Yongtae Park (2014)
27.	A novel hybrid MCDM model based on fuzzy DEMATEL, fuzzy ANP and fuzzy VIKOR for city logistics concept selection	Logistics concept selection	SneznaTadic , Slobodan Zecevic , MladenKrstic (2014)
28.	Application of VIKOR and fuzzy AHP for conservation priority assessment in coastal areas: Case of Khuzestan district, Iran	Conservation priority assessment, Iran	ShararehPourebrahim, Mehrdad Hadipour, Mazlin Bin Mokhtar, ShahabaldinTaghavi (2014)
29.	Site selection in waste management by the VIKOR method using linguistic assessment	Site selection	Hu-Chen Liua, Jian-XinYoua, Xiao-JunFan, Yi-ZengChen (2014)
30.	Corrigendum to "Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: The case of Istanbul" [Energy 35(6) (2010) 2517e2527]	Renewable energy, Istanbul	Mahdi Saeedpoor, Amin Vafadarnikjoo (2015)
31.	An integrated AHP and VIKOR for design concept evaluation based on rough number	Concept evaluation	Guo-Niu Zhu, Jie Hu, Jin Qi, Chao-Chen Gu, Ying-Hong Peng (2015)
32.	A novel approach for failure mode and effects analysis using combination weighting and fuzzy VIKOR method	Failure mode and effects analysis	Hu-Chen Liua, Jian-Xin Youa, Xiao-Yue You, Meng-Meng Shana (2015)
33.	Product design concept evaluation using rough sets and VIKOR method	Design Evaluation	VarunTiwari, Prashant KumarJain, PuneetTandon (2016)
34.	Assessing the global productive efficiency of Chinese banks using the cross-efficiency interval and VIKOR	Working Efficiency of bank	MeiqinWua, ChanghongLiaJianpingFan (2017)

Table 18. Application of TOPSIS in research literature

Sn. No.	Topic of research paper	Use/ Implementation/Country	Researcher(s)
1.	Weapon selection using the AHP and TOPSIS methods under fuzzy environment	Weapon selection	MetinDagdeviren, Serkan Yavuz, NevzatKılınc (2009)
2.	Project selection for oil-fields development by using the AHP and fuzzy TOPSIS methods	Project selection	MortezaPakdinAmiri (2010)
3.	A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods	Performance evaluation	Chia-Chi Sun (2010)
4.	Group AHP-TOPSIS framework for human spaceflight mission planning at NASA	Mission planning	MadjidTavana, Adel Hatami-Marbini (2011)
5.	An STEEP-fuzzy AHP-TOPSIS framework for evaluation and selection of thermal power plant location: A case study from India	Evaluation and selection of location	Devendra Choudhary, Ravi Shankar (2012)
6.	Emergency alternative evaluation under group decision makers: A method of incorporating DS/AHP with extended TOPSIS	Emergency alternative evaluation	Yanbing Ju, Aihua Wang (2012)
7.	A combined fuzzy AHP and fuzzy TOPSIS based strategic analysis of electronic service quality in healthcare industry	Healthcare industry	GulcinBuyukozkan, GizemCifci (2012)
8.	Combination of TOPSIS and AHP in load shedding scheme for large pulp mill electrical system	Electrical system	H.H. Goh, B.C. Kok, H.T. Yeo, S.W. Lee, A.A. Mohd. Zin (2013)
9.	A multi-expert system for ranking patents: An approach based on fuzzy pay-off distributions and a TOPSIS–AHP framework	Ranking patents	Mikael Collan, Mario Fedrizzi, PasiLuukka (2013)
10.	Study on the Status Evaluation of Urban Road Intersections Traffic Congestion Base on AHP-TOPSIS Modal	Traffic Congestion	Jingfei YU, Li WANG, Xiuling GONG (2013)
11.	Integrated Fuzzy AHP–TOPSIS for selecting the best plastic recycling method: A case study	Recycling method	S. Vinodh, M. Prasanna, N. Hari Prakash (2014)
12.	A fuzzy AHP-TOPSIS framework for ranking the solutions of Knowledge Management adoption in Supply Chain to overcome its barriers	Supply Chain	Sachin K. Patil, Ravi Kant (2014)
13.	Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies	Projects selection	Osman Taylana, Abdallah O. Bafail, Reda M.S. Abdulaala, Mohammed R. Kablia (2014)
14.	A hybrid approach using AHP-TOPSIS for analyzing e- SCM performance	E- SCM	Mohit Tyagia, Pradeep Kumar, Dinesh Kumar (2014)
15.	The application of ISM model in evaluating agile suppliers selection criteria and ranking suppliers using fuzzy TOPSIS-AHP methods	Suppliers selection	YokabedBeikkhakhian, Mohammad Javanmardi, Mahdi Karbasian, Bijan Khayambashi (2015)
16.	Public service quality evaluation with SERVQUAL and AHP-TOPSIS: A case of Philippine government agencies	Evaluation of service quality among employment-related government agencies	LanndonOcampo, JovirAlinsub, Ruselle AnneCasul (2017)
17.	Optimisation of Process Parameters for Gas Tungsten Arc Welding of Incoloy 800HT Using TOPSIS	To Determine the optimal TIG welding process parameters	ArunKumarSrirangan, PaulrajSathiya (2017)
18.	Combining SCOR® model and fuzzy TOPSIS for supplier evaluation and management	Supplier Evaluation and Management	Francisco RodriguesLima-Junior (2017)

Conclusion

Multi-criteria decision-making MCDM) is one of the most widely used decision methodologies in the sciences, business, government and engineering worlds. MCDM methods can help to improve the quality of decisions by making the decision-making process more explicit, rational, and efficient.In a decisional process the making of choices derives from complex hierarchical comparisons among alternative options, which are often based on conflictual criteria.Multi Criteria Decision making MCDM) techniques are the best way to make these decisions. Although Multi Criteria Decision making MCDM) techniques are used in various fields but still these are relatively new methodologies. In recent years, there is a significant increase in the number of research studies on MCDM techniques. The relevant literature on Multi Criteria Decision making MCDM) techniques ELECTRE, PROMETHEE, VIKOR and TOPSIS has been reviewed and reported in this paper. All aspects of ELECTRE, PROMETHEE, VIKOR and TOPSIS literature are reviewed in this paper. Very less work has been reported in the field of development of these methods. Hybrid methods reported are generally in the combination of AHP or ANP; other hybrid method has not developed. Most of the applications of these methods are found in supplier selection, site selection, energy, material selection; applications of these methods in various other fields are not reported.

Future research direction

The following directions of future researches can be drawn from this literature review

- In many cases any of the multi criteria decision making method is used for selecting the best alternative. Further

work can be done by using more than one method for ranking and comparing the results to study the efficiency, reliability and sensitivity of those methods.

- Many of the researchers worked on hybrid multi criteria decision making models in decision making problems but the hybrid models used are with AHP or ANP. Instead of hybrid models of AHP or ANP with other MCDM methods, hybrid models of other MCDM methods can be developed that can combine the efficiency of two methods and reduce the chances of errors and mistakes.
- Most of the research work in the field of multi criteria decision making is done on selecting the best alternatives from a set of alternatives. Multi criteria decision making methods can be used for improvements in the alternatives by changing the values of alternatives and analysing the change in rankings. This research can provide a way to improvement in a large number of fields.

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