Recent Advances in Electrical & Electronic Engineering, 2021, *14*, 779-801

SYSTEMATIC REVIEW ARTICLE

Multi-criteria Decision Making: A Systematic Review

Nayli Adriana Azhar[1], Nurul Asyikin Mohamed Radzi[1,2,*] and Wan Siti Halimatul Munirah Wan Ahmad[1]

[1]*Electrical and Electronics Engineering Department, College of Engineering, Universiti Tenaga Nasional, Kajang 43000, Malaysia;* [2]*The Institute of Informatics and Computing in Energy, Universiti Tenaga Nasional, Kajang 43000, Malaysia*

ARTICLE HISTORY

Received: September 2, 2021
Revised: October 6, 2021
Accepted: October 10, 2021

DOI:
10.2174/2352096514666211029112443

This is an Open Access article published under CC BY 4.0 https://creativecommons.org/licenses/by /4.0/legalcode

Abstract: Multi Criteria Decision Making (MCDM) helps decision makers (DMs) solve highly complex problems. Accordingly, MCDM has been widely used by DMs from various fields as an effective and reliable tool for solving various problems, such as in site and supplier selection, ranking and assessment. This work presents an in-depth survey of past and recent MCDM techniques cited in the literature. These techniques are mainly categorised into pairwise comparison, outranking and distance-based approaches. Some well-known MCDM methods include the Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Elimination et Choix Traduisant la Realité (ELECTRE), Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR). Each of these methods is unique and has been used in a vast field of interest to support DMs in solving complex problems. For a complete survey, discussions related to previous issues and challenges and the current implementation of MCDM are also presented.

Keywords: multi-criteria decision making, industrial decision making, analytical hierarchy process, analytical network process, electre, vikor, topsis, promethee.

1. INTRODUCTION

In many fields, decision makers (DMs) need to address a problem systematically, accurately and reliably according to their preferences. Multi-Criteria Decision Making (MCDM) is particularly useful in this area, given that each problem requires a unique decision. MCDM deals with complex problems depending on the solution methods selected by DMs. Specifically, MCDM breaks down a problem into small pieces to help DMs clearly view the issue at hand [1]. Given these benefits, MCDM has been widely used in many fields, such as management, economics, medicine, environment and energy. MCDM is mainly used to improve the quality, efficiency, rationality and explicitness of decisions. One main field that implements MCDM is renewable energy resources (RES). The authors in a study [2] used various MCDM approaches to rank the priority of RES and to recommend a suitable RES to be implemented in Taiwan. Similarly, the authors in [3] proved MCDM as a reliable and effective policy making support tool for achieving the most suitable solution. Integrating MCDM may also increase the chances for DMs to achieve solid outcomes. The recent advancement of MCDM in RES has been mainly ascribed to the increasing investments in RES as a solution to the depleting global fossil fuel supply.

MCDM can also be used in supply selection domains in production, manufacturing and other related fields. Industrial practitioners view this approach as a crucial step in producing high-quality products and advancing towards sustainable development. For instance, the proposed model in a study [4] integrates several MCDM methods to help achieve a green supplier selection. The proposed model was proven to provide valuable support for solving complex problems. Similar approaches were applied in another study [5], which mainly focused on an easily implementable green supply chain management. In transportation, MCDM was used as an efficient indicator of passenger's satisfaction in public transport in Tehran [6], where the authors proposed a novel traffic policy for reducing the number of private cars traveling on the streets during rush hour, hence avoiding traffic congestion and encouraging people to use public transportation. In another study [10], the authors used MCDM to evaluate the performance of rapid bus transit systems in a bid to promote the satisfaction of customers with this transportation mode.

MCDM approaches can be divided into two subcategories [8, 11], namely, Multi-Attribute Decision Making

*Address correspondence to this author at the The Institute of Informatics and Computing in Energy, Universiti Tenaga Nasional, Kajang 43000, Malaysia; Tel/Fax: 03-89212020 Ext: 2350/3286;
E-mail: asyikin@uniten.edu.my

 © 2021 Bentham Science Publishers

Recent Advances in Electrical & Electronic Engineering

Table 1. Comparison between previous MCDM review papers and the proposed review paper.

Author	Paper Description	Proposed Paper Description
Abbas *et al.* [1]	Review of the literature published between 2000 and 2014 Includes some basic overview of the selected method The authors classify each utilized method and the paper is reviewed generally	Presents a comprehensive review of the literature across various fields, including renewable energy, sustainability, manufacturing, production and transportation Reviews papers published between 2008 and 2021 Covers the processes, advantages and disadvantages of each method Reviews six widely used methods and briefly mentions others Each reviewed paper is summarized and explained in detail Summarizes each application in table form and classifies them based on the method Mentions several software widely used Highlights the advantages and disadvantages of each reviewed method The issues and challenges encountered in implementing MCDM are discussed
Velasquez and Hester [7]	Reviews papers published between and 2002 and 2013 Provides a brief explanation for each method Literature review on 12 methods Focuses only on the methods and does not critically review their application Highlights the advantages and disadvantages of each reviewed method	
Singh and Malik [8]	Reviews the literature focusing on MCDM only Covers only three major MCDM methods Each reviewed method is illustrated in detail (as numerical equations) and described step by step Presents some calculation examples	
Kumar *et al.* [9]	Presents a comprehensive review of the literature on sustainable renewable energy development Reviews papers published until 2016 Highlights the steps, strengths and weaknesses of each method Presents the software mainly used when applying MCDM Summarises each application in table form Classifies each method based on region	
Penadés-Plà [11]	Presents a comprehensive review of the literature on sustainable bridge design Reviews papers published until 2016 Presents the tools that can be integrated with MCDM Address the drawbacks of classic MCDM techniques Summarises each MCDM method in term of bridge design criteria	

(MADM) and Multi-Objective Decision Making (MODM). In MADM, DMs select, classify, rank or prioritise a finite number of alternatives and then obtain the best solution. MADM has three main approaches, namely, pairwise comparison, outranking and distance-based approaches. Pairwise comparison mainly involves assessing and comparing the importance of several criteria based on a fundamental scale. Pairwise comparisons often utilise Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP). Meanwhile, outranking approaches provide several alternatives and check whether one alternative has any degree of dominance over another [12]. These approaches are particularly suitable in cases with unclear and incomplete information [11]. Some example outranking approaches include the ELimination Et Choix Traduisant la REalité (ELECTRE) and Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE) [13]. Distance-based approaches evaluate how far away a solution is from the ideal point, and the solution with the shortest distance to this point is considered optimal. Some well-known distance-based approaches include the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [14] and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR). Studies aiming to promote maintenance delivery mainly utilise MADM given the availability of a finite number of solutions in maintenance management [15]. Meanwhile, MODM deals with situations involving multiple DMs and an infinite number of choices. In this approach, experts only take part at the end of the process and choose among several solutions. Some well-known MODM methods include Goal Programming (GP) [16, 17] and Genetic Algorithm (GA) [18, 19].

Instead of viewing these approaches individually, this paper focuses on MCDM as a whole. Table **1** compares several

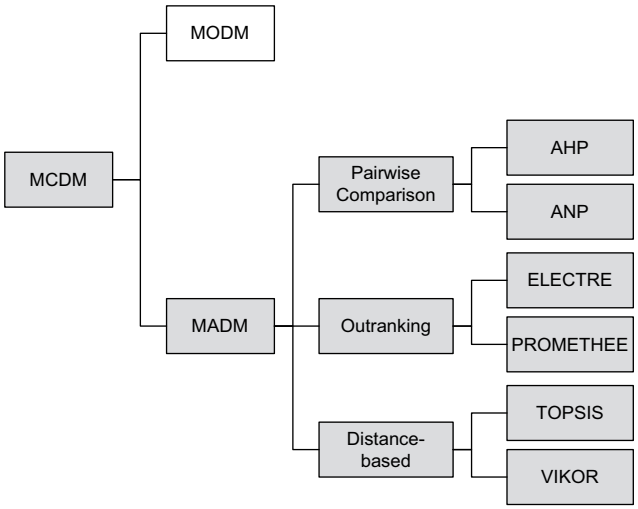


Fig. (1). Overall view of MCDM approaches. This paper will be focusing on the shaded categories.

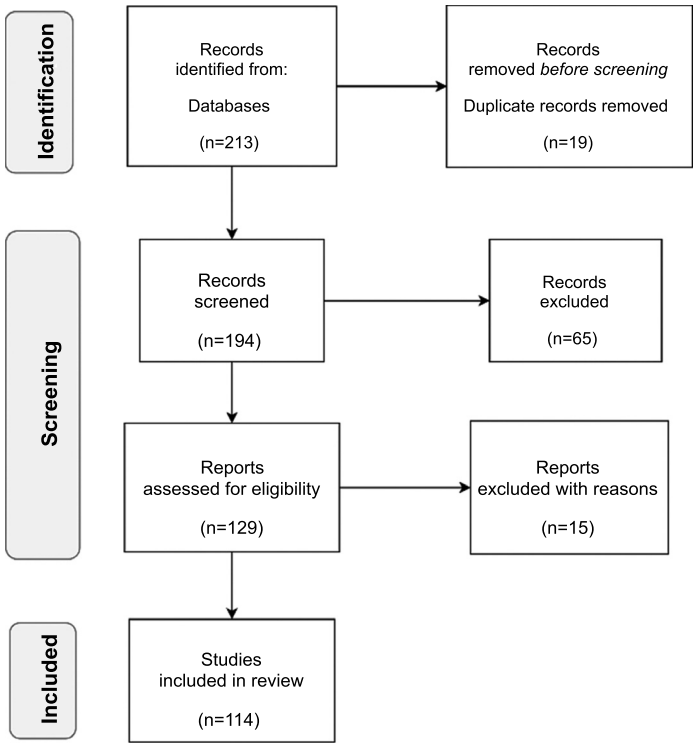


Fig. (2). Flowchart of the PRISMA study selection process.

Table 2. Common terms used in MCDM.

Term	Definition
The decision-maker (DM)	Where experts are assigned to weigh tasks given
Goal	What DM wants to achieve
Criteria or attributes	The alternatives to be compared with and evaluated
Alternatives	The methods or decisions that are to be chosen or ranked
Weights	Representing the relative importance of the criteria

Table 3. Definitions of acronyms and notations.

Acronym	Definition
AHP	Analytical Hierarchy Process
ANP	Analytical Network Process
BWM	Best-Worst Method
COPRAS	Complex Proportional Assessment
DEMATEL	Decision Making Trial and Evaluation Laboratory
DANP	DEMATEL-ANP
DEA	Data Envelopment Analysis
DG	Distributed Generator
DGs	Distributed Generations
DM	Decision-Maker
DMs	Decision Makers
ELECTRE	ELimination Et Choix Traduisant la REalité
EVS	Electric Vehicle Sharing
FAHP	Fuzzy AHP
GA	Genetic Algorithm
GCPVS	Grid-Connected Photovoltaic System
GIS	Geographical Information Systems
GM	Green Manufacturing
GMP	Green Manufacturing Practices
GP	Goal Programming
GRA	Grey Relational Analysis
HFLTS	Hesitant Fuzzy Linguistic Term Set
IDM	Islanding Detection Method
IGRA	Improved Grey Relational Analysis
LCRPS	Large Commercial Rooftop Photovoltaic System
MADM	Multi-Attribute Decision Making
MAUT	Multi-Attribute Utility Theory
MAVT	Multi-Attribute Value Theory
MCDM	Multi Criteria Decision Making
MODM	Multi-Objective Decision Making
MOORA	Multiple-Objective Optimization by Ratio Analysis
MULTIMOORA	Multiple-Objective Optimization by Ratio Analysis plus the full MULTIplicative form
OWPS	Offshore Wind Power Station
p-ELECTRE	Probabilistic ELECTRE
PROMETHEE	Preference Ranking Organization METHod for Enrichment of Evaluations
RES	Renewable Energy Sources
RTUs	Remote Terminal Units
SAW	Simple Addictive Weighting
SHP	Small Hydropower
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
V2G	Vehicle-to-Grid
VIKOR	VIseKriterijumska Optimizacija I Kompromisno Resenje

review papers related to MCDM to highlight the gaps in this field and to underscore the importance of conducting this work. Recent review papers on MCDM (published between 2018 and 2021) have mostly examined a specific field or area of application. By contrast, this paper covers several fields where MCDM is implemented.

Fig. (**1**) presents those MCDM methods that are widely applied in different fields. Each method has unique characteristics and can be implemented in a broad area of interest. Other known MCDM methods that are not listed in Fig. (**1**) include the scoring approach that uses Simple Addictive Weighting (SAW) and Complex Proportional Assessment (COPRAS), the utility/value approach that uses Multi-Attribute Utility Theory (MAUT) and Multi-Attribute Value Theory (MAVT) [11], Goal Programming, Decision Making Trial and Evaluation Laboratory (DEMATEL) and Grey Relational Analysis (GRA). Whilst these methods are not standalone, they generate promising results when combined with the main MCDM methods. In recent years, researchers have been using hybrid MCDM methods to obtain superior outputs [20-22]. These methods are often combined with fuzzy or grey sets [23, 24] and other approaches, such as machine learning [25, 26] and geographical information systems (GIS) [27, 28]. Combining MCDM with fuzzy theory [29] can overcome the limitations of the traditional MCDM approach in certain situations. Fuzzy logic can also effectively address those uncertainties arising from complex decisions [30]. Several terms that are commonly used when implementing MCDM are listed in Table **2** and will be used accordingly throughout the rest of this paper.

A total of 213 articles were initially identified from various databases. Duplicate records were removed, leaving 194 articles to be screened. During the screening, 80 records were excluded mainly due to out-of-scope or outdated articles. Finally, 114 papers are deemed to be fit and were included in this paper. Fig. (**2**) shows the PRISMA flow chart of the selection of studies.

The contributions of this paper are as follows:

- This paper provides a complete list of well-known MCDM methods used in the industry and presents a brief overview of each method.
- This paper reviews the related literature on MCDM published between 2008 and 2021. The focuses and contributions of each study are summarised in a table.
- This paper tabulates the advantages and disadvantages of each related MCDM method.
- This paper discusses the issues and challenges encountered in implementing MCDM methods.

The rest of this paper is organised as follows. Section 2 presents an overview of the MCDM literature. Section 3 examines the recent application of MCDM methods in several fields. Section 4 highlights some issues and provides some recommendations for future work. Section 5 concludes the paper. Table **3** lists the acronyms used throughout the paper.

2. BACKGROUND STUDY

This section presents an in depth introduction and discussion on the background, definition and steps involved in pairwise comparison, outranking and distance-based MDCM approaches.

2.1. Pairwise Comparison

2.1.1. Analytical Hierarchy Process (AHP)

DMs often face difficulties when choosing what is best for reaching their goals. To overcome this problem, Saaty [31] in 1986 proposed AHP, whose broad framework involves the problem of the DM, the elements or criteria related to his/her goals and the alternative solutions.

To develop priorities in an organised manner, decisions should be made in the following manner [32]:

1. The problem and targets must be properly defined.
2. Several criteria and alternatives should be derived from the specified problem.
3. The problem should be structured hierarchically as shown in Fig. (**3**), where the goal of the decisions is placed at the top, followed by the objectives and problem criteria at the mid-level and the hierarchy structure, usually comprising a set of alternatives, at the lowest level.

Pairwise comparison matrices can be built by comparing the element from the top level with those at the mid and bottom levels. The fundamental scale of importance is then used to evaluate the weightage of the criteria in pairwise comparisons. The scale of importance is summarised in Table **4**.

To evaluate the consistency of the evaluation, the consistency ratio (CR) is calculated by dividing the consistency index (CI) by the random index (RI). The CR should be less than 10%. If this percentage is exceeded, then the procedure should be repeated to improve consistency.

$$CR = \frac{CI}{RI} \tag{1}$$

The main advantages of AHP lie in its ease of use and scalability, given that the weightage can be calculated by using Internet software, including MakeItRational, Transparent Choice, SpiceLogic, Decerns MCDA, MATLAB, R and Super Decisions, or by using an Excel template as stated in another study [33]. The overall hierarchy structure clarifies the importance of each element (criteria and alternative). Given its suitability for low-complexity problems, AHP is considered a convenient and straightforward approach.

However, AHP [34] prefers only 7 ± 2, or approximately 5 to 9 elements (criteria) based on Saaty's scale of importance. Although the number of hierarchy levels in AHP is limited, the same capacity limit should be followed to avoid creating a gigantic hierarchy structure [34]. The authors in another study [35] argued that most companies do not prefer AHP due to its inability to provide good rankings with a few number of options.

2.1.2. Analytical Network Process (ANP)

To address the above limitations, researchers have proposed ANP as an extension of AHP [36]. The network structure form of ANP allows DMs to make decisions under complex conditions [11]. Unlike in AHP, the elements

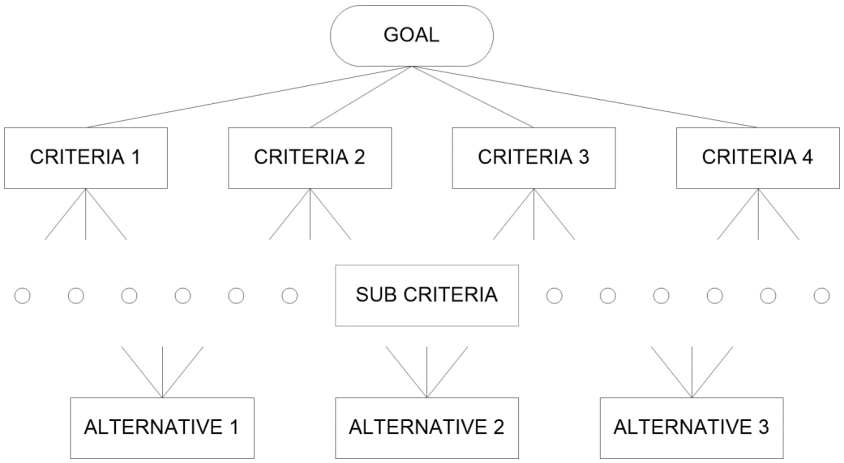


Fig. (3). Overall view of the AHP hierarchy structure.

Table 4. The fundamental scale of importance.

Scale of Importance	Definitions	Explanations
1	Equally Significant	Equality of two values
3	Slightly Significant	The value is slightly important than the other
5	More Significant	The value is preferable than the other
7	High Significant	The value is strongly preferable than the other
9	Very High Significant	The value is preferable than the other
2,4,6,8	Values between 1,3,5,7,9	According to explanations in 1,3,5,7 and 9

(decision criteria and alternatives) in ANP are independent of one another. However, in some real-life problems, interactions and dependencies between the top- and low-level elements are necessary. In this case, ANP is more efficient than AHP by promoting a relational dependency amongst the elements. However, ANP requires long brainstorming sessions and involves a lot of expertise among the people who will implement the method. Another drawback is the complexity of ANP which requires the use of additional software, such as Super Decisions, Expert Choice and Decision Lens. Fig. (**4**) illustrates the ANP network structure, where some elements are dependent on other elements or clusters.

In ANP, the elements (criteria, sub-criteria and alternatives) are referred to as nodes that can be compared with one another if they are related. Unlike in AHP, the alternatives in ANP depend on the weighting of criteria. ANP also provides additional functions that allow the alternatives to influence the ranking of criteria.

An ANP model is developed in four steps as follows [37]:

1. The problem should be clearly structured similar to a network.
2. Pairwise comparison is performed.
3. A super matrix is built (concept similar to the Markov chain process).
4. The criteria are synthesised with the priorities of alternatives, and the best alternatives are selected.

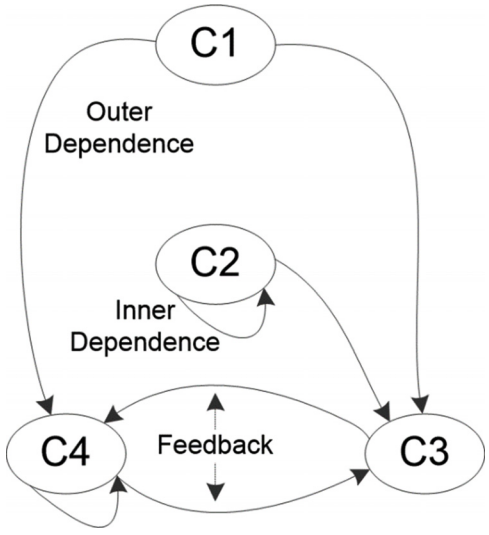


Fig. (4). The network structure of ANP method.

Table 5. The variants of ELECTRE method.

Problem	Method
Choice Problem	ELECTRE I ELECTRE Iv ELECTRE IS
Ranking Problem	ELECTRE II ELECTRE III ELECTRE IV ELECTRE SS
Sorting Problem	ELECTRE TRI

One advantage of ANP over AHP is that independence amongst elements is not required due to its network structure. Moreover, ANP can improve the priorities *via* feedback, thereby enhancing the accuracy and effectiveness of predictions. However, ANP may not support uncertainty in information. Due to its complexity, ANP also requires additional software, which may extend the time needed to solve problems. Some available software for ANP include ANPSolver, SuperDecision and other mathematical software such as Excel, Maple and Mathematica.

2.2. Outranking

2.2.1. ELimination Et Choix Traduisant la REalité (ELECTRE)

By taking into account both the min and max directions, ELECTRA is considered one of the best outranking methods in MCDM [38]. Although some variants of ELECTRE are being applied depending on the type of problem, they all describe the same concepts. Some of these variants include ELECTRE I, ELECTRE Iv and ELECTRE IS for solving choice problems, ELECTRE II, ELECTRE III, ELECTRE IV and SS for solving ranking problems and ELECTRE TRI for solving sorting problems. These variants are listed in Table **5**.

ELECTRE I and its modified variants, ELECTRE Iv and ELECTRE IS, are most suitable for solving choice problems [39]. In these approaches, the DM needs to select the best choice in the smallest available subset [40]. In ELECTRE I, all actions of the DM will form a cycle, which is considered indifferent and thus inconvenient [41]. ELECTRE IS is a generalisation of ELECTRE Iv that addresses the inconvenience brought by ELECTRE I. To solve ranking problems, the authors [42] proposed ELECTRE SS, which can assess the reliable performance of alternatives unlike ELECTRE III. A ranking problem involves the ranking of all actions in a given set from best to worst. A sorting problem involves the classification of data, objects or items in a categorical set. The authors [43] compared two MCDM methods, namely, TOPSIS and ELECTRE TRI, of which the former works in a continuous manner and the latter works in a discreet manner. Unlike TOPSIS, ELECTRE TRI considers the uncertainty and vagueness of both qualitative and quantitative criteria.

The authors in another study [9] argued that ELECTRE is grounded on three factors, namely,

1. Determination of threshold function.
2. Concordance index and discordance index.
3. Outranking degree.

Despite its advantages, ELECTRE consumes a lot of time. Some software that use ELECTRE include DecisionLab, ChemDecide, MATLAB, R, Python, XLSTAT, J-Electre and SMAA-TRI.

2.2.2. Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE)

PROMETHEE is a famous MCDM outranking approach introduced in 1982 by Professor Brans [13]. Similar to ELECTRE, PROMETHEE has several variants, including PROMETHEE I and II for partial and complete ranking problems, respectively. PROMETHEE III and IV were later developed by J.P. Brans and B. Mareschal based on interval and continuous cases, respectively [13]. Years of research have led to the discovery of further PROMETHEE extensions, including PROMETHEE V in 1992 and PROMETHEE VI in 1994, also proposed by J.P. Brans and B. Mareschal [13]. PROMETHEE V is specifically tailored for problems with segmentation constraints, whereas PROMETHEE VI addresses human brain representation [7]. Fig. (**5**) shows the structure of the PROMETHEE family.

J. P. Brans, P. Vincke and B. Mareschal [44] compared the stability of ELECTRE III and PROMETHEE and found that the latter is more stable due to the discontinuities in the preference functions or derivatives of ELECTRE III. Similar to ELECTRE, PROMETHEE also deals with both qualitative and quantitative criteria. However, as an advantage, PROMETHEE expresses these criteria in its own units and requires fewer inputs, thereby reducing complexity and facilitating the use of this approach. However, if many criteria and options are available, then the outcomes of PROMETHEE may be difficult for the DM to evaluate. PROMETHEE may also suffer from the rank reversal problem whenever a new alternative is introduced.

As summarised [9], the standard steps in PROMETHEE are as follows:

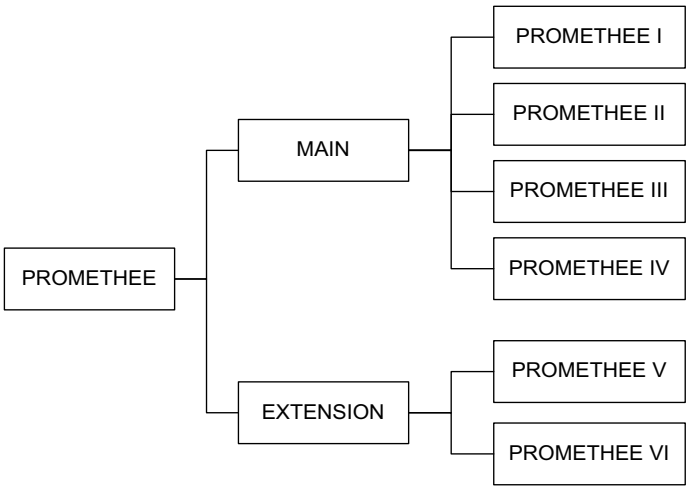


Fig. (5). The structure of PROMETHEE family.

1. Find the evaluation matrix and perform a pairwise comparison.
2. Assign a preference function with values ranging from 0 to 1 depending on the difference between pairs.
3. Calculate the global matrix and obtain the rank.

PROMETHEE is considered a user-friendly outranking approach that has been widely used in addressing real-life planning problems due to the completeness of its ranking [45]. Several software for PROMETHEE is available, including Decerns MCDA, Virtual PROMETHEE, D-Sight, MATLAB, R and Smart Picker Pro.

2.3. Distance-based

2.3.1. Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is a distance-based method proposed by Hwang and Yoon in 1981 [14]. The overall concept of this method is that the best alternative should have the nearest distance from the ideal solution and the farthest distance from the negative ideal solution [46]. Ideal and negative ideal solutions are defined as follows:

Ideal solution: An ideal solution should have the best attribute values, maximise the benefit criteria and minimise the disadvantages criteria [11].

Negative ideal solution: A negative ideal solution should have the worst attribute values, maximise the disadvantage criteria and minimise the benefit criteria [11].

TOPSIS is implemented in the following steps [47, 48]:

1. Establish a standardised decision matrix and normalised decision matrix, where J is denoted as alternatives.

$$j = 1, \ldots, J \text{ and } i = 1, 2, \ldots, n$$

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{J} f_{ij}^2}} \tag{2}$$

where r_{ij} and f_{ij} are an original and normalized score of the decision matrix, respectively.

2. Calculate the weighted normalised decision matrix as

$$v_{ij} = w_i r_{ij} \tag{3}$$

where w_i is the weight of the *i*-th attribute or criterion and,

$$\sum_{i=1}^{n} w_i = 1 \tag{4}$$

3. Determine the ideal solution, A^* and negative ideal solution, A^-

The A^* and A^- defined in terms of the weighted normalized values.

$$A^* = \{v_i^*, \ldots, v_n^*\}$$

$$= \left\{\left(\max_j v_{ij} \,|\, i \in I'\right), \left(\min_j v_{ij} \,|\, i \in I''\right)\right\}, \tag{5}$$

$$A^- = \{v_j^-, \ldots, v_n^-\}$$

$$= \left\{\left(\min_j v_{ij} \,|\, i \in I'\right), \left(\max_j v_{ij} \,|\, i \in I''\right)\right\}, \tag{6}$$

where, I' is associated with benefit criteria, and I'' is associated with cost criteria.

4. Construct a separation between the ideal solution and negative ideal solution using the *n*-dimensional Euclidean distance.

$$D_j^* = \sqrt{\sum_{i=1}^{n} \left(v_{ij} - v_i^*\right)^2}, \text{ Ideal solution} \tag{7}$$

$$D_j^- = \sqrt{\sum_{i=1}^{n} \left(v_{ij} - v_i^-\right)^2}, \text{ Negative solution} \tag{8}$$

5. Determine a relative closeness to the ideal solution.

The relative closeness of the alternative a_j with respect to A^* is defined as

$$C_j^* = \frac{D_j^-}{D_j^* + D_j^-} \tag{9}$$

6. Rank the order of preferences.

The advantages of TOPSIS lies in its simplicity of usage and easy programming. The steps involved in TOPSIS are always the same regardless of the number of attributes. However, by using Euclidean distance, TOPSIS does not consider the correlation amongst the attributes. Moreover, maintaining a consistent judgement is difficult in TOPSIS, and this approach completely disregards the uncertainty in weightings. Apart from Microsoft Excel, TOPSIS can be used with some online software, including Decerns MCDA, Scikit-Criteria, R, OnlineOutput and MATLAB.

The authors in another study [49] compared ELECTRE, TOPSIS and Grey Theory and found that TOPSIS is mainly used for ranking, ELECTRE is mainly used for selection and Grey Theory is mainly used in cases where no data are available.

2.3.2. VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR)

Initially called Multicriteria Optimisation and Compromise Solution, VIKOR was proposed by Opricovicfor in 1979 and first applied with Duckstein in 1980 [50]. However, the name VIKOR was only used starting in 1990. This technique is mainly used to evaluate and compare the sustainability of various energy plans or renewable energy technologies to provide decision support for selecting the most sustainable and appropriate options [51]. The differences between TOPSIS and VIKOR were studied [48], where the authors found that both methods use different types of normalisation to eliminate the units of criterion functions. VIKOR uses linear normalisation, whereas TOPSIS uses vector normalisation. The authors also highlighted other features that distinguish these two methods, such as their procedural basis, aggregation and solution. Different normalisation approaches produce different aggregating functions for ranking [48].

The procedures in VIKOR can be summarised as follows [48, 52]:

1. Calculate the best f_i^* and the worst f_i^-

Where, f_{ij} is the value of the i-th criterion function for the alternative f_i

$$f_i^* = \max_j f_{ij}$$

$$f_i^- = \min_j f_{ij} \tag{10}$$

2. Compute S_j and R_j

Where S_j and R_j denote the utility measure and regret and w_i denotes the weights of the criterion, indicating their relative importance.

$$S_j = \sum_{i=1}^{n} w_i \left(\frac{f_i^* - f_{ij}}{f_i^* - f_i^-} \right) \tag{11}$$

$$R_j = \max_i \left[w_i \left(\frac{f_i^* - f_{ij}}{f_i^* - f_i^-} \right) \right] \tag{12}$$

3. Compute S^* and R^*.

$$S^* = \min_j S_j \quad S^- = \max_j S_j$$

,

$$R^* = \min_j R_j \quad R^- = \max_j R_j \tag{13}$$

,

4. Determine value of Q_j, where $j = 1, \ldots, J$ and rank the alternatives.

$$Q_j = v\left(\frac{S_j - S^*}{S^- - S^*} \right) + (1 - v)\left(\frac{R_j - R^*}{R^- - R^*} \right) \tag{14}$$

where v is weight of maximum group utility, and 1-v is the weight of individual regret. v is ideally equivalent to 0.5. When $v > 0.5$, Q_j indicates majority agreement, and when $v < 0.5$, Q_j indicates majority negative attitude.

Similar to other MCDM methods, VIKOR can be integrated or modified to obtain better results for specific applications. Variants of VIKOR include the fuzzy VIKOR for water resources planning [53], modified VIKOR for improving the service quality of domestic airlines [54], interval VIKOR [55], comprehensive VIKOR for selecting femoral components in total knee replacement [56] and regret-theory-based VIKOR [57]. Amongst these variants, the interval and regret-theory-based VIKOR demonstrate the worst performance [58]. Fuzzy VIKOR is generally preferred in cases where information about the decision problem is imprecise. However, in some cases [59], the original VIKOR is a much better option given the low complexity in its mathematical computation. A new version of VIKOR called VIKORRUG was proposed [60] as a compromise-ranking algorithm that allows DMs to further improvise any objections and rank the unimproved gaps in the alternatives.

Similar to TOPSIS, the advantages of VIKOR lie in its simple process and consistent number of steps regardless of the number of attributes. VIKOR provides additional strength with its capability to maximise the utility group and minimise the regret group. However, VIKOR suffers from drawbacks in its performance rating, which is quantified as a crisp value that is generally inadequate in modelling real-life situations. To address this drawback, DMs need to consider imprecise or ambiguous data. VIKOR can be used with Excel, R, MATLAB and OnlineOutput.

3. REVIEW OF APPLICATIONS FOR ALL METHODS

MCDM is used in various types of DM problems, such as location or site selection, supplier selection, project assessment, method or procedure selection, maintenance or configuration planning, energy resources selection and social assessment, and covers many industries from energy, sustainability, transportation, manufacturing and production. This section exhaustively reviews the applications of MCDM across various fields.

3.1. Pairwise Comparison Methods

The AHP has been used in various applications, such as selection, cost-benefit analysis, forecasting, evaluation, DM, priority and ranking and planning and development, and in several major fields, including medical and healthcare [61, 62], business [63-65], transportation [66, 67] and renewable energy [68, 69]. The AHP is commonly used in selecting locations for power plants around the world [20, 27, 28, 70] and in measuring the performance and configurations of microgrids [71], including their load shedding and optimisation cost. The authors in another study [72] identified a few challenges associated with islanding detection method (IDM) selection, which greatly depends on the type of distributed generator (DG) units and their connection topologies. The lifetime, location and future expandability of DGs and utility grids are some of factors associated with IDM selection. The AHP method is used in a grid-connected photovoltaic system (GCPVS) to help the IDM provide a complete solution for anti-islanding. The authors proposed a passive/active hybrid method, with the passive method measuring the system parameters and the active method introducing perturbations in system quantities. However, the AHP faces some limitations related to the weightings of DMs because DMs often encounter difficulties in expressing their preferences based on the defined ration scale, but these challenges are easily overcome by using group DM tools, such as consensus.

In energy planning, the AHP is often combined with other methods. For instance, the AHP may be used to weigh the criteria, and then the DM will apply Multiple-Objective Optimisation by Ratio Analysis and the full MULTIplicative form (MULTIMOORA) method to sort the alternatives [73]. MOORA is an MCDM method developed by Brauers and Zavadskas in 2006 [74], where each response of an alternative per objective is compared with the square root of the sum of squares of the responses. As an extended version of MOORA proposed in 2010, MULTIMOORA [75] summarises the ratio scheme, point of reference and complete multiplication form used in MOORA [76]. The authors in another study [73] determined the best configuration plans to achieve an optimum planning of microgrids. These plans included several combinations of energy resources, such as wind turbine, biomass and diesel, and considered three loading conditions (high, medium and low). Another energy planning research from Turkey combined ANP with fuzzy TOPSIS and Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis [77]. Specifically, ANP and fuzzy TOPSIS were combined to overcome the overall complexities of the DM process, and the SWOT framework was subsequently integrated to create a strategic plan. The authors used ANP to weigh each SWOT factor and subfactor and found that the usage of fossil fuels can be reduced by deploying other renewable energy resources, such as nuclear, geothermal, solar and wind energy.

AHP can also be used in maintenance planning, such as in measuring the health of substations by integrating multiple criteria for equipment conditions. This method was proven effective in assessing the conditions of 74 substations in the Tokyo Electric Power service areas [78]. The effectiveness and practicality of AHP were evaluated within five years using its developed procedure. The condition indices were compared across three regions, namely, urban, suburban and remote regions, with the urban region having the smallest indices, followed by the suburban and remote regions (a smaller index is generally preferred). These results were then validated by frontline engineers responsible for maintenance planning. The AHP also allows DMs to predict the future health conditions of substations. Meanwhile, the authors used the fuzzy-AHP model in selecting maintenance policies in the manufacturing industry [23]. Faced with increasing competition in their markets, companies should acknowledge the progressive maintenance system of their competitors. AHP selects maintenance strategies based on seven types of equipment that are mainly used in the chemical industry, especially by manufacturers of sulfuric acid. The main goal of this approach is to reduce the overall costs and risks whilst increasing the added value for the manufacturer.

Another difficult DM problem is selecting a site or location for various projects, such as smart grids, power plants and transportation midi-hubs. Both AHP and ANP are often used to this end. Whilst some practitioners used either AHP or ANP, others developed a hybrid approach, especially when using either AHP or ANP alone cannot solve the specified problem. In a case study involving the selection of an Algerian network, the authors used AHP to prevent the cascading degradation of electrical networks and cascading blackouts that can lead to losses [79]. In this work, AHP was employed as a DM tool to solve complex problems in issuing judgments based on past experience and informal data. Several scenarios around the world, including those in the US, China, India, Italy and Germany, were also reviewed to select the best scenario for Algerian smart grid projects. The decision criteria included service continuity, power quality, energy efficiency, control of peak demand, transportation over long distances with minimal losses, integration of renewable sources with minimum investment, decentralisation and launching of electric vehicles, development of clean energy and environment protection. The authors highlighted the value of learning from the actions and goals of projects conducted in the US, Italy and Germany. In another work, the authors used GIS and AHP to find a suitable location for a solar PV power plant in Saudi Arabia [27]. The AHP has been widely applied in planning RES, especially for location selection whilst taking into consideration several aspects, such as economic, environmental and technical factors. They integrated GIS with AHP in consideration of 14 criteria and evaluated the importance of each criterion using AHP. A similar approach was adopted by the authors [28] in selecting the best location for a wind farm. They considered several parameters, such as environment and climate change, to determine the optimal wind farm location and harnessing of wind energy. Konstantinos *et al.* [70] used a hybrid of GIS-AHP and TOPSIS for the site selection of a wind farm in Greece. This hybrid tool could help policymakers determine optimal installation sites whilst considering several critical parameters, such as social and public attitudes, which play important roles in the selection of installation sites. Some other parameters that need to be critically reviewed given their potential effects on the installation location include accessibility, current land use and legislation frameworks.

The authors [80] studied some alternatives for selecting the location of a solar power plant in Turkey. They found

that using ANP was a lengthy endeavour, given its consideration of the interdependencies across and along the decision hierarchies. However, this approach provides a more reliable solution compared with AHP. An ANP-based methodology also considers quantitative and qualitative elements when evaluating location alternatives. The authors applied ANP using Microsoft Excel, given that they only considered a limited number of elements. ANP also can be integrated with other methods, such as GQM and fuzzy DEMATEL [81], where the authors focused on those key factors that affect wind farm location selection and wind energy accumulation, such as wind sources, accessibility of electrical grids and population distribution. They applied ANP for weighing the dimensions and criteria and used fuzzy DEMATEL to ascertain the effects of these criteria and their relative intensities. When using ANP, the authors considered 6 factors associated with 28 evaluation criteria. From the ranking of these criteria, they identified regular wind farm testing, secure setup distance and destroyed windbreaks as the key criteria for practitioners and environmental ecology monitoring, destroyed windbreaks and regular wind farm testing as the key criteria for academics. In other words, practitioners tend to focus on the safety of wind turbines, whereas academics focus on data monitoring and environmental issues. Safety and Quality, together with Environment and Ecology, emerged as the major factors that affect the wind farm location selection.

A recent study [82] identified those factors that prevented the development of renewable technologies in Pakistan and proposed some methods for overcoming these barriers. The authors employed the hybrid AHP-fuzzy TOPSIS approach, with AHP assessing the criteria and sub criteria and fuzzy TOPSIS evaluating the strategies for the long-term implementation of renewable energy technologies. The authors initially determined the potential barriers to the implementation of renewable technologies, including 7 main barriers and 29 sub-barriers. From their list, they formulated 10 strategies for addressing the identified barriers. The most suitable strategy obtained from fuzzy TOPSIS was capital subsidies, which may assist the Pakistani government and DMs in overcoming the obstacles to achieving sustainable energy planning and development in their country. Another recent study in Vienna employed AHP for site selection in the transportation field [67]. The authors aimed to select a location that is suitable for a midi-hub or a medium-size city hub. They discussed their criteria with DMs and then weighed them by using AHP given that this approach takes the judgment of DMs into account. Suitable midi-hub locations were then determined based on the indicators defined for each criterion, and then these locations were evaluated in a pairwise manner.

Other than site selection, ANP was also used to determine the suitability of power plants in Turkey in response to the growing demand for electrical energy driven by the increasing population and industrial growth in the country [83]. The authors aimed to determine the most suitable power plant from six types of widely used power plants (*i.e.* nuclear, geothermal, wind, natural gas, hydroelectric and coal/lignite). They evaluated the future installation of these power plants in Turkey whilst considering several important criteria, such as technology, sustainability, life quality, economical suitability and socioeconomic impacts corresponding to the energy needs of the country. They found that the ANP was particularly suitable for complex DM environments given that this approach allows feedback amongst the elements. The ranking decision results show that nuclear power plants are most suitable for Turkey, with coal/lignite power plants being the most unsuitable given their low reserves-to-production ratio and high radioactivity.

A recent case study in China [84] proposed the application of fuzzy ANP for wind turbine selection in response to the increasing variety of wind turbines available in the market. The selection was based on three aspects, namely, operation reliability, economy and supplier cooperation. A total of 12 indicators were evaluated, and the authors proposed a fuzzy ANP model to evenly distribute the weight of the evaluation index and facilitate the selection of the best wind turbine. Operational reliability emerged as the most important indicator for the selection, followed by economic indicators and availability of wind turbines. The G100-2.5 MW unit wind turbine produced by Goldwind Company was chosen as the most suitable alternative due to its permanent magnet direct-driven generator with excellent performance and low maintenance. The authors added that the FANP model may help evaluate other renewable energy equipment by changing indicators. However, one downside of the hybrid fuzzy model is that the calculations tend to be increasingly complex, thereby adding to the workload in the assessment phase.

The project assessment in another study [20] integrated AHP and ANP to check the profitability of investing in a solar thermal power plant project. The authors proposed a three-level decision. At level 1, they evaluated whether using AHP is worthwhile in assessing the acceptability of a solar-thermal power plant project. At Level 2, they analysed the accepted projects by using a new set of criteria and a deeper knowledge of these projects. At Level 3, they defined new criteria for assessing the project risks. The decision alternatives are the different projects of the portfolio. The authors proposed using both the AHP and ANP models in the assessment. Whilst the AHP is conceptually easy to use, given its strict hierarchical structure, the AHP cannot easily handle complex real-world problems. Therefore, the authors resorted to using ANP in handling complex problems, given that its network structure can incorporate the feedback and interdependence relationships within and between clusters. Rather than overtaking the decision of DMs, the proposed hybrid AHP/ANP model helped evaluate and analyse the outcomes of the projects. However, relative to AHP, the ANP could better reflect the complexity of a problem by allowing DMs to compare the outcomes of various models and evaluate their pros and cons. The authors [85] assessed a supply chain by using an ANP-MOORA hybrid to identify and evaluate issues in green supply chain management. Implementing the ANP-based framework effectively reduced the complexity of MCDM approaches, hence facilitating the selection of the best supply chain.

Some challenges in the implementation of ANP require pairwise group comparisons. Given the difficulty in achieving the optimal minimum and maximum values for each metric, the usage of fuzzy numbers in this model is limited. Moreover, the chosen approach often reflects the subjective bias of a DM. Therefore, a restricted rationality bias may be observed. For example, in the supplier evaluation and selec-

tion work of Giannakis *et al.* [86], they faced challenges in measuring accuracy given that the overload measures are biased towards heavy works and that very few alternatives may not fit well. To address this problem, they developed a framework that can be used across various industries for evaluating and selecting suppliers that are tailored to the industry needs. In the production field, the ANP is mainly used in green supplier selection, where finding an effective and reliable alternative is crucial.

This topic has received much attention from researchers and practitioners due to growing concerns on the detrimental impacts of businesses operations on the environment. The authors [87] modelled a framework for evaluating the green performance of an alternative (supplier) whilst considering economic and environmental criteria. They employed the Improved GRA (IGRA) to reduce the uncertainty from ANP. The IGRA may also gather and integrate the judgement of experts into the model, thereby enhancing its flexibility. The authors also performed a sensitivity analysis on the decision parameters to observe the changes in the order of suppliers whenever some changes in scenarios are observed.

The above reviews on the application of AHP and ANP are summarised in Table **6**, and sorted according to the goal of the projects and the field of alternatives. These approaches are popular in selecting the locations of energy farm power plants, and combining them with GIS presents a very promising direction for future work.

3.2. Outranking Based Methods

The site selection problem can also be solved by using outranking-based MCDM methods. Selecting an appropriate location for logistic facilities, such as distribution, plants and collection centres, is an important and complex problem. Therefore, many methods have been formulated to assist DMs in making an appropriate choice. However, some of these methods have limitations, as listed in another study [38]. For example, these methods do not take the preference of DMs into account and only deal with quantitative criteria, such as transport costs, proximity to customers and connectivity to multimodal transport. The importance of qualitative criteria should be considered in the DM process given that they cover several important factors, such as congestion level, customer satisfaction and safety. To overcome these limitations, ELECTRE I was used in another study [38] to determine the location of distribution centres given its capability to improve DM by taking quantitative and qualitative criteria into account. The selected solution was validated by testing concordance and discordance simultaneously. The authors found that ELECTRE I can be used in other sectors, such as in logistic, biomedical and automatic sectors. Sennaroglu and Celebi [88] investigated the military airport selection in Turkey by integrating PROMETHEE with AHP and VIKOR. They built a two-level hierarchy of criteria, where the first level comprises 9 main criteria, namely, military, expansion potential, cost, environmental and social effects, climate conditions, infrastructure facilities, land, geographical features and needs, and the second level comprising 33 sub-criteria. These criteria were selected from a literature review and through consultations with three DM experts. They eventually used AHP to subjectively determine the weights of these criteria. In a comparative analysis, both PROMETHEE and VIKOR identified location C as the best alternative and outputted the same ranking for the alternatives (C > A > D > B).

A site selection work using ELECTRE III was conducted in the energy conversion field for the deployment of an offshore wind power station (OWPS). The authors [89] proposed a framework that determines the best site in China for deploying an OWPS with the aid of an intuitionistic fuzzy set to handle uncertain and imprecise information. A robust OWPS site selection index system comprising veto and assessment criteria was also designed to exclude vulnerable areas and classify possible alternatives. By implementing ELECTRE III, any unclear information can be avoided or outranked, and the importance of basic knowledge can be utilised. The authors [90] combined fuzzy AHP and PROMETHEE with ArcGIS to select a suitable location for an 8,8000 MW solar farm in Bali, Indonesia.

This hybrid method came in the form of a toolbox in the ArcGIS application that allows users to effectively determine the best location and accelerate the generation of electricity from solar energy in the case area by reducing the time needed for analysing the suitability of land. Another study in Padang, Indonesia integrated the Borda method into PROMETHEE to determine a suitable location for naval bases [91]. The authors implemented the Borda method by allocating weights to each of the first, second and subsequent ranking criteria. Amongst the 16 criteria considered, the Sailing Channel obtained the largest weight, indicating its significant impact on the choice of the base site. The criterion with the second largest weight was Depth of Sea. with Political Condition obtaining the lowest weight. The 16 criteria were evaluated across three proposed base locations, namely, the Semabuk Bay, Siuban and Semebai Bay. Results eventually point towards Semebai Bay as the best location for the naval base. The proposed model was deemed robust because the effects of sensitivity analysis on the parameters and alternative weightings did not change along with the chosen alternative ranking result.

The authors [92] integrated DEMATEL-ANP (DANP) into PROMETHEE to determine the best green manufacturing (GM) practice and to optimise the use of valuable green strategies. External drivers, such as pressures from stakeholders, customers and general bodies, helped determine the level of GM implementation in the context of developing countries. They utilised DANP to analyse the dimensions and criteria and avoid an irrational weighted super matrix. As a result, DANP provides DMs with the best solution for their respective industries. In another study, the authors attempted to identify the optimum vehicle-to-grid (V2G) battery storage for electric vehicle users [93]. Although ELECTRE has been successfully applied across various fields, the authors adopted a probability approach called Probabilistic ELECTRE (p-ELECTRE) instead of relying on direct scores to evaluate the favourableness of an action based on instantaneous values of criteria. p-ELECTRE considers many parameters, such as SoC, electricity price, system load and availability of renewable energy throughout the day. The optimal dispatch was obtained whilst meeting the system load and reducing losses, cost and voltage deviation. In a distribution system, Kamble *et al.* [21] developed an improvised AHP-PROMETHEE method, which provides a better

Table 6. The summary of previous work on AHP and ANP methods.

Authors	Goal	Field	Method	Description
Rietz and Suryanarayanan, 2008 [71]	Identify procedure	Energy/ Microgrids	AHP	Used for determining the various procedure for microgrids such as load shedding
Datta *et al.*, 2014 [72]	Identify method	Energy	AHP	Used to identify the islanding detection methods in a GCPVS
Moravej and Afshar, 2014 [73]	Energy planning	Energy/Microgrid	AHP MULTI MOORA	Used to find the possible configuration plans that include several combinations of energy resources for the microgrids.
Ervural *et al.* 2018 [77]	Energy planning	Sustainability	ANP fuzzy TOPSIS SWOT Analysis	A case study in Turkey on how to reduce energy dependence on foreign sources by deploying a framework to determine energy resources strategies.
Tanaka *et al.* 2010 [78]	Maintenance planning	Energy/Substation	AHP	To evaluate the substation maintenance planning in Tokyo where the substation is classified into three different areas: urban, suburban and remote areas.
Hemmati *et al.*, 2018 [23]	Maintenance planning	Manufacturing	fuzzy ANP	Case study of a sulfuric acid manufacturer in determining the suitable maintenance strategies based on several types of equipment.
Iberraken *et al.*, 2013 [79]	Scenario selection	Energy/Smart grid	AHP	Using other countries as the alternatives for the best scenarios for the Algerian smart grid project
Al Garni and Awasthi, 2017 [27]	Site selection	Energy/Solar PV Power Plant	AHP GIS	Taking the case study in Saudi Arabia to find the most suitable location to implement the solar PV power plant
Baseer *et al.*, 2017 [28]	Site selection	Energy/Wind Farm	AHP GIS	A case study in Saudi Arabia to determine the optimal wind farm location and harnessing wind energy
Konstantinos *et al.*, 2019 [70]	Site selection	Energy/Wind Farm	AHP TOPSIS GIS	A case study in Eastern Macedonia and Thrace region, Greece to determine the wind farm installation location based on several criteria.
Ayag and Samanlioglu, 2010 [80]	Site selection	Energy/Solar Power Plant	ANP	To determine the solar power plant location by taking into consideration of quantitative and qualitative elements.
Yeh and Huang, 2014 [81]	Site selection	Energy/Wind Farm	ANP GQM fuzzy DEMATEL	Taking consideration of six factors in finding the wind farm location by having a total of 28 evaluation criteria.
Y. A. Solangi *et al.*, 2021 [82]	Project assessment	Renewable Energy	AHP Fuzzy TOPSIS	To overcome the renewable energy development barriers by finding the best strategy
Anderluh *et al.*, 2020 [67]	Site selection	Transportation	AHP	The selection of the location in midi-hub consider as one of the challenges thus requires a support tool to assist the DMs
Atmaca and Basar, 2012 [83]	Power plant selection	Energy/Power Plant	ANP	To find suitable power plants in Turkey that can provide a supply-demand balance based on several criteria.
Beltrán *et al.*, 2014 [20]	Project assessment	Energy/Thermal Power Plant	AHP ANP	Determine whether it is profitable to invest in solar thermal power plant project

(Table 6) contd…

Authors	Goal	Field	Method	Description
Pang *et al,.* 2021 [84]	Product selection	Renewable Energy	fuzzy ANP	To find a suitable wind turbine for case study in China
Chand *et al.*, 2018 [85]	Project assessment	Manufacturing	ANP MOORA	To evaluate and analyse the selected issues in green supplier chain management and help the DM to evaluate the impact of different types of supply chains
Giannakis *et al.*, 2020 [86]	Supplier selection	Sustainability	ANP	To evaluate and select suppliers by developing a framework that can be utilised in various industries.
Hashemi *et al.*, 2015 [87]	Supplier selection	Production	ANP IGRA	A selection of green supplier in green supply chain management

evaluation of alternatives for the selection of configuration in a distribution system. The first step in this method was to short-list alternatives based on identified criteria and then prepare a decision table that presents the measurements or values of all criteria with a focus on minimising losses. Afterward, the preference function would translate the difference between the evaluations obtained by several alternatives based on a particular criteria into a preference degree ranging from 0 to 1. AHP-PROMETHEE allows DMs to systematically assign values of relative importance to several criteria according to their preferences.

A similar work was performed in China to predict the future cost of using fossil fuels as the main energy source [94]. The authors examined whether a rise in electricity usage would increase or deplete fossil fuels and necessitate the identification of alternative energy production methods. As a case study, they used PROMETHEE II to select a suitable location for the Parabolic Trough Concentrating Solar Power Plant in China based on several criteria. However, concentrating solar electricity generation encounters several obstructions, such as low efficiency and large land cover. The authors adopted PROMETHEE II instead of TOPSIS given the unavailability of various functions in the latter, making this approach unable to deal with a flexible and diverse DM process. The authors also compared fuzzy VIKOR with fuzzy ELECTRE and found that fuzzy PROMETHEE II provides the most accurate and creditable ranking sequence. In the field of sustainable energy, the authors used ANP, fuzzy PROMETHEE and TOPSIS to evaluate whether power plants are ideal investment projects in response to the increasing usage of renewable energies and to determine which renewable energy resource is worthy of investment in case the cost of fossil fuel rises in the future [95]. Their study covered both environmental and social aspects, which are fundamental in investment prioritisation. Other factors considered included the final production cost of thermal power plants and the capacity of wind and solar power plants. The authors found that both fuzzy PROMETHEE and fuzzy TOPSIS provide similar rankings of power plants.

The authors in another study [45] used PROMETHEE to investigate the effect of different preference functions for a green supplier selection problem in Malaysia. They started out by evaluating a set of alternatives with respect to the criteria where the first net outflows and preference order were obtained by adopting the usual criterion preference function. The second net outflows and preference order were then acquired by adopting a combination of the linear and level preference functions. Both of these functions were chosen based on the nature of their criteria. The authors stated that previous literature on PROMETHEE did not fully discuss the effect of preference functions on the final preference order. In their case study of green supplier selection involving four alternatives, five DMs and seven criteria, the authors concluded that such effect is not significant. The authors in another study [24] evaluated the performance of green suppliers by using the fuzzy extended ELECTRE to ensure sustainable systems. They prepared a fuzzy decision matrix using the weighted average of ratings of suppliers against various attributes. A total of 38 factors were considered and grouped into 6 clusters, namely, cost, quality, flexibility, service, green practice, environmental management and pollution control. The authors focused on outranking the poor performers and only considered the comparable performers in the ranking. Their findings could benefit other work related to supplier selection that focuses on green production and practices, such as solid waste, chemical waste, air emissions, water waste and other environmentally friendly materials and methods.

Assessing sustainable cities is critical for understanding the state of urban growth in real time and making policy changes. In a case study of China [96], the authors proposed an ELECTRE model for assessing the level of urban sustainability across the key dimensions of economy, society and environment. A total of 17 cities in Henan Province were selected for the case study between 2013 and 2017. Amongst these cities, Zhengzhou reported the highest degree of economic sustainability, and Shangqiu ranked the lowest. Zhengzhou also ranked first in the social dimension, with Zhoukou ranking last. Meanwhile, in the environmental dimension, Zhumadian reported the highest sustainability, whereas Jiaozuo reported the lowest sustainability. Zhengzhou, as the city with the highest sustainability, invested large amounts of its capital in economic, social construction

Table 7. The summary of previous work on ELECTRE and PROMETHEE method.

Authors	Goal	Field	Method	Description
Agrebi *et al.*, 2017 [38]	Site selection	Transportation	ELECTRE I	Selection of a possible location to optimize the logistic system for the distribution centre
Sennaroglu and Celebi, 2018 [88]	Site selection	Transportation	PROMETHEE AHP VIKOR	Determination of the military airport location and making comparisons with other methods
Wu *et al.*, 2016 [89]	Site selection	Energy/Wind Power Station	IF-ELECTRE III	Develop a framework to decide the site selection for the offshore wind power station in China
Wiguna *et al.*, 2018 [90]	Site selection	Energy	PROMETHEE fuzzy AHP ArcGIS	The case study in Bali on integrating methods to find the most suitable places for the solar farm
Ahmadi and D. Herdiawan , 2021 [91]	Site selection	Marine	Borda PROMETHEE	To find the suitable location for dock and office of naval bases
Govindan *et al.*, 2015 [92]	Method selection	Production	DEMATEL-ANP PROMETHEE	The GMP requires some efficient and valuable practices for the DMs to select the best solution
Yammani *et al.*, 2016 [93]	Method selection	Energy	p-ELECTRE	To find the optimum V2G battery storage for the electric vehicles user
Kamble *et al.*, 2018 [21]	Method selection	Energy	PROMETHEE AHP	Development of a configuration for the distribution system to minimize the losses that occur.
Wu *et al.*, 2019 [94]	Method selection and site selection	Energy	PROMETHEE TIFGOWA	The selection of solar power plant using PROMETHEE II specifically and compared with other MCDM methods
Tabaraee *et al.*, 2018 [95]	Project selection	Sustainability	ANP fuzzy PROMETHEE	Identification of the best renewable energy solution.
Abdullah *et al.*, 2019 [45]	Supplier selection	Manufacturing	PROMETHEE	Used for green supply selection by using seven criteria in economic and environmental factor
Li et al., 2021 [96]	Sustainability evaluation	Sustainability	ELECTRE	To evaluate the urban sustainability based on 17 cities in Henan Province
Kumar *et al.*, 2017 [24]	Supplier assessment	Sustainability	fuzzy ELECTRE	To evaluate the performances of green suppliers
Polatidis *et al.*, 2015 [97]	Method assessment	Energy/Geothermal Energy	ELECTRE III PROMETHEE II	Comparison of two outranking technique on analysis for the geothermal energy
Dias *et al.*, 2018 [98]	Policy assessment	Energy/Smart Grid	Delphi ELECTRE Tri	To create an assessment on sort and rank policies in the smart grids in Brazil
Wu *et al.*, 2017 [99]	Social assessment	Sustainability	PROMETHEE HFLTS ANP	Evaluation of the assessment of social sustainability in China

and environmental protection. Meanwhile, those cities with the lowest sustainability were usually located in regions with concentrated cultivated land. In another work, the performance of ELECTRE III in geothermal analysis was compared with that of PROMETHEE II [97]. The authors aimed to understand whether these methods could obtain convergent results related to renewable energy development under the same situation and determine whether a DM process can be facilitated by using more than one method. The authors converged both methods and used a real data set from a case study. Their findings shows that both ELECTRE II and PROMETHEE II obtained almost the same results because they are both outranking-based MCDM methods.

The authors used ELECTRE TRI to sort and rank policies with the aid of the Delphi process [98]. Specifically, the expert judgment of 28 stakeholders was obtained by conducting a Delphi survey that aimed to elicit inputs about policy impacts and some main parameters of the ELECTRE TRI model (criteria weights and veto thresholds). The case study was conducted in Brazil with the goal of modelling an assessment method for smart grids. ELECTRE TRI was used to evaluate the merits of each policy without any relation to other policies. The authors discovered that ELECTRE TRI could not address potential synergies amongst policies given that these policies were evaluated independently of one another considering their intrinsic advantages and disadvantages. If a few policies need to be synergised, then ELECTRE TRI can be used to evaluate composite policies (*e.g.* policy P9 could represent the implementation of two other policies at the same time), but using this approach to evaluate all combinations would be impractical. Amidst the growing awareness regarding sustainable energy development, small hydropower (SHP) witnessed a rapid development due to its small scale, low investment, low cost and rapid effect. The authors [99] employed PROMETHEE and the novel Hesitant Fuzzy Linguistic Term Set (HFLTS) to assess the social sustainability of SHP in China. Their assessment focused on self-interests that can be generated in the construction and operation of SHP. For instance, some operators may aim for public recognition, whereas others may pursue SHP development to benefit the local residents. The HFLTS can overcome the uncertainty and inaccuracies in the evaluation and provide a full description of the fuzziness and randomness of criteria value information.

The previous work on ELECTRE and PROMETHEE as reviewed in this section are summarised in Table **7** and sorted according to their project goals and field of alternatives.

3.3. Distance Based Method

Distance-based methods have often been used to fulfill many goals, such as energy planning, site selection, method selection, supplier selection and project assessment. Similar to other MCDM methods, these approaches are applicable to many fields, including energy, sustainability, manufacturing and production. For instance, power distribution planning was investigated to optimise the network routing problem by minimising the feeder routes subject to a set of constraints [22]. The AHP-TOPSIS hybrid model was used in consideration of several reliability aspects, such as miles of conductor, feeder failures, customer interruption, maximum interruption and estimated relative cost. The AHP was used to weigh the criteria, and planning for the power distribution system was carried out by using TOPSIS.

Sustainable development faces critical issues related to the depletion of natural resources, deterioration of the ecological environment and energy crises. One initiative geared towards solving these problems is selecting the optimal sites for electric vehicle charging stations using fuzzy TOPSIS, which is deemed a robust and effective method [100]. However, some real-world problems cannot be solved using the original TOPSIS because some criteria cannot be measured by crisp value. The site selection is conducted from the sustainability perspective and in consideration of environmental, economic and social criteria and 11 other sub-criteria. The authors [101] proposed a decision framework for a Large Commercial Rooftop Photovoltaic System (LCRPS) site selection by using a hybrid of fuzzy ANP and fuzzy VIKOR. They proposed 5 alternatives across China (2 in Guangzhou, 2 in Dongguan and 1 in Foshan) [101] and focused on 5 main criteria (resource, economy risk, environmental and social factors) and 16 sub criteria. However, their framework development was restricted by the lack of complete information that can contribute to the LCRPS site selection, a problem that can be solved by using fuzzy VIKOR. The AHP-fuzzy TOPSIS hybrid was also used in the field of renewable and sustainable energy. With the rising usage of fossil fuels, researchers have attempted to reduce fossil fuel intake by proposing other sources of renewable energy. A case study in India reported that selecting a location for the deployment of a solar farm needs to take into account the efficiency of receiving solar resources [102]. They highlighted the importance of social, technical, economic, environmental and political factors in the site selection. Another study planned the location of a solar power plant in Vietnam by integrating fuzzy AHP (FAHP), data envelopment analysis (DEA) and TOPSIS [103]. The authors eventually identified 46 potential locations using several DEA models, employed FAHP to weigh the factors and applied TOPSIS to rank the locations.

AHP-VIKOR was used [59] to identify renewable energy projects in Spain that are worthy of investment. This hybrid approach allows DMs to rank the importance of attributes based on their preferences. The studied renewable energy plan involved several energy sources, including wind power, hydroelectric, solar thermal, solar thermo-electric, photovoltaic, biomass, biogas and biofuels, and took into account social, economic, technological and environmental factors. The authors identified biomass plants as the best alternative, followed by wind power and solar thermo-electric. A greater weight was given to power and the amount of carbon dioxide emissions avoided per year. The authors used AHP-VIKOR to determine possible renewable energy resource alternatives to be installed at Banaras Hindu University, India [104]. They used AHP to weigh eight factors or criteria and then applied VIKOR to measure the closeness of each alternative to the ideal solution. They considered five alternatives, namely, photovoltaic, concentrated solar power, wind turbine, biomass and geothermal energy, all of which were selected based on their geographical feasibility for onsite power generation. They identified wind turbine as the best

Table 8. The summary of previous work on TOPSIS and VIKOR method.

Authors	Goal	Field	Method	Description
Chakravorty and Ghosh, 2009 [22]	Energy planning	Energy/Power Distribution	AHP TOPSIS	To solve the network routing problem that occurs in the power distribution system
Guo 2015 [100]	Site selection	Sustainability/Electric Vehicle Charging Station	fuzzy TOPSIS	To determine the optimal electric vehicle charging station in the sustainability perspective.
Wu *et al.*, 2018 [101]	Site selection	Sustainability	fuzzy ANP fuzzy VIKOR	To determine the selection of large commercial rooftop PV system in China using incomplete information
Sindhu *et al.*, 2017 [102]	Site selection	Energy/ Solar Plant	AHP fuzzy TOPSIS	To select the best locations for the deployment of solar farm in India
Wang *et al.*, 2018 [103]	Site selection	Energy/Solar Power Plant	FAHP DEA TOPSIS	To provide a proper location for the deployment of solar power plant using the proposed model
Cristóbal, 2011 [59]	Method selection	Energy/Renewable Energy	AHP VIKOR	Implementing the method in Spain to find the most appropriate renewable energy investment
Wu *et al.*, 2016 [106]	Method selection	Energy/Nuclear Power	extended VIKOR	Introducing an extended VIKOR method on supply selection for the nuclear power industry.
Kumar and Samuel, 2017 [104]	Method selection	Energy	AHP VIKOR	To find the most suitable energy resources investment project
Sattarpour *et al.*, 2018 [105]	Method selection	Energy/Power Distribution Grid	GA TOPSIS	To provide a framework that can identify the sizing and siting of DGs and RTUs in the power distribution grid
Freeman and Chen, 2015 [107]	Supplier selection	Manufacturing	AHP Entropy TOPSIS	To assist the manufacturer on green supplier selection to reduce the cost and environmental risk
Venkateswarlu and Sarma, 2016 [108]	Supplier selection	Manufacturing	SAW VIKOR	To solve the problem that occurs in manufacturing by selecting a suitable supplier
Awasthi *et al.*, 2018 [109]	Supplier selection	Production	fuzzy AHP fuzzy VIKOR	To achieve sustainability in supplier selection by taking the sustainability risks into account
Xu *et al.*, 2016 [110]	Project assessment	Sustainability/Power Grid	TOPSIS Matter Element Extension	Implementing an evaluation model for the power grid and renewable energy resources
You *et al.*, 2017 [111]	Project assessment	Sustainability/Power Grid	BWM TOPSIS	To evaluate the operation of the performance of power grid enterprise
Xu *et al.*, 2017 [112]	Project assessment	Energy Performances	DELPHI VIKOR	To evaluate the service performances of EVS programme conducted in Beijing
C.-N. Wang et al., 2021 [113]	Project Assessment	Renewable Energy Performances	DEA window fuzzy TOPSIS	Assessing the renewable energy capabilities on selected countries

Table 9. The summary of all MCDM methods: advantages, disadvantages and our verdict.

Method	Advantages	Disadvantages	Verdict
AHP	Easy to use and scalable The importance of each element is clarified due to its hierarchical structure Convenient and straightforward	Interdependence amongst elements (criteria and alternatives) Not suitable for problems with too many criteria and levels, which will lead to a lengthy process May show some irregularities in ranking Some important data may be lost due to the use of additive aggregation Increasing the number of alternatives/criteria may lead to inconsistency in pairwise comparison	Suitable for most goals (plan, identify, select and assess) with a small number of criteria, can stand alone depending on the criteria and their hierarchical relations and can be incorporated into GIS for accurate location selection
ANP	Due to its network structure, independence is not required amongst elements The priorities can be improved by feedback, hence improving prediction accuracy	Uncertainty may not be supported Requires software and consumes much time due to its complexity	
ELECTRE	Take uncertainty and vagueness into account Considers both qualitative and quantitative criteria	Complex processing The strength and weakness of alternatives are not directly identified Difficult to understand and time consuming	Suitable for goals requiring selection or assessment, but given that both outranking methods have many variants, one needs to choose a variant wisely. Some variants can stand alone, and others may perform better when hybridised. These variants are often combined with pairwise comparison
PROMETHEE	Deals with both qualitative and quantitative criteria Criteria scores can be expressed in their own unit Easy to use and requires less input	Lacks a clear method for assigning weights. If many criteria and options are available, then DMs may face difficulties in evaluating the results Whenever a new alternative is introduced, a rank reversal problem may arise PROMETHEE also has limited preference function and needs more preference functions or improvement to existing function for better result	
TOPSIS	Has a simple process, hence facilitating its use and programming The number of steps remains the same regardless of the number of attributes Takes an infinite number of criteria and attributes as inputs	Usage of Euclidean distance does not consider the correlation amongst attributes Difficult to weigh and maintain a consistent judgement Does not consider uncertainty in weightings	Mostly used for goals requiring selection or assessment, but cannot stand alone and must be combined with pairwise comparison, fuzzy, GA or other methods that can handle inconsistencies and uncertainties
VIKOR	Has a simple process, hence facilitating its use and programming The number of steps remains the same regardless of the number of attributes Maximises the utility group and minimises the regret group	Performance rating is quantified as a crisp value Crisp data are inadequate for modelling a real-life situation. DMs need to consider imprecise/ambiguous data	

alternative, followed by photovoltaic energy. The DMs gave the highest weights to investment cost, operation and maintenance cost and environmental loss. In another study, GA was combined with TOPSIS to develop a framework that identifies the best way of integrating a demand response programme for the optimal siting and sizing of distributed generations (DGs) and remote terminal units (RTUs) [105]. The reactive power in DGs, along with the adaptive power factor, contributed to minimising power loss and improving the voltage profile.

An extended VIKOR method was introduced in [106] for nuclear power industry supplier selection based on the cloud model. The authors stated that the original VIKOR shows some limitations when used under a linguistic environment that may lead to inaccurate information or some information loss. Therefore, they proposed the extended VIKOR to reduce such uncertainty. With its excellent handling of imprecise information, the cloud variable was used to define the criteria, sub criteria and their uncertain weights. The authors ensured the correctness and advantages of the extended VIKOR by using triangular fuzzy numbers and found that this

approach can efficiently identify the best alternative. In green supplier selection, the AHP-Entropy-TOPSIS model was proposed to help manufacturers reduce environmental risks and production costs and increase their competitiveness [107]. One benefit of AHP-Entropy-TOPSIS is that this model considers both quantitative and qualitative criteria. In the first phase, the key dimensions and criteria for potential suppliers are determined by conducting interviews with the senior management representatives of companies. In the second phase, a two-part questionnaire survey is administered to gather data for calculating subjective criteria weights *via* AHP. In the third phase, supplier preference rankings are obtained using TOPSIS by translating the entropy weight calculations.

The VIKOR method was also widely used in supplier selection, especially in the manufacturing industry, because choosing an appropriate supplier can be considered a complex problem, especially when dealing with fuzzy environments and limited information. Simple Additive Weighting (SAW) was integrated with VIKOR to solve the supplier selection problem in Anatapuram, India, aiming at reducing waste and improving production quality [108]. The linguistic variables for SAW were obtained from the ratings of qualitative criteria using Saaty's scale of pairwise comparison. The involved criteria included performance, financial position, management organisation just-in-time, and technical capability. In the production field, fuzzy theory was integrated into AHP-VIKOR to achieve a sustainable global supplier selection [109]. However, the authors lacked enough quantitative information, thereby driving them to adopt fuzzy theory to address this limitation. The process began by using fuzzy AHP to weight the supplier criteria and ended with rating supplier performance using fuzzy VIKOR based on certain evaluation criteria. The selection involved two stages. The first stage aimed for sustainability and global sourcing by using economic, environmental, social, global risks and quality of relationship as criteria. The second stage extended the evaluation criteria to cover the supplier sustainability risks based on the environmental and social risks identified in the first stage.

A study in Ningxia, China used the entropy weight method, an improved TOPSIS, a matter element extension and a mathematical model to comprehensively evaluate regional power grids and renewable energy power sources [110]. They stated that the traditional TOPSIS only managed to rank the evaluation results and was unable to obtain the evaluation classification. The authors in another study [111] assessed the operation performance of a power grid enterprise by weighing their criteria using a hybrid of the best-worst method (BWM) and TOPSIS. Specifically, they used TOPSIS to rank the performance of the power grid based on three criteria (economy, society and environmental factors) and seven sub-criteria (overall labour productivity, asset-liability ratio, return on equity, power supply reliability rate, time of handling customer complaints, rate of purchasing new energy power generation technologies and SF6 gas emissions). In another study, given the wide usage of electric vehicles across the globe, researchers in Beijing launched an initiative aiming to promote the usage of these vehicles. They employed a VIKOR-based approach to assess and improve service performance in the Electric Vehicle Sharing (EVS) programme [112]. They also used the Delphi method as a survey technique to reach a consensus amongst the participants. The DMs involved included an office worker, a university student, a professor and a project manager from an electric vehicle company. The authors combined several methods, such as DEA window and fuzzy TOPSIS, to assess the capability of 42 countries in producing renewable energy [113]. At the first stage, the DEA window model was used to choose a few potential countries. Afterwards, the variables were well defined, given their potential effects on the DEA process. Amongst the 42 countries identified, only 10 countries with the highest efficiency scores were selected. At the second stage, fuzzy TOPSIS was implemented to rank the 10 selected countries based on five criteria, namely, availability of resources, energy of security, technological infrastructure, economic stability and social acceptance. Triangular fuzzy numbers were used to determine the rating of each alternative and the weight of each criterion. Those countries with the greatest capabilities were the US, Japan and Australia.

The reviewed studies on distance-based methods, including TOPSIS and VIKOR, are summarised in Table **8** and sorted according to their project goals and field of alternatives. None of these studies used the original distance-based method solely and always combined this method with fuzzy combination or with other MCDM approaches.

4. RECOMMENDATIONS AND SUMMARY

Some issues encountered in the implementation of MCDM methods and several recommendations for addressing these issues are presented in this section to generally expose them for assisting our knowledge in choosing the methods for our application. One major issue in pairwise comparison is that adding a new criterion into the AHP model would require DMs to perform the calculation process all over again [107, 114].

The entropy weight method can be implemented to overcome this issue. AHP also requires expert judgment, which often leads to its subjective nature, and DMs may face difficulties in expressing their preference by using the defined ratio scale [72]. Meanwhile, ANP utilises fuzzy numbers and is therefore exposed to the subjective bias of DMs [86]. One way to address this problem is to integrate ANP with any aggregation method, such as TOPSIS, ELECTRE or MAUT. ANP is also a time-consuming and exhaustive approach [80, 85] that requires the use of additional third party software, such as Super Decisions. The importance of each factor or criteria in ANP cannot be measured quantitatively, but implementing SWOT analysis can effectively solve this problem [77].

For outranking and distance-based methods, ELECTRI I is generally preferred over TOPSIS because the former considers both qualitative and quantitative criteria and the latter does not consider the relative importance of the distance from two reference points [38]. However, ELECTRE has a limitation which requires the integration of the fuzzy method to accelerate the process, where DMs can choose or discard the unwanted alternatives with poor criteria [24]. Meanwhile, PROMETHEE has limited preference function and needs more preference functions or improvement to existing function for better result [21]. TOPSIS is also unable to deal with insufficient information; if some criteria cannot be measured

by crisp value but only with a fuzzy number, then the fuzzy method should be adopted [100]. The problem with VIKOR lies in the description of element (criteria/sub-criteria) information under linguistic environment, which can lead to misinformation and poor accuracy. This problem can also be solved by using the fuzzy method [106].

From the literature, we summarise the advantages and disadvantages of all MCDM methods that have been discussed in this paper, together with our verdict in Table **9**.

CONCLUSION

MCDM has been applied in various areas given its role in solving real-world problems in energy, transportation, sustainability, manufacturing and production. This approach significantly reduces the time consumed by DMs in complex DM processes. MCDM approaches can be integrated not only with one another but also with other methods, such as fuzzy, grey sets, machine learning and GIS, which have been explored throughout this paper. A detailed survey on well-known MCDM methods, such as AHP, ANP, ELECTRE, PROMETHEE, TOPSIS and VIKOR, is presented in this paper. The implementation of these methods is crucial in solving complex problems that cannot be addressed *via* straightforward human thinking. However, some methods are incapable of handling problems with insufficient information. Thus, some researchers have integrated MCDM into other methods. Another ongoing issue is that the application of MCDM requires much time and expensive calculations. Future reviews should explore the usage of other MCDM methods, such as MAUT, MAVT, GP and COPRAS, in different fields.

In addition, investigation/review can be made on modifications of the MCDM methods (modified AHP, TOPSIS, ELECTRE, and *etc.*) in the literature for uncertain sets (such as fuzzy set, rough set, soft set, *etc.*) in future studies.

CONSENT FOR PUBLICATION

Not applicable.

STANDARD OF REPORTING

PRISMA guidelines were followed in this study.

FUNDING

This work was supported in part by UNITEN R & D Sdn Bhd through TNB Seed Fund under Grant UTD-RD-20-03.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

ACKNOWLEDGEMENTS

Declared none.

REFERENCES

[1] A. Mardani, A. Jusoh, K.M.D. Nor, Z. Khalifah, N. Zakwan, and A. Valipour, "Multiple criteria decision-making techniques and their applications - A review of the literature from 2000 to 2014", *Economic Research-Ekonomska Istrazivanja,* vol. 28, no. 1, pp. 516-571, 2015. http://dx.doi.org/10.1080/1331677X.2015.1075139

[2] H.C. Lee, and C.T. Chang, "Comparative analysis of MCDM methods for ranking renewable energy sources in Taiwan", *Renew. Sust. Energ Rev.,* vol. 92, pp. 883-896, 2018. http://dx.doi.org/10.1016/j.rser.2018.05.007

[3] M.L. Kamari, H. Isvand, and M.A. Nazari, "Applications of multi-criteria decision-making (MCDM) methods in renewable energy development: A review", *Renew. Energ. Res. Appl.,* vol. 1, no. 1, pp. 47-54, 2019.

[4] H. Zhang, Y. Peng, G. Tian, D. Wang, and P. Xie, "Green material selection for sustainability: A hybrid MCDM approach", *PLoS One,* vol. 12, no. 5, p. e0177578, 2017. http://dx.doi.org/10.1371/journal.pone.0177578 PMID: 28498864

[5] M. Yazdani, P. Chatterjee, E.K. Zavadskas, and S.H. Zolfani, "Integrated QFD-MCDM framework for green supplier selection", *J. Clean. Prod.,* vol. 142, pp. 3728-3740, 2017. http://dx.doi.org/10.1016/j.jclepro.2016.10.095

[6] M. Nassereddine, and H. Eskandari, "An integrated MCDM approach to evaluate public transportation systems in Tehran", *Transp. Res. Part A Policy Pract.,* vol. 106, pp. 427-439, 2017. http://dx.doi.org/10.1016/j.tra.2017.10.013

[7] M. Velasquez, and P. Hester, "An analysis of multi-criteria decision making methods", *Int. J. Operat. Res.,* vol. 10, no. 2, pp. 56-66, 2013.

[8] A. Singh, "Major MCDM Techniques and their application-A Review", *IOSR J. Eng.,* vol. 4, no. 5, pp. 15-25, 2014. http://dx.doi.org/10.9790/3021-04521525

[9] A. Kumar, "A review of multi criteria decision making (MCDM) towards sustainable renewable energy development", *Renew. Sustain. Energy Rev.,* vol. 69, pp. 596-609, 2017. http://dx.doi.org/10.1016/j.rser.2016.11.191

[10] R. Kiani Mavi, N. Zarbakhshnia, and A. Khazraei, "Bus rapid transit (BRT): A simulation and multi criteria decision making (MCDM) approach", *Transport Policy,* vol. 72, pp. 187-197, 2018.

[11] V. Penadés-Plà, T. García-Segura, J. V. Martí, and V. Yepes, "A review of multi-criteria decision-making methods applied to the sustainable bridge design", *Sustainability,* vol. 8, no. 12, 2016. http://dx.doi.org/10.3390/su8121295

[12] J. Kangas, A. Kangas, P. Leskinen, and J. Pykäläinen, "MCDM methods in strategic planning of forestry on state-owned lands in Finland: Applications and experiences", *J. Multi-Criteria Decis. Anal.,* vol. 10, no. 5, pp. 257-271, 2001. http://dx.doi.org/10.1002/mcda.306

[13] J-P. Brans, and B. Mareschal, "Chapter 5 promethee methods", *Multiple Criteria Decision Analysis: State of the Art Surveys,* pp. 163-186, 2005.

[14] C.L. Hwang, and K. Yoon, *Multiple Objective Decision Making - Methods and Applications,* Springer-Verlag Berlin Heidelberg: Berlin, New York, 1981, pp. 58-191.

[15] D. Sabaei, J. Erkoyuncu, and R. Roy, "A review of multi-criteria decision making methods for enhanced maintenance delivery", *Procedia CIRP,* vol. 37, pp. 30-35, 2015. http://dx.doi.org/10.1016/j.procir.2015.08.086

[16] M. Tamiz, D. Jones, and C. Romero, "Goal programming for decision making: An overview of the current state-of-the-art", *Eur. J. Oper. Res.,* vol. 111, no. 3, pp. 569-581, 1998. http://dx.doi.org/10.1016/S0377-2217(97)00317-2

[17] E.C. Özcan, S. Ünlüsoy, and T. Eren, "A combined goal programming – AHP approach supported with TOPSIS for maintenance strategy selection in hydroelectric power plants", *Renew. Sust. Energ. Rev.,* vol. 78, pp. 1410-1423, 2017.

[18] C. Bharathi, D. Rekha, and V. Vijayakumar, "Genetic algorithm based demand side management for smart grid", *Wirel. Pers. Commun.,* vol. 93, no. 2, pp. 481-502, 2017. http://dx.doi.org/10.1007/s11277-017-3959-z

[19] C. Ma, W. Hao, F. Pan, and W. Xiang, "Road screening and distribution route multi-objective robust optimization for hazardous materials based on neural network and genetic algorithm", *PLoS One,* vol. 13, no. 6, p. e0198931, 2018. http://dx.doi.org/10.1371/journal.pone.0198931 PMID: 29927981

[20] P. Aragonés-Beltrán, F. Chaparro-González, J.P. Pastor-Ferrando, and A. Pla-Rubio, "An AHP (Analytic Hierarchy Process)/ANP (Analytic Network Process)-based multi-criteria decision approach for the selection of solar-thermal power plant investment projects", *Energy,* vol. 66, pp. 222-238, 2014. http://dx.doi.org/10.1016/j.energy.2013.12.016

[21] S.G. Kamble, K. Vadirajacharya, and U.V. Patil, "Decision making in distribution system using improved AHP-PROMETHEE method", In: *Proceedings of the International Conference on Computing Methodologies and Communication, ICCMC, Erode, India,* 2017, pp. 279-283. http://dx.doi.org/10.1109/ICCMC.2017.8282691

[22] S. Chakravorty, and S. Ghosh, "Power distribution planning using multi-criteria decision making method", *Int. J. Comput. Electric. Eng.,* vol. 1, no. 5, pp. 596-601, 2009. http://dx.doi.org/10.7763/IJCEE.2009.V1.92

[23] N. Hemmati, M.R. Galankashi, D.M. Imani, and H. Farughi, "Maintenance policy selection: A fuzzy-ANP approach", *J. Manuf. Tech. Manag.,* vol. 29, no. 7, pp. 1253-1268, 2018. http://dx.doi.org/10.1108/JMTM-06-2017-0109

[24] P. Kumar, R.K. Singh, and A. Vaish, "Suppliers' green performance evaluation using fuzzy extended ELECTRE approach", *Clean Technol. Environ. Policy,* vol. 19, no. 3, pp. 809-821, 2017. http://dx.doi.org/10.1007/s10098-016-1268-y

[25] H. Kartal, A. Oztekin, A. Gunasekaran, and F. Cebi, "An integrated decision analytic framework of machine learning with multi-criteria decision making for multi-attribute inventory classification", *Comput. Ind. Eng.,* vol. 101, pp. 599-613, 2016. http://dx.doi.org/10.1016/j.cie.2016.06.004

[26] K. Khosravi, "A comparative assessment of flood susceptibility modeling using multi-criteria decision-making analysis and machine learning methods", *J. Hydrol. (Amst.),* vol. 573, pp. 311-323, 2019. http://dx.doi.org/10.1016/j.jhydrol.2019.03.073

[27] H.Z. Al Garni, and A. Awasthi, "Solar PV power plant site selection using a GIS-AHP based approach with application in Saudi Arabia", *Appl. Energy,* vol. 206, pp. 1225-1240, 2017. http://dx.doi.org/10.1016/j.apenergy.2017.10.024

[28] M.A. Baseer, S. Rehman, J.P. Meyer, and M.M. Alam, "GIS-based site suitability analysis for wind farm development in Saudi Arabia", *Energy,* vol. 141, pp. 1166-1176, 2017. http://dx.doi.org/10.1016/j.energy.2017.10.016

[29] Y. Wu, C. Xu, and T. Zhang, "Evaluation of renewable power sources using a fuzzy MCDM based on cumulative prospect theory: A case in China", *Energy,* vol. 147, pp. 1227-1239, 2018. http://dx.doi.org/10.1016/j.energy.2018.01.115

[30] I. Kaya, M. Çolak, and F. Terzi, "A comprehensive review of fuzzy multi criteria decision making methodologies for energy policy making", *Energy Strategy Rev.,* vol. 24, pp. 207-228, 2019. http://dx.doi.org/10.1016/j.esr.2019.03.003

[31] T.L. Saaty, "Axiomatization of the analytic hierarchy process", *Manage. Sci.,* vol. 32, no. 7, pp. 841-855, 1986. http://dx.doi.org/10.1287/mnsc.32.7.841

[32] T.L. Saaty, "Decision making with the analytic hierarchy process", *Int. J. Serv. Sci.,* vol. 1, no. 1, pp. 83-98, 2008. http://dx.doi.org/10.1504/IJSSCI.2008.017590

[33] K.D. Goepel, "Implementing the analytic hierarchy process as a standard method for multi-criteria decision making in corporate enterprises – a new AHP excel template with multiple inputs", In: *Proceedings of the International Symposium on the Analytic Hierarchy Process,* vol. 2, 2013, pp. 1-10. http://dx.doi.org/10.13033/isahp.y2013.047

[34] E. Mu, and M. Pereyra-Rojas, "Practical decision making", In: *Springer Brief in operations research book series (BRIEFSOPERAT),* 2017, pp. 110-110. http://dx.doi.org/10.1007/978-3-319-33861-3

[35] M.R. Asadabadi, E. Chang, and M. Saberi, "Are MCDM methods useful? A critical review of Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP)", *Cogent Eng.,* vol. 6, no. 1, pp. 1-11, 2019. http://dx.doi.org/10.1080/23311916.2019.1623153

[36] T.L. Saaty, "Fundamentals of the analytic network process", In: *Proceedings of the ISAHP,* 1999, pp. 1-14.

[37] A. Gorener, "Comparing AHP and ANP: An application of strategic decisions making in a manufacturing company", *Int. J. Bus. Soc. Sci.,* vol. 3, no. 11, pp. 194-208, 2012.

[38] M. Agrebi, M. Abed, and M. N. Omri, "ELECTRE I based relevance decision-makers feedback to the location selection of distribution centers", *J. Adv. Transport.,* 2017. http://dx.doi.org/10.1155/2017/7131094

[39] S.A.S.A. Mary, and G. Suganya, "Multi-criteria decision making using ELECTRE", *Circuits Syst.,* vol. 07, no. 6, pp. 1008-1020, 2016. http://dx.doi.org/10.4236/cs.2016.76085

[40] A. Lima, and V.S. Soares, "Multi criteria decision making models: An overview on electre methods. *WORKING PAPERS,* Universidade Portucalense: Portugal, 2011.

[41] V. Mousseau, B. Roy, and U. Paris-dauphine, "Chapter 4 Introduction: A brief history", *Multiple Criteria Decision Anal.,* vol. 78, no. 4, pp. 1-35, 2005.

[42] A.E. Hanandeh, and A. El-zein, "A new stochastic multi-criteria decision analysis tool based on ELECTRE III method", In: *ANZSEE Conference: Re-inventing sustainability: A climate for change,* 2006.

[43] J.M. Sánchez-Lozano, M.S. García-Cascales, and M.T. Lamata, "Comparative TOPSIS-ELECTRE TRI methods for optimal sites for photovoltaic solar farms. Case study in Spain", *J. Cleaner Production,* vol. 127, no. 2016, pp. 387-398, 2016. http://dx.doi.org/10.1016/j.jclepro.2016.04.005

[44] J.P. Brans, P. Vincke, and B. Mareschal, "How to select and how to rank projects: The PROMETHEE method", *Eur. J. Oper. Res.,* vol. 24, pp. 228-238, 1986. http://dx.doi.org/10.1016/0377-2217(86)90044-5

[45] L. Abdullah, W. Chan, and A. Afshari, "Application of PROMETHEE method for green supplier selection: A comparative result based on preference functions", *J. Indust. Eng. Int.,* vol. 15, no. 2, pp. 271-285, 2019. http://dx.doi.org/10.1007/s40092-018-0289-z

[46] V. Balioti, C. Tzimopoulos, and C. Evangelides, "Multi-criteria decision making using TOPSIS method under fuzzy environment. Application in Spillway selection", *Proceedings,* vol. 2, no. 11, pp. 637-637, 2018. http://dx.doi.org/10.3390/proceedings2110637

[47] G. Villacreses, G. Gaona, J. Martínez-Gómez, and D.J. Jijón, "Wind farms suitability location using geographical information system (GIS), based on multi-criteria decision making (MCDM) methods: The case of continental Ecuador", *Renew. Energy,* vol. 109, pp. 275-286, 2017. http://dx.doi.org/10.1016/j.renene.2017.03.041

[48] S. Opricovic, and G.H. Tzeng, "Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS", *Eur. J. Oper. Res.,* vol. 156, pp. 445-455, 2004. http://dx.doi.org/10.1016/S0377-2217(03)00020-1

[49] M. Aruldoss, T. Miranda Lakshmi, and V.P. Venkatesan, "A survey on multi criteria decision making methods and its applications", *American J. Inform. Syst.,* vol. 1, no. 1, pp. 31-43, 2013.

[50] L. Duckstein, and S. Opricovic, "Multiobjective optimization in river basin development", *Water Resour. Res.,* vol. 16, no. 1, pp. 14-20, 1980. http://dx.doi.org/10.1029/WR016i001p00014

[51] A. Mardani, E.K. Zavadskas, K. Govindan, A.A. Senin, and A. Jusoh, "VIKOR technique: A systematic review of the state of the art literature on methodologies and applications", *Sustainability (Switzerland),* vol. 8, no. 1, pp. 1-38, 2016. http://dx.doi.org/10.3390/su8010037

[52] M. Yazdani, and F.R. Graeml, "VIKOR and its Applications", *Int. J. Strateg. Decis. Sci.,* vol. 5, no. 2, pp. 56-83, 2014. http://dx.doi.org/10.4018/ijsds.2014040105

[53] S. Opricovic, "Fuzzy VIKOR with an application to water resources planning", *Expert Syst. Appl.,* vol. 38, no. 10, pp. 12983-12990, 2011. http://dx.doi.org/10.1016/j.eswa.2011.04.097

[54] J.J.H. Liou, C.Y. Tsai, R.H. Lin, and G.H. Tzeng, "A modified VIKOR multiple-criteria decision method for improving domestic airlines service quality", *J. Air Transp. Manage.,* vol. 17, no. 2, pp. 57-61, 2011. http://dx.doi.org/10.1016/j.jairtraman.2010.03.004

[55] A. Jahan, and K.L. Edwards, "VIKOR method for material selection problems with interval numbers and target-based criteria", *Mater. Des.,* vol. 47, pp. 759-765, 2013. http://dx.doi.org/10.1016/j.matdes.2012.12.072

[56] M. Bahraminasab, and A. Jahan, "Material selection for femoral component of total knee replacement using comprehensive VIKOR", *Mater. Des.,* vol. 32, no. 8-9, pp. 4471-4477, 2011. http://dx.doi.org/10.1016/j.matdes.2011.03.046

[57] J.J. Huang, G.H. Tzeng, and H.H. Liu, "A revised vikor model for multiple criteria decision making - The perspective of regret theory", *Commun. Comput. Inf. Sci.,* vol. 35, pp. 761-768, 2009. http://dx.doi.org/10.1007/978-3-642-02298-2_112

[58] P. Chatterjee, and S. Chakraborty, "A comparative analysis of VIKOR method and its variants", *Decision Sci. Lett.,* vol. 5, no. 4, pp. 469-486, 2016. http://dx.doi.org/10.5267/j.dsl.2016.5.004

[59] J.R. San Cristóbal, "Multi-criteria decision-making in the selection of a renewable energy project in spain: The Vikor method", *Renew. Energy,* vol. 36, no. 2, pp. 498-502, 2011. http://dx.doi.org/10.1016/j.renene.2010.07.031

[60] Y.P. Ou Yang, H.M. Shieh, J.D. Leu, and G.H. Tzeng, "A vikor-based multiple criteria decision method for improving information security risk", *Int. J. Inf. Technol. Decis. Mak,* vol. 8, no. 2, pp. 267-287, 2009. http://dx.doi.org/10.1142/S0219622009003375

[61] M.J. Liberatore, and R.L. Nydick, "The analytic hierarchy process in medical and health care decision making: A literature review", *Eur. J. Oper. Res.,* vol. 189, no. 1, pp. 194-207, 2008. http://dx.doi.org/10.1016/j.ejor.2007.05.001

[62] K.K.F. Yuen, "The primitive cognitive network process in healthcare and medical decision making: Comparisons with the analytic hierarchy process", *Appl. Soft Comput. J.,* vol. 14, Part A, pp. 109-119, 2014.

[63] M. Oudah, F. Jabeen, and C. Dixon, "Determinants linked to family business sustainability in the UAE: An AHP approach", *Sustainability,* vol. 10, no. 1, 2018. http://dx.doi.org/10.3390/su10010246

[64] Z.D. Unutmaz Durmuşoğlu, "Assessment of techno-entrepreneurship projects by using Analytical Hierarchy Process (AHP)", *Technol. Soc.,* vol. 54, pp. 41-46, 2018. http://dx.doi.org/10.1016/j.techsoc.2018.02.001

[65] Y. Lee, and K.A. Kozar, "Investigating the effect of website quality on e-business success: An analytic hierarchy process (AHP) approach", *Decis. Support Syst.,* vol. 42, pp. 1383-1401, 2006. http://dx.doi.org/10.1016/j.dss.2005.11.005

[66] K.L. Poh, and B.W. Ang, "Transportation fuels and policy for Singapore: An AHP planning approach", *Comput. Ind. Eng.,* vol. 37, no. 3, pp. 507-525, 1999. http://dx.doi.org/10.1016/S0360-8352(00)00020-6

[67] A. Anderluh, V.C. Hemmelmayr, and D. Rüdiger, "Analytic hierarchy process for city hub location selection-The Viennese case", *Transp. Res. Procedia,* vol. 46, pp. 77-84, 2020. http://dx.doi.org/10.1016/j.trpro.2020.03.166

[68] L.P. Ghimire, and Y. Kim, "An analysis on barriers to renewable energy development in the context of Nepal using AHP", *Renew. Energy,* vol. 129, pp. 446-456, 2018. http://dx.doi.org/10.1016/j.renene.2018.06.011

[69] S. Luthra, S. Kumar, D. Garg, and A. Haleem, "Barriers to renewable/sustainable energy technologies adoption: Indian perspective", *Renew. Sustain. Energy Rev.,* vol. 41, pp. 762-776, 2015. http://dx.doi.org/10.1016/j.rser.2014.08.077

[70] I. Konstantinos, T. Georgios, and A. Garyfalos, "A decision support system methodology for selecting wind farm installation locations using AHP and TOPSIS: Case study in eastern Macedonia and thrace region, Greece", *Energy Policy,* vol. 132, pp. 232-246, 2019.

[71] R.K. Rietz, and S. Suryanarayanan, "A review of the application of analytic hierarchy process to the planning and operation of electric power microgrids", In: *40th North American Power Symposium, NAPS2008,* vol. 80401, 2008, pp. 1-6. http://dx.doi.org/10.1109/NAPS.2008.5307403

[72] A. Datta, A. Ray, D. Mukherjee, and H. Saha, "Selection of islanding detection methods based on multi-criteria decision analysis for grid-connected photovoltaic system applications", *Sustain. Energy Technol. Assess.,* vol. 7, pp. 111-122, 2014. http://dx.doi.org/10.1016/j.seta.2014.04.003

[73] Z. Moravej, and H. Afshar, "Optimal planning of microgrid using multi criteria decision analysis", *Int. J. Multidiciplinary Sci. Eng.,* vol. 5, no. 8, pp. 1-6, 2014.

[74] W.K.M. Brauers, and E.K. Zavadskas, "The MOORA method and its application to privatization in a transition economy", *Control Cybern.,* vol. 35, pp. 445-469, 2006.

[75] W.K.M. Brauers, and E.K. Zavadskas, "Project management by multimoora as an instrument for transition economies / ProjektŲ Vadyba Su Multimoora Kaip PriemonĖ Pereinamojo Laikotarpio Ūkiams", *Technol. Econ. Dev. Econ.,* vol. 16, no. 1, pp. 5-24, 2010. http://dx.doi.org/10.3846/tede.2010.01

[76] E. A. Adalı, and A.T. Işık, "The multi-objective decision making methods based on Multimoora and Moosra for the laptop selection problem", *J. Industrial Eng. Int.,* vol. 13, no. 2, pp. 229-237, 2016. http://dx.doi.org/10.1007/s40092-016-0175-5

[77] B.C. Ervural, S. Zaim, O.F. Demirel, Z. Aydin, and D. Delen, "An ANP and fuzzy TOPSIS-based SWOT analysis for Turkey's energy planning", *Renew. Sust. Energ. Rev.,* vol. 82, pp. 1538-1550, 2018.

[78] H. Tanaka, S. Tsukao, D. Yamashita, T. Niimura, and R. Yokoyama, "Multiple criteria assessment of substation conditions by pairwise comparison of analytic hierarchy process", *IEEE Trans. Power Deliv.,* vol. 25, no. 4, pp. 3017-3023, 2010. http://dx.doi.org/10.1109/TPWRD.2010.2048437

[79] F. Iberraken, R. Medjoudj, and D. Aissani, "*Decision making on smart grids projects moving using AHP method: The case of Algerian network",* IFAC, pp. 543-548, 2013.

[80] Z. Ayag, and F. Samanlioglu, "Analytic Network Process (ANP) for solar power plant location problem", In: *IIE Annual Conference and Expo 2010 Proceedings,* 2010.

[81] T.M. Yeh, and Y.L. Huang, "Factors in determining wind farm location: Integrating GQM, fuzzy DEMATEL, and ANP", *Renew. Energy,* vol. 66, pp. 159-169, 2014. http://dx.doi.org/10.1016/j.renene.2013.12.003

[82] Y.A. Solangi, C. Longsheng, and S.A.A. Shah, "Assessing and overcoming the renewable energy barriers for sustainable development in Pakistan: An integrated AHP and fuzzy TOPSIS approach", *Renew. Energy,* vol. 173, pp. 209-222, 2021. http://dx.doi.org/10.1016/j.renene.2021.03.141

[83] E. Atmaca, and H.B. Basar, "Evaluation of power plants in Turkey using Analytic Network Process (ANP)", *Energy,* vol. 44, no. 1, pp. 555-563, 2012. http://dx.doi.org/10.1016/j.energy.2012.05.046

[84] N. Pang, M. Nan, Q. Meng, and S. Zhao, "Selection of wind turbine based on fuzzy analytic network process: A case study in China", *Sustainability,* vol. 13, no. 4, 2021. http://dx.doi.org/10.3390/su13041792

[85] M. Chand, N. Bhatia, and R.K. Singh, "ANP-MOORA-based approach for the analysis of selected issues of green supply chain management", *Benchmarking (Bradf.),* vol. 25, no. 2, pp. 642-659, 2018. http://dx.doi.org/10.1108/BIJ-11-2016-0177

[86] M. Giannakis, R. Dubey, I. Vlachos, and Y. Ju, "Supplier sustainability performance evaluation using the analytic network process", *J. Clean. Prod.,* vol. 247, pp. 119439-119439, 2020. http://dx.doi.org/10.1016/j.jclepro.2019.119439

[87] S.H. Hashemi, A. Karimi, and M. Tavana, "An integrated green supplier selection approach with analytic network process and improved grey relational analysis", *Int. J. Prod. Econ.,* vol. 159, pp. 178-191, 2015. http://dx.doi.org/10.1016/j.ijpe.2014.09.027

[88] B. Sennaroglu, and G. Varlik Celebi, "A military airport location selection by AHP integrated PROMETHEE and VIKOR methods", *Transp. Res. Part D Transp. Environ.,* vol. 59, no. January, pp. 160-173, 2018. http://dx.doi.org/10.1016/j.trd.2017.12.022

[89] Y. Wu, J. Zhang, J. Yuan, S. Geng, and H. Zhang, "Study of decision framework of offshore wind power station site selection based on ELECTRE-III under intuitionistic fuzzy environment: A case of China", *Energy Convers. Manage.,* vol. 113, pp. 66-81, 2016. http://dx.doi.org/10.1016/j.enconman.2016.01.020

[90] K. Aldrin Wiguna, R. Sarno, and N.F. Ariyani, "Optimization solar farm site selection using multi-criteria decision making fuzzy AHP and PROMETHEE: Case study in Bali", In: *International Conference on Information & Communication Technology and Systems (ICTS), Surabaya, Indonesia,* 2016, pp. 237-243. http://dx.doi.org/10.1109/ICTS.2016.7910305

[91] A. Ahmadi, and D. Herdiawan, "*The implementation of BORDA and PROMETHEE for decision making of Naval base selection",* *Decision Sci. Lett.,* 2021, pp. 129-138.

[92] K. Govindan, D. Kannan, and M. Shankar, "Evaluation of green manufacturing practices using a hybrid MCDM model combining DANP with PROMETHEE", *Int. J. Prod. Res.,* vol. 53, no. 21, pp. 6344-6371, 2014. http://dx.doi.org/10.1080/00207543.2014.898865

[93] C. Yammani, P. Prabhat, and K. Dahal, "Optimal dispatch of Vehicle-to-Grid (V2G) battery storage using p-ELECTRE method and its impact on optimal scheduling of DGs in distribution system", *Electr. Power Compon. Syst.,* vol. 47, no. 14-15, pp. 1362-1374, 2019.
http://dx.doi.org/10.1080/15325008.2019.1666179

[94] Y. Wu, B. Zhang, C. Wu, T. Zhang, and F. Liu, "Optimal site selection for parabolic trough concentrating solar power plant using extended PROMETHEE method: A case in China", *Renew. Energy,* vol. 143, pp. 1910-1927, 2019.
http://dx.doi.org/10.1016/j.renene.2019.05.131

[95] E. Tabaraee, S. Ebrahimnejad, and S. Bamdad, "Evaluation of power plants to prioritise the investment projects using fuzzy PROMETHEE method", *Int. J. Sustain. Energy,* vol. 37, no. 10, pp. 941-955, 2018.
http://dx.doi.org/10.1080/14786451.2017.1366489

[96] H. Li, "Dynamic evaluation of urban sustainability based on ELECTRE: A case study from China", *Discrete Dyn. Nat. Soc.,* vol. 2021, pp. 1-18, 2021.

[97] H. Polatidis, K. Haralambidou, and D. Haralambopoulos, "Multicriteria decision analysis for geothermal energy: A comparison between the ELECTRE III and the PROMETHEE II methods", *Energy Sources B Econ. Plan. Policy,* vol. 10, no. 3, pp. 241-249, 2015.
http://dx.doi.org/10.1080/15567249.2011.565297

[98] L.C. Dias, C.H. Antunes, G. Dantas, N. de Castro, and L. Zamboni, "A multi-criteria approach to sort and rank policies based on Delphi qualitative assessments and ELECTRE TRI: The case of smart grids in Brazil", *Omega (United Kingdom),* vol. 76, pp. 100-111, 2018.
http://dx.doi.org/10.1016/j.omega.2017.04.004

[99] Y. Wu, Y. Wang, K. Chen, C. Xu, and L. Li, "Social sustainability assessment of small hydropower with hesitant PROMETHEE method", *Sustain Cities Soc.,* vol. 35, pp. 522-537, 2017.
http://dx.doi.org/10.1016/j.scs.2017.08.034

[100] S. Guo, and H. Zhao, "Optimal site selection of electric vehicle charging station by using fuzzy TOPSIS based on sustainability perspective", *Appl. Energy,* vol. 158, pp. 390-402, 2015.
http://dx.doi.org/10.1016/j.apenergy.2015.08.082

[101] Y. Wu, B. Zhang, C. Xu, and L. Li, "Site selection decision framework using fuzzy ANP-VIKOR for large commercial rooftop PV system based on sustainability perspective", *Sustain Cities Soc.,* vol. 40, pp. 454-470, 2018.
http://dx.doi.org/10.1016/j.scs.2018.04.024

[102] S. Sindhu, V. Nehra, and S. Luthra, "Investigation of feasibility study of solar farms deployment using hybrid AHP-TOPSIS analysis: Case study of India", *Renew. Sustain. Energy Rev.,* vol. 73, pp. 496-511, 2017.
http://dx.doi.org/10.1016/j.rser.2017.01.135

[103] C.N. Wang, V.T. Nguyen, H.T.N. Thai, and D.H. Duong, "Multi-criteria decision making (MCDM) approaches for solar power plant location selection in Viet Nam", *Energies,* vol. 11, no. 6, 2018.
http://dx.doi.org/10.3390/en11061504

[104] M. Kumar, and C. Samuel, "Selection of best renewable energy source by using VIKOR method", *Technol. Economics Smart Grids Sustainable Energ.,* vol. 2, no. 1, pp. 1-10, 2017.
http://dx.doi.org/10.1007/s40866-017-0024-7

[105] T. Sattarpour, D. Nazarpour, S. Golshannavaz, and P. Siano, "A multi-objective hybrid GA and TOPSIS approach for sizing and siting of DG and RTU in smart distribution grids", *J. Ambient Intell. Humaniz. Comput.,* vol. 9, no. 1, pp. 105-122, 2018.
http://dx.doi.org/10.1007/s12652-016-0418-8

[106] Y. Wu, K. Chen, B. Zeng, H. Xu, and Y. Yang, "Supplier selection in nuclear power industry with extended VIKOR method under linguistic information", *Appl. Soft Comput.,* vol. 48, pp. 444-457, 2016.
http://dx.doi.org/10.1016/j.asoc.2016.07.023

[107] J. Freeman, and T. Chen, "Green supplier selection using an AHP-Entropy-TOPSIS framework", *Supply Chain Manag.,* vol. 20, no. 3, pp. 327-340, 2015.
http://dx.doi.org/10.1108/SCM-04-2014-0142

[108] P. Venkateswarlu, and B. Dattatraya Sarma, "Selection of equipment by using saw and Vikor methods", *J. Engineering Res. Appl.,* vol. 6, no. 111, pp. 2248-962261, 2016. Available from: www.ijera.com

[109] A. Awasthi, K. Govindan, and S. Gold, "Multi-tier sustainable global supplier selection using a fuzzy AHP-VIKOR based approach", *Int. J. Production Econ.,* vol. 195, pp. 106-117, 2018.
http://dx.doi.org/10.1016/j.ijpe.2017.10.013

[110] X. Xu, "Comprehensive evaluation of coordination development for regional power grid and renewable energy power supply based on improved matter element extension and topsis method for sustainability", *Sustainability,* vol. 8, no. 2, 2016.
http://dx.doi.org/10.3390/su8020143

[111] P. You, S. Guo, H. Zhao, and H. Zhao, "Operation performance evaluation of power grid enterprise using a hybrid BWM-TOPSIS met", *Sustainability,* vol. 9, no. 12, pp. 1-15, 2017.

[112] F. Xu, J. Liu, S. Lin, and J. Yuan, "A VIKOR-based approach for assessing the service performance of electric vehicle sharing programs: A case study in Beijing", *J. Clean. Prod.,* vol. 148, pp. 254-267, 2017.
http://dx.doi.org/10.1016/j.jclepro.2017.01.162

[113] C-N. Wang, T-T. Dang, H. Tibo, and D-H. Duong, "Assessing renewable energy production capabilities using DEA window and fuzzy TOPSIS model", *Symmetry (Basel),* vol. 13, no. 2, 2021.
http://dx.doi.org/10.3390/sym13020334

[114] C.E. Shannon, "A mathematical theory of communication", *Bell Syst. Tech. J.,* vol. 27, no. 3, pp. 379-423, 1948.
http://dx.doi.org/10.1002/j.1538-7305.1948.tb01338.x