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A State-of-the-Art Survey on Analytical Hierarchy Process Applications in Sustainable Development

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Abstract
Nowadays, utility of the multi-criteria decision making (MCDM) technique in tackling real-world complex problems has risen tremendously. Even the United Nations is focusing on decision-making in order to accomplish Agenda 2030, as stated in its paragraph 48**.** The desire to promote sustainable development (SD) necessitates complex decision models, which could be achieved through the use of an efficient MCDM approach. Analytical Hierarchy Process (AHP) is one of the most efficient MCDM techniques that is incorporated in this study. The purpose of this work is to provide a contrasting of AHP's application that emerged between 2011 and 2022, rather than to reflect on its methodological improvements. Its application encompasses a wide range of disciplines including Renewable Energy, Sustainable manufacturing, Natural Hazards, Environmental Pollution, Landfill waste management and many others which lies explicitly or implicitly under the theme of SD. Previously, many reviews have been conducted that concentrated on a single decision topic; moreover, this review explore the comprehensive viewpoint of decision problems. As per statistical results, Middle Eastern countries such as Iran placed top in terms of applying AHP application in different sectors. GIS and fuzzy logic are the most often used approaches to incorporate AHP across all disciplines. Notably, the

findings indicate that the most decision problem have selection and assessment as a major concern whereas, environmental, economical, LULC & DFR are more frequently used criteria.

Keywords- Multicriteria decision making, Analytic hierarchy process, Sustainable development, Renewable energy, Sustainable environment.

Abbreviation

MCDM : Multi Criteria Decision Making
AHP : Analytical Hierarchy Process
SD : Sustainable Development
DM : Decision Making
MADM : Multi-Attribute Decision Making
MODM : Multi-Objective Decision Making
MAVT : Multi-Attribute Value Theory
MAUT : Multi-Attribute Utility Theory
SAW : Simple Additive Weighting
ANP : Analytical Network Process
TOPSIS : Technique for Order Preference by Similarity to Ideal Solution
ELECTRE : Elimination and Choice Expressing Reality
PROMETHEE : Preference Ranking Organization Method for Enrichment Evaluation
LP : Linear Programming
SA : Simulating Annealing
TS : Tabu Search
HPSO : Hybrid Particle Swarm Optimization
NSGA : Non dominated sorted Genetic Algorithm
SDG : Sustainable Development Goal
PCM : Pairwise Comparison Matrix
RES : Renewable Energy Source
GIS : Geographic Information System
RET : Renewable Energy Technology
SEB : Social & Economic barriers
TB : Technical barriers
AMB : Administrative & Market barriers
EFB : Economic Financial Barrier
PPB : Political & Policy barriers
MB : Market barriers
IAB : Institutional & Administrative barriers
SCB: Social & Cultural barriers
EB : Ecological/Environmental barrier
SB : Social barrier
GRASP : Greedy Randomized Adaptive Search Procedure
D-models : Dynamic Models
GP : Goal Programming
CP : Compromise Programming
MILP : Mixed Integer Linear Programming
NILP : Non Integer Linear Programming
RE : Renewable Energy
scr : Sub-Criteria

1. Introduction

Decision making (DM) plays a very crucial role in improving the living standards and human life quality. It examines the decision problem and afterwards selects the best alternatives based on a number of criteria. However, perfect decision-making methods remain an elusive goal for complex real-world decision problems. A renounced branch in decision making is referred to as MCDM. In a nutshell, MCDM is a decision-making technique for dealing with numerous competing criteria in decision-making situations. Since 1960, MCDM seems to have been a popular study topic with several theoretical and practical publications and books (Diaz-Balteiro et al., 2017). Zavadskas presents the MCDM technique for ranking journals in civil engineering field based on numerous factors (Zavadskas et al., 2014). Yazdani et al. proposes a novel approach for prioritizing investment strategies in Iran's private sector, which demonstrate that the suggested method has a high degree of capacity to prioritize investment plans (Yazdani-Chamzini et al., 2014). The empirical study of Shyur & Shih shows that how well the technique may be utilized for the problem of strategic vendor selection (Shyur & Shih, 2006). Behzadian has described the different applicability of MCDM (TOPSIS) approaches in numerous disciplines (Behzadian et al., 2012).

MCDM problems are typically composed of five parts: the goal, the decision maker’s preferences, alternatives, criteria, and outcomes. Several methods for improving MCDM have been developed, including the analytic hierarchy process (AHP) (Saaty, 1990b); preference ranking organization method for enrichment evaluations (PROMETHEE) (Brans & Vincke, 1985); elimination and choice corresponding to reality (ELECTRE) (Benayoun et al., 1966; Roy, 1991); Simos' ranking method (Figueira & Roy, 2002); technique for Order preference by similarity to ideal solution (TOPSIS) (Hwang & Yoon, 1981); Vlse Kriterijumska Optimizacija Kompromisno Resenje (which means multicriteria optimization and

compromise solution, in Serbian) (VIKOR) (Opricovic & Tzeng, 2004); multi-attribute utility theory (MAUT) (Edwards et al., 1982). One of the well-established, promising and perhaps the most famous methods of MCDM is analytic hierarchy process (AHP). The earliest mention of AHP we've uncovered is from 1972 (Saaty, 1972; Saaty, 1977).

AHP addresses the subjective and objective components of DM by simplifying complex choice issues to a series of pairwise comparisons and afterwards synthesizing the results. AHP helps in this regard such as resource allocation, selecting best alternatives, planning, resolving conflicting and subjective criteria. A problem is structured in AHP into a hierarchy, starting with the goal, moving on to criteria and sub-criteria, and finally to alternatives, with a relationship analysis between the goal, criteria, and alternatives. AHP is inspired by the earlier mathematical discoveries like use of pair-wise comparison, direct allocation of weights (Thurstone, 1927; Yokoyama, 1921); the 1-9 scale (Fechner, 1860; Stevens, 1957); Hierarchic formulation of criteria (Miller III, 1966; Miller, 1970). The application of AHP can be found almost in every area, including banks (Haghighi et al., 2010; Seçme et al., 2009), university evaluation (Lee, 2010), manufacturing systems (İç & Yurdakul, 2009; Yang et al., 2009), energy selection (Kahraman & Kaya, 2010), operators evaluation (Şen & Çınar, 2010), customer requirement rating (Li et al., 2010; Lin et al., 2010), drugs selection (Vidal et al., 2010), project selection (Amiri, 2010), site selection (Önüt et al., 2010), route planning (Niaraki & Kim, 2009), strategy selection (Chen & Wang, 2010; Li & Li, 2009; Mansar et al., 2009; Wu et al., 2009), technology evaluation (Lai & Tsai, 2009), vendor selection (Chamodrakas et al., 2010; Labib, 2011; Wang & Yang, 2009), warehouse selection (Ho & Emrouznejad, 2009), selection of recycling technique (Hsu et al., 2010), construction method selection (Pan, 2009), firm competence evaluation (Amiri et al., 2009), selection of mining methods (Naghadehi et al., 2009) and assessment of their long-term sustainability (Su et al., 2010). Several other studies such as (Crouch & Ritchie, 2005; Forman & Gass, 2001; Ishizaka & Labib, 2011; Golden et al., 1989; Ho, 2008; Subramanian & Ramanathan, 2012; Saaty & Forman, 2003; Sipahi & Timor, 2010; Vaidya & Kumar, 2006; Vargas, 1990; Zahedi, 1986) tell the success stories of AHP.

SD is a difficult concept to describe since it has diverse meanings in different fields (White, 2013). However, most academics define it as a balance of three factors: environmental, economic, and social. So, in a nutshell, SD is the combination of these three components. SD necessitates complicated decision-making among these three factors, and MCDM approaches aid in resolving this problem (Diaz-Balteiro et al., 2017; Kumar et al., 2017; Shen & Tzeng, 2018). AHP is an excellent MCDM strategy to handle SD decision making. AHP is discovered to be employed alone or in combination with TOPSIS, GIS, and other tools in various research. SD is supported by a wide number of AHP applications. There are a few questions that inevitably emerge: “How extensive have AHP's applications to enable SD been in recent years? What are the most important and emerging themes in AHP as a means of assisting SD?” (Santos et al., 2019). What will be the most popular study subjects in this discipline in the future? To address these questions, the researcher must focus AHP and SD difficulties that have arisen in previous years. This study examines the literature on AHP applications in many emerging fields and may be able to provide answers to all of these queries. In his works, Saaty has attempted to elucidate the different practical applications of AHP (Saaty, 2008; Saaty & Shang, 2011; Saaty, 2013; Saaty et al., 2015; Saaty & De Paola, 2017). As the relevance of SD concerns grows, AHP has established links with RE sources (Ahmad & Tahar, 2014), optimal clean tech selection (Promentilla et al., 2018), Waste-Water management (Challcharoenwattana & Pharino, 2016; Piadeh et al., 2018), Manufacturing practices that are environmentally friendly (Darmawan et al., 2018; Gupta et al., 2015; Jiang et al., 2011; Kolotzek et al., 2018; Singla et al., 2018), long-term demand and supply (Mangla et al., 2017), investment strategies (Gottfried et al., 2018), and others.

The present review includes the brief discussion on the application of AHP in different areas which explicitly or implicitly lie under the theme of SD. Those areas are: renewable energy; assessment of natural hazard; environment pollution; health care and ecotourism site selection. Research gaps and potential research directions are also revealed, so that the community of researchers can explore the new dimension of multi criteria decision making to support SD. The remainder of this work is structured as follows. Section 2 highlights the theoretical background of AHP. In section 3, the search methodology for this review article is presented. Section 4 provides a comprehensive review followed by results & discussion of AHP applications in various fields. Potential research directions and Final thoughts are discussed in Section 5 and Section 6 respectively.

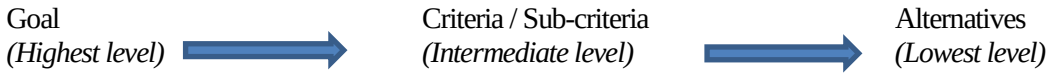
2. Theoretical Background of AHP

AHP was coined by Thomas Saaty in his seminal work in 1977 (Saaty, 1977). This method became quite popular since then among the research community due to its simplicity and strong mathematical approach to address complicated judgment problems with conflicting criteria like selection, investment, evaluation & ranking etc. (Saaty, 1986; Saaty, 1987; Saaty, 1990a; Saaty, 2003; Saaty, 2006; Saaty, 2008). AHP is based on the pairwise comparisons of criteria. Pairwise comparison between the two alternatives is measured by using a numerical scale, which was proposed by Saaty (Saaty, 1977) which highlights the relevance of the ith criteria in relation to the jth criteria. A Saaty's scale can be defined mathematically as a function f which establish one to one correspondence between the cartesian product of the two sets (i.e. the cartesian product $A \times A$ of the set of alternatives A) and the subset of the rational numbers

$$S = \left\{\frac{1}{9}, \frac{1}{8}, \frac{1}{7}, \frac{1}{6}, \frac{1}{5}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, 1, 2, 3, 4, 5, 6, 7, 8, 9\right\}. \quad \text{i.e.} \quad f: A \times A \to S.$$

There are many alternative scales such as combination of verbal and geometric scales (Ji & Jiang, 2003), Root square scale (Harker & Vargas, 1987), Power scale (Harker & Vargas, 1987), Balanced scale (Salo & Hämäläinen, 1997), Geometric scale (Lootsma, 1989), Asymptotical scale (Dodd & Donegan, 1995), Logarithmic scale (Ishizaka et al., 2011), Millet and Schoner (Millet & Schoner, 2005) developed a scale with negative numerical values. However, Linear scale (Saaty, 1977) using integers (1-9) and their reciprocals have been utilised the most frequently in applications. Saaty mentioned in his paper (Saaty, 1980) that the optimum scale to depict weight ratio is the linear scale, that's why it is frequently referred to as the Saaty (1-9) scale.

AHP consists of following four phases (Saaty, 1988) in most of the cases:
(i) Actual problem modelling,
(ii) Hierarchy structuring



The pairwise comparisons at each level are mathematically represented by pairwise comparison matrix (PCM).

(iii) Weight evaluation is carried out by decision maker or expert for construction of a PCM for each upper-level element that is compared to a lower-level element.

(iv) Take the PCM priorities and weight them according to each element, then aggregate the results to create a global priority. Continue the weighting and aggregation procedure until the ultimate priority of the alternative is determined.

It is relatively simple to choose between two alternatives, but when the decision maker is faced with a huge number of alternatives, it is likely to be difficult. As a result, pairwise comparisons play an important role in dealing with this situation. In this case, the decision maker considers only two alternatives at a time so that he may break down the main problem into numerous smaller sub-problems and deal with them. If there is a transitivity rule for all comparisons, a matrix A is said to be consistent. The main advantage of AHP is that it permits inconsistency in the judgements, which can be further measured and helps decision-makers to revise his judgements (Pant et al., 2022).

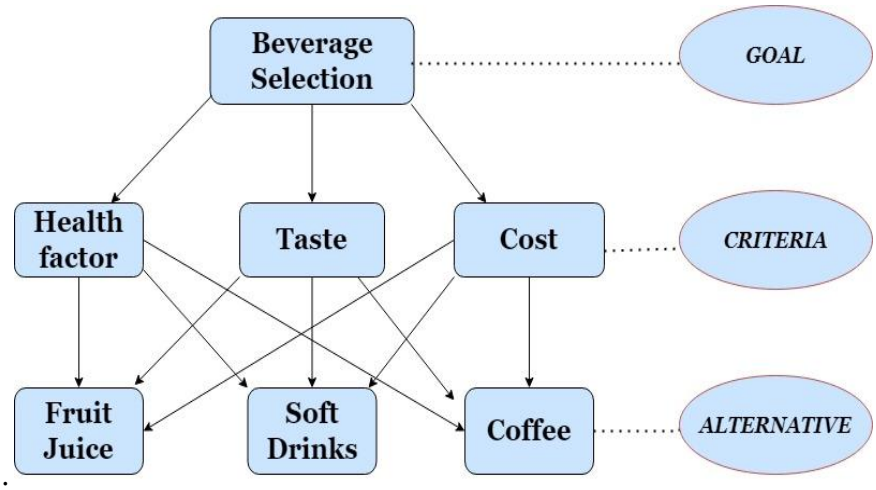


Figure 1. Hierarchy structuring of a decision problem.

For example, if a person prefers fruit juice to drink two times than coffee and coffee three times than soft drinks, then the same person may create the connection between juice and soft drinks using the transitivity rule, i.e., he/she prefer juices to drink six times than soft drink, so if all elements of a PCM follow the same rule then matrix is said to be consistent.

Criteria help decision maker to fill initial entries of PCM, and later entries can be obtained by using transitivity and reciprocity. Criteria are traits that make one alternative better to another in terms of achieving specific goals. In the case of beverage selection, the list of criteria may be health factor (C_1), taste (C_2) and the price (C_3). Let C be the set of these three criteria i.e.,

$$C = \{\text{Health factor}, \text{Taste}, \text{Price}\} = \{C_1, C_2, C_3\}.$$

As a result, a hierarchy may be created at this stage to represent the alternatives, criteria, and goal in a single frame, allowing the problem to be organized in an intuitive manner. The structure of the problem is presented in Figure 1. Furthermore, we can achieve specific goals by applying following steps:

STEP-1 **Formation of PCM** $\boldsymbol{A = [a_{ij}]}$	**STEP-2** **Evaluation of Normalised PCM** $\boldsymbol{\overline{A} = [\overline{a_{ij}}]}$	**STEP-3** **Evaluation of normalised Eigen vector** $\boldsymbol{W = [w_1, w_2, w_3]^T}$	**STEP-4** **Evaluation of Principal Eigen value**	**STEP-5** **Consistency Ratio (CR)**
$A = \begin{bmatrix} 1 & a_{12} & a_{13} \\ \frac{1}{a_{12}} & 1 & a_{23} \\ \frac{1}{a_{13}} & \frac{1}{a_{23}} & 1 \end{bmatrix}$ where, $a_{12}, a_{13}, a_{23} \in S$	$A = \begin{bmatrix} \overline{a_{11}} & \overline{a_{12}} & \overline{a_{13}} \\ \overline{a_{21}} & \overline{a_{22}} & \overline{a_{23}} \\ \overline{a_{31}} & \overline{a_{32}} & \overline{a_{33}} \end{bmatrix}$ $\overline{a_{ij}} = \frac{a_{ij}}{\sum_{k=1}^{3} a_{kj}}$	$w_i = \frac{\sum_{k=1}^{3} \overline{a_{ik}}}{3}$	$\lambda_{max} = \sum_{j=1}^{3} \left(\sum_{i=1}^{3} \overline{a_{ij}} \right) w_j$	$CR = \frac{CI}{RI}$ where, $CI = \frac{(\lambda_{max} - n)}{n-1}$ and RI is random index.

3. Search Methodology

In order to increase knowledge of the application of AHP in various field, a critical literature review required for that a certain methodology adopted to find suitable relevant articles. Articles have been searched in the academic databases Science Direct and Web of Science (WoS). In addition to that google scholar and UPES Library utilized as a significant search engine. Following combination of keyword utilized for searching articles through mentioned search engines: AHP + sustainability + Renewable Energy, AHP + sustainability + Environment, AHP + sustainable manufacturing, AHP + natural hazard + management + sustainable development, AHP + Industrial Pollution + Hospital Pollution + sustainable development, AHP + Ecotourism + sustainable development, AHP + Medical field + sustainable development.

All of the articles in this collection have been published between 2011 and 2022. Figure 3 depicts the research methodology. Following the extraction and filtering of data from the aforementioned sources, a total of 100 published publications were deemed appropriate and adequate for systematic literature review (see Figure 2). However, not all papers were utilized just by stating AHP in the abstract; instead, papers that employed AHP as a major or secondary tool, either alone or in combination with other techniques, were considered.

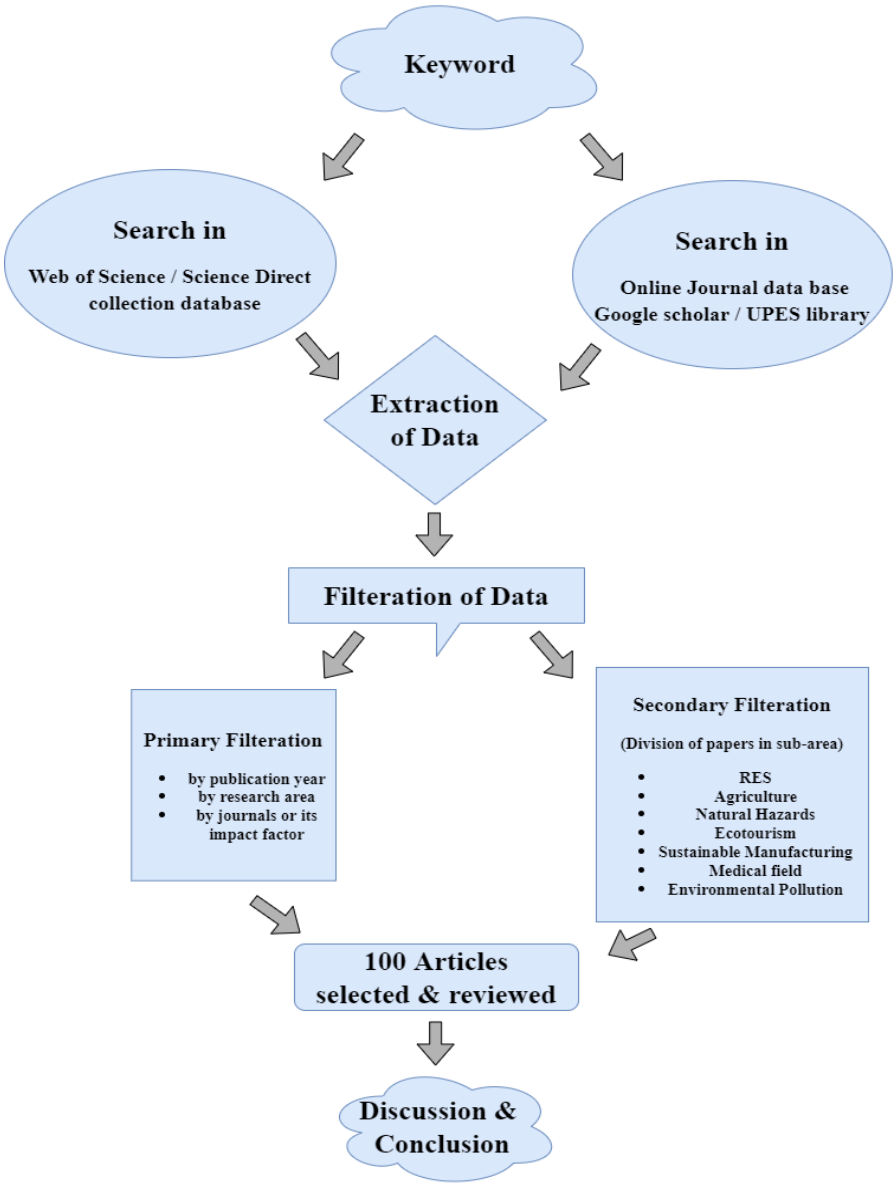


Figure 2. Search methodology.

4. Result and Discussion

Last AHP, being the most widely used MCDM approach, draws decision makers' attention due to its diverse applications and enormous literature (Podvezko, 2009). Amos darko (Darko et al., 2019) has focused extensively on the use of AHP in construction management, finding that risk management and sustainable manufacturing are the most prominent AHP application areas in construction management. Therefore, to understand the decision problems of real life, AHP recent application need to be more addressed. All identified papers that provide a fast reference guide and suitable information about the application of AHP are listed in the Table (1), (2), (3), (4), (5). The table was created using data gathered from a peer-reviewed study. Under the decision area, articles are grouped according to similar decision problem theme (e.g.

suitable site selection for RE source). A single decision area is allocated to each article, however some papers have numerous decision areas (e.g. Saha et al., 2019 paper address both environmental hazard & agriculture issue). All table consisting five columns provides information regarding the author, year of publication, major focus area, number of criteria/sub-criteria employed, and techniques used in the study. In terms of geographical origin, the nations in the south west of Asia (mainly Iran and Turkey) accepted the most AHP-based papers, as indicated in Figure 3 and Figure 4. Although developing nations such as India and others have achieved significant progress in the field of AHP-based applications, they still have significant chance to perform more research. In terms of publication growth, Figure 5 demonstrates that interest in the AHP fluctuates from 2010 to 2017, but afterwards steadily increases, with a curve that approximates 2022 as a leading publication year.

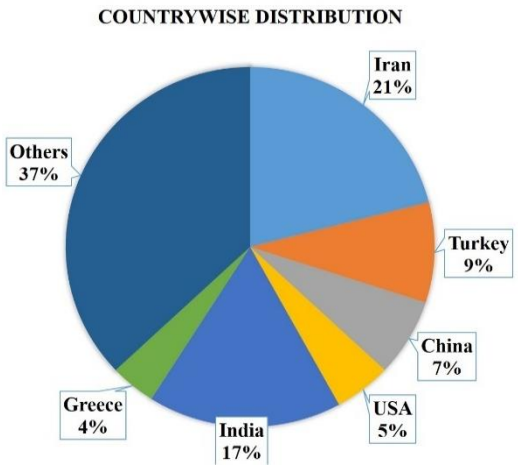


Figure 3. Country wise distribution of published papers.

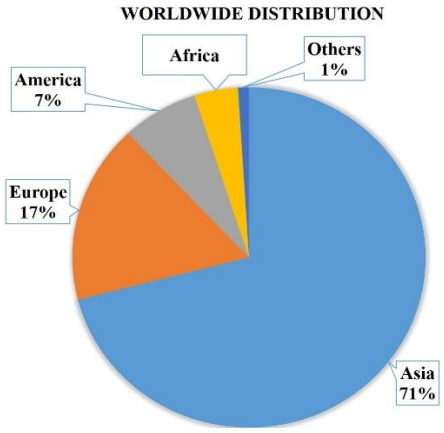


Figure 4. World wise distribution of published papers.

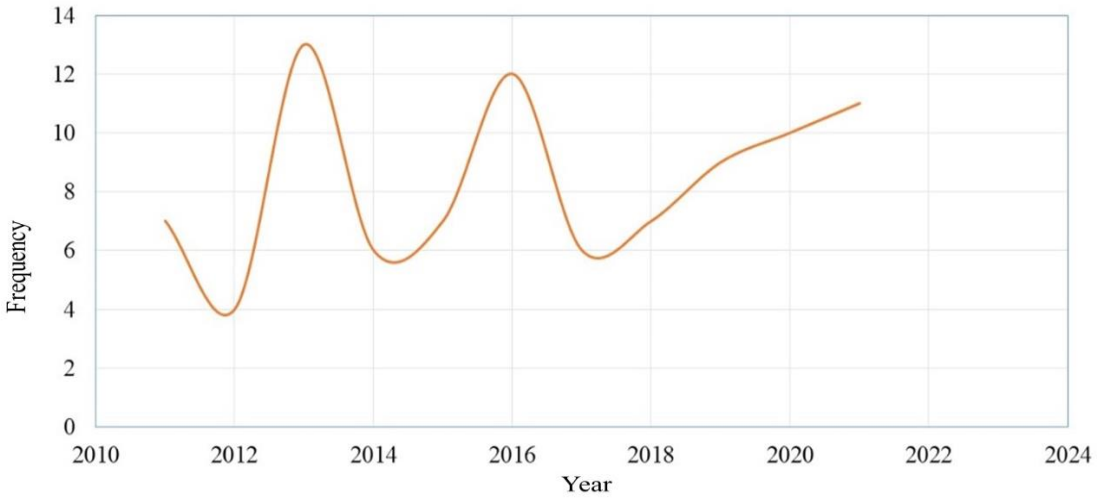


Figure 5. Year wise distribution of selected papers.

4.1 AHP Studies on RE Source

Energy is essential for human survival, yet the current situation shows that energy resources have negative environmental implications. Renewable energy as a solution is gaining traction as a long-term, cost-effective, and environmentally benign source of energy (Diakoulaki & Karangelis, 2007). Using the RE is a multi-faceted DM process that considers a variety of factors at several levels. By connecting all the alternative and criteria that impact DM together, MCDM looks to be a good tool for combining and assessing all views engaged in the DM process of RE. Through a review of chosen literature, this study explores and emphasizes the application range and expansion of the most often used MCDM method i.e., AHP in RE analysis. A classification of author name, year, main focus of study, criterion, and technique used is provided to emphasize the research of decision making in RE. The application field of AHP in RE was divided into four groups: barriers to RE deployment and policy, RE project site selection, appropriate RE deployment and evaluation in various locations, and investment assessment in RE projects. Pohekar & Ramachandran (2004) offered articles on MCDM in his review study, with an emphasis on RE application. A comprehensive literature evaluation on the MCDM approach for energy selection & its relevance to energy concern was undertaken by Wang et al. (2009). Table 1 provide further information regarding literature review carried in area of RE.

Table 1. Literature reviews on RE source.

Decision Problem: Barrier Analysis in RE Source					
Reference	**Decision area**	**Major focus**	**Study origin**	**Criteria considered**	**Techniques used**
Pathak et al. (2022)	Evaluation	Evaluation and identification of barriers to the development of RE Technology depending on the severity of their impact.	India	Economic barrier (EB), Political barrier (PB), Technical barrier (TB), Market barrier (MB)	AHP, Delphi method
Solangi et al. (2021)	Prioritization	Providing general idea about creating a methodology for prioritizing the most critical RE Barriers, which will assist the government and policymakers in designing efficacious policies to address this multifaceted problem.	Pakistan	EB, Ecological / Environmental barrier (EEB), PB, Institutional barrier (IB), MB, Socio-Cultural barrier (SCB), TB	Integrated AHP, Fuzzy TOPSIS
Bukari et al. (2021)	Selection	The focus of this study is to hasten the deployment of decentralized RE mini-grids in Ghana	Ghana	PB, SCB, TB, EB, EEB	AHP
Karatayev et al. (2016)	Selection	Identification of most significant barriers to RE adoption in Kazakhstan's power industry	Kazakhstan	MB (3 s.cr), SCB (3 s.cr), EB (4 s.cr), IB (3 s.cr), TB (4 s.cr)	AHP
Luthra et al. (2015)	Prioritization	Examine the priority ordering stability of barriers to the adoption of renewable/sustainable technology.	India	EB (5 s.cr), MB (4 s.cr), Information & Awareness (3 s.cr), TB (7 s.cr), EEB (3 s.cr), SCB (3 s.cr), PB (3 s.cr)	AHP
Shah et al. (2019)	Prioritization	The current study attributes a systematic approach for prioritizing barriers to cleaner energy technology adoption in Pakistan based on their relevance.	Pakistan	PB (5 s.cr), Social (5 s.cr), MB (5 s.cr), TB (5 s.cr), IB (2 s.cr)	FAHP, Modified Delphi
Punia Sindhu et al. (2016)	Selection / prioritization	Identify and prioritize the obstacles that stand in the way of solar power's growth in India.	India	IB (6 s.cr), high cost capital (4 s.cr), TB (6 s.cr), EB (4 s.cr), SCB (4 s.cr), PB (6 s.cr), MB (6 s.cr)	AHP

Table 1 continued…

Decision Problem: Risk Assessment of RES					
Zhou & Yang (2020)	Assessment	Assessing risk over the life cycle of dispersed wind farms	china	Political risk, technical risk, economic risk, and social risk	AHP
Vidal et al. (2011)	Assessment	The general goal of this work is to measure complexity of project including RE.	France	Project size (1 s.cr), Project context-dependence (3 s.cr), Project variety (3 s.cr), Project Interdependence (10 s.cr)	Delphi Process, AHP
Redfoot et al. (2022)	Assessment / management	In this study, the risk assessment and management approach will be applied to a nuclear renewable hybrid energy system (NRHES)	France	Safety, Profitability, & Flexible operation	FAHP
Decision Problem: Site selection of RES					
Díaz et al. (2022)	Selection	Investigate the best suitable offshore wind farm location for turbine deployment.	Spain	23 criteria divided into six groups, facilities, viability, marine environment, logistics, techno-economic, met ocean	Monte-Carlo simulation, FAHP
Rios & Duarte (2021)	Selection	Using a hybrid of MCDM and GIS to discover potential locations for large Scale solar PV projects.	Peru	Solar irradiance (SI), Land Use/ Land Cover (LULC), Slope (SL), Distance from Roads (DFL), Slope Orientation, Distance to Transmission lines (DTL), Distance from Urban Areas (DFU)	AHP, GIS (geographic information systems)
Agyekum et al. (2021)	Selection	Developing a new strategy of choosing suitable areas for the construction of solar farm.	Ghana	Energy availability, Transportation network expansion, Transmission network expansion, Terrain ruggedness	AHP, Density based Clustering DBC, GIS
Waewsak et al. (2020)	Evaluation	Examine prospective locations for small – scale RE based power plant.	Thailand	Environmental (climate, LULC, Protection Buffers), Socio-Economic (Topography, Locations, Land Procurement, Residential buffer)	AHP, GIS
Xu et al. (2020)	Selection	Site selection for windfarms.	China	Wind speed (WS), DFR, DTL, SL, DFU, Protected bird areas	Interval AHP, Stochastic VIKOR, GIS
Colak et al. (2020)	Selection	Locating the ideal location for a solar PV power station.	Turkey	LULC, gas line, residential areas, Dams & rivers location, Distance from fault (DFF), DTL, SL, DFR, transformer center, aspect and solar energy potential	AHP, GIS
Shorabeh et al. (2019)	Selection	Developing a strategic decision analysis to choose a suitable location for the installation of a solar power project, taking risk factors into account.	Iran	Rainfall (RF), DFU, DFR, Normalized difference vegetation Index (NDVI), SL, Dust, SI, surface temperature, DFF, Sunshine	AHP, OWA, GIS
Moradi et al. (2020)	Evaluation	Estimating wind energy resources in through multi-criteria decision support system.	Iran	Ecological/Environmental (ENV) (5 s.cr), Structural (7 s.cr), Topographical (3 s.cr)	AHP, ArcGIS
Al Garni & Awasthi (2017)	Assessment / selection	Assess and locate the best place for utility-scale solar PV installations.	Saudi Arabia	ENV (2 s.cr), Climatic (2 s.cr), Location (8 s.cr), Orography (3 s.cr), Economic (ECO) (2 s.cr)	GIS, AHP, LSI (land suitability index)
Latinopoulos & Kechagia (2015)	Selection	The current article develops and executes an integrated evaluation system for choosing the most suitable locations for wind-farm development projects.	Greece	SL, WS, DFR, Distance from specific sites, LULC, Natura 2000 regions' distance	MCDA, AHP, GIS
Al-Yahyai et al. (2012)	Selection	This study used a MCDM technique to generate a wind farm site suitability index.	Oman	Wind power density, Urban Sand, Wind occurrence >=5 & >=20, DFR, Peak hour matching, Intensity of Turbulence	AHP-OWA, LSI, GIS

Table 1 continued…

Höfer et al. (2016)	Selection	Site selection for wind farms.	Germany	Techno-economic, ENV, Socio-economic	GIS-AHP
Asakereh et al. (2017)	Selection/ prioritization	This study was carried out to determine which area in Iran's Khuzestan province should be prioritised for solar photovoltaic farms	Iran	ENV, Technical (TEC) and ECO	GIS, Fuzzy logic, AHP
Uyan (2013)	Selection	Choosing the best location for solar farms in the Karapinar area of Konya.	Turkey	DFU, DTL, LULC, SL, DFR	AHP, GIS
Noorollahi et al. (2022)	Selection	The purpose of this research is to find and assess the possibility of a photovoltaic solar power plant in Khuzestan province	Iran	DTL, Sunshine time, LULC, air temperature, SL, DFR, relative humidity, DFU, distance to villages & substations, SI, orientation, WS, and altitude	Fuzzy Boolean logic, AHP, GIS
Decision Problems: Suitable selection & analysis of RES					
Çolak & Kaya (2017)	Selection	Identifying the most suitable renewable energy source.	Turkey	ENV (5 s.cr), ECO (6 s.cr), Quality of energy source (3 s.cr), TEC (5 s.cr), Socio-political (4 s.cr), Technological (TECH) (6 s.cr)	Fuzzy AHP, Hesitant fuzzy TOPSIS
Ali et al. (2020)	Selection	The current study is to determine the best RETs for Rohingya refugees, including solar-wind hybrid energy systems, solar mini-grids, and wind mini-grids.	Banglad esh	TEC, ECO, ENV and socio-political	AHP, Combinative Distance-based Assessment (CODAS)
Ertay et al. (2013)	Assessment	Assessing RES as a crucial means of addressing energy-related issues.	Turkey	TECH (5 s.cr), ECO (3 s.cr), Socio-Political (4 s.cr), ENV (3 s.cr)	Fuzzy AHP, MACBETH software (Measuring Attractiveness by a Categorical Based Evaluation Technique)
Ahmad & Tahar (2014)	Selection	Selection of RES for power production system's with long-term development.	Malaysia	TEC (3 s.cr), ENV (3 s.cr), ECO (4 s.cr), Social (2 s.cr)	AHP
Wang et al. (2020)	Selection	Pakistan's strategic RE resource selection	Pakistan	ECO (5 s.cr), socio-political (4 s.cr), ENV (3 s.cr), TEC (5 s.cr)	Fuzzy AHP
Mourmouris & Potolias (2013)	Selection	The study's ultimate goal is to determine the best quantity of each renewable energy source that may be generated in the Thassos area of Greece, in order to contribute to an optimal energy balance.	Greece	ENV, ECO & Social, TEC & TECH	MCDA, AHP
Singh & Nachtnebel (2016)	Assessment	Examine the implementation of hydropower projects in Nepal during the last several decades and give recommendations for the optimal scale of growth.	Nepal	Political (5 s.cr), TEC (5 s.cr), ECO (18 s.cr), Social (5 s.cr), ENV (5 s.cr),	AHP
Kheybari et al. (2019)	Assessment	Examine biomass-to-biofuel conversion technology.	Iran	TEC category (9 cr), ECO category (5 cr), ENV category (5 cr), Social category (3 cr)	AHP
Tian et al. (2013)	Evaluation/ assessment	This report outlines a comprehensive approach for determining the long-term viability of coastal beach exploitation	China	Wind energy capacity, electromagnetic radiation, land resource capacity, visual pollution, power grid capacity, noise pollution, air environment quality, birds, water environment quality, plant coverage, sound environment quality, biodiversity, net income, recreation value	AHP

Table 1 continued…

Decision Problem: Investment Analysis of RES					
Karatop et al. (2021)	Evaluation/ selection	Figure out how to make the best investment decisions in renewable energy sector.	Turkey	Cost (3 s.cr), TEC (3 s.cr), Political (3 s.cr), ENV (9 s.cr), Constructional/Management (11 s.cr)	Fuzzy AHP, (EDAS) Evaluation Based on Distance from Average Solution method
Aragonés-Beltrán et al. (2014)	Evaluation/ assessment	This research will help companies identify whether or not to invest in a particular solar thermal power plant project.	Spain	Risk (6 s.cr), Cost(1 s.cr), Opportunity (4 s.cr),	AHP, ANP

Based on the Table 1, it seems to be that economic criteria are employed in more studies, demonstrating their importance. Afterward, technical, environmental, and socio-political aspects become more significant in the RE sector. Somewhere in dilemma of selection, evaluation, management or assessment of RES, these criteria must be taken into account. Figure 6 provides a more illustration.

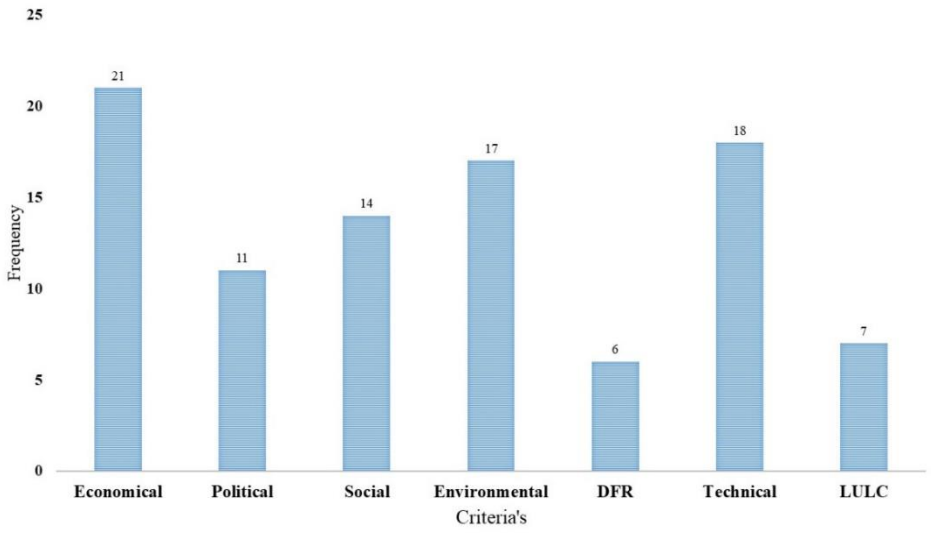


Figure 6. Frequency distribution of important criteria involved in RES.

4.2 AHP Studies Related to Assessment of Various Hazard

Multi-meteorological events such as floods, wildfires, landslides, earthquakes, avalanches, storms, and temperature variations are the most common natural catastrophes in the earth, and responsible for major loss (both living and non-living), as well as affecting social and economic structures (Luber et al., 2014; Kourgialas & Karatzas, 2011; McMichael et al., 2003). Several research have been done in attempt to determine the key element which is responsible for the severity of natural calamities (Kourgialas & Karatzas, 2017; Woldesenbet et al., 2018; Xiao et al., 2017; Udin et al., 2018). Depending on the data available, a various number of methodologies utilized to integrate different criteria for the forecasting & prevention of various hazards. In this context, the MCDM technique has been employed, notably in natural hazards for integrating, detecting, or assessing regulating elements (Al-shabeeb, 2016; Anand et al., 2018; Bradford & Denich, 2007; Chowdhury et al., 2010; Kourgialas & Karatzas, 2016; Jajarmizadeh et al., 2016; Jozaghi et al., 2018; Nefeslioglu et al., 2013; Neale & Weir, 2015; Sinha et al., 2008; Tehrany et al., 2013).

This study focuses on the use of the renounced MCDM technique one and only AHP, which seeks to address all aspects of natural hazards, such as assessment and identification of susceptible zones, through a review of picked literature. Table 2 provide the literature review done in assessment of various hazards.

Table 2. Literature review on various hazards.

Decision Problem: Disaster management					
Reference	**Decision area**	**Measure focus**	**Country origin**	**Criteria considered**	**Technique used**
Kazakis et al. (2015)	Selection	The major goal of this research is to provide a mechanism for identifying flood-prone zones that may be used in diverse places.	Greece	Flow accumulation, Geology, Distance from river / stream / drainage (DFS), SL, Elevation, Rainfall intensity, LULC	GIS, AHP
Kayastha et al. (2013)	Assessment	Mapping the Tinau watershed's susceptibile landslides zone.	Nepal	Slope aspect, Distance from syncline folds, slope angle, slope shape, DFF, Relative Relief, Annual rainfall, DFS, Geology, distance from anticline folds	AHP, GIS
Pourghasemi et al. (2012)	Selection / assessment	In this work, Identification of Iran's Haraz Mountains landslide-prone locations done.	Iran	Slope degree, Topographic witness Index (TWI), Aspect, slope length, altitude, stream power index (SPI), plan curvature, DFF, Lithology, DFR, LULC, DFS	Fuzzy-AHP
Yalcin et al. (2011)	Evaluation	The goal of this study was to estimate the susceptibility of landslides in Trabzon province, which is located in north-east Turkey.	Turkey	Lithology, DFR, elevation, SL, aspect, DFS, LULC	AHP, GIS
Ouma & Tateishi (2014)	Evaluation / assessment	The goal of this research is to provide expertise in the preparation of public-based flood mapping and the estimation of flood hazards in rapidly increasing metropolitan regions	Kenya	Rainfall, LULC, DFS, Soil, Elevation, SL	GIS, AHP
Pourghasemi et al. (2013)	Assessment	The current research presents a comprehensive landslide hazard mapping analysis.	Iran	Slope degree, slope length (LS), slope aspect, SPI, altitude, DFF, plan curvature, DFR, difference vegetation index (DVI), DFS, LULC, lithology	Binary logistic regression (BLR), AHP, Statistical Index (SI)
Das (2019)	Assessment	The current study uses AHP to analyze flood mapping in the Ulhas River in India, as well as hydro-geomorphic responses to floods using geospatial analysis.	India	Elevation, curvature of topography, SL, TWI, geomorphology, SPI, DFS, geology, rainfall, flow accumulation	AHP, GIS
Panchal & Shrivastava (2022)	Assessment	Creating a landslide threat map across National Highway 5 (from 197.600 to 283.200 km).	India	Drainage density, SL, lithology, aspect, DFR, curvature, relative relief, geology, TWI, fault density	AHP, WLC (weighted linear combination)
Yariyan et al. (2020)	Assessment	assess and analyze the earthquake susceptibility zones	Iran	physical criteria, demographic, environmental	Fuzzy-AHP, ANN (Artificial Neural Network)
Toosi et al. (2019)	Selection/ assessment	The approach proposed in this research was used to classify probable flood dangers at the river basin phase in north-east Iran	Iran	Run-off coefficient, LULC, elevation, soil erosion, SL, rainfall intensity, DFS	AHP
Han et al. (2021)	Assessment	The study's main objective is to conduct a thorough assessment of transmission lines that have been impacted by many meteorological disasters.	China	Lightning, Pollution, Ice, Wind	AHP

Table 2 continued…

Rahmati et al. (2016)	Selection/assessment	compare the findings of a hydraulic model with AHP to identify probable flood hazard zones in the Yasooj area of Iran	Iran	DFR, elevation, land-slope, LULC	AHP, GIS
Jabbari et al. (2021)	Assessment	analyze the high risk of fire, explosion, and hazardous gas leakage in pipes from the sour gas pipeline	Iran	Highly desirable, highly undesirable, favorable, unfavorable, moderate	FAHP
(Stefanidis & Stathis (2013)	Assessment	Flood risk assessment in the Northern Peninsular region of Greece	Greece	LULC, density of hydrographic network, rock erodibility, watershed shape, watershed slope, rock permeability, mainstream slope, encroachments, Shaped cross-section at the plain area of the stream, Inadequate technical works	AHP
Ghorbanzadeh et al. (2018)	Assessment	Using the IPCM (Interval Pairwise Comparison Matrix) approach to optimize PCM in the AHP method for land erosion susceptibility mapping	Iran	LULC, geology, rainfall, DFS, DEM, DFF, distance to aqueduct, depth of groundwater, SL, land capability, distance to well	AHP, GIS
Saha et al. (2019)	Selection	In an agricultural watershed in India's Burdwan region, mathematical modelling were used to identify soil erosion-prone zones.	India	Sediment transportation index (STI), SL, geomorphology, DFF, annual mean rainfall, DFS, NDVI, Elevation, Overland flow, SPI, soil, aspect, LULC, TWI, rainfall Erosivity index (REI)	AHP, Fuzzy logic

When it comes to landslide or flood hazard susceptibility zone, slope, DFS, LULC, elevation, and rainfall found found to be the most hazardous criteria. Figure 7 shows some additional sensitive hazardous criteria, like TWI, that need to be more focused in order to avoid future disasters.

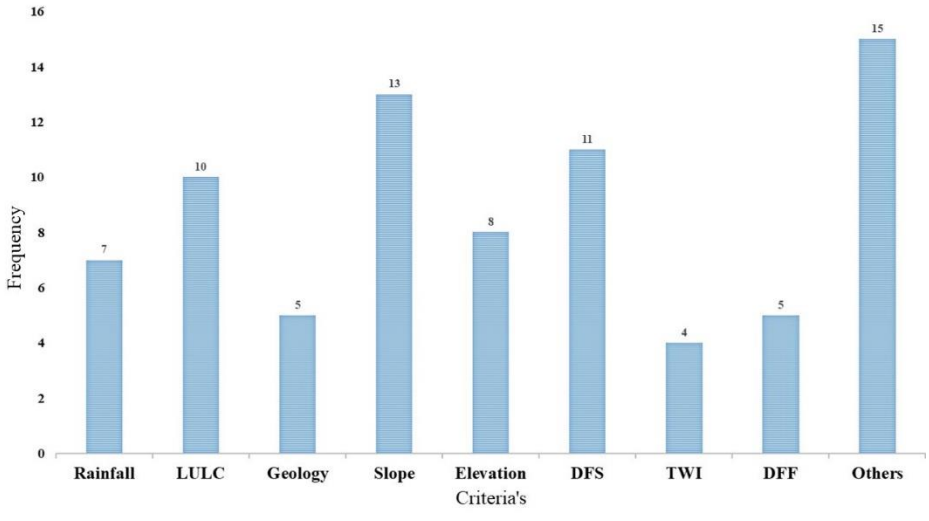


Figure 7. Frequency distribution of important environmental hazardous criteria's.

4.3 AHP Studies Related to Environmental Pollution

The continued growth of the population and expansion of industries to meet their needs has resulted in a significant increase in pollution (Prosperi et al., 2020). Excessive sewage production causes water pollution (Samolada & Zabaniotou, 2014), solid waste production from manufacturing causes landfill, air & water pollution, and Rising food demands incorporated in massive fertilizer utilization which results in soil pollution, health Hazards etc. (Foley et al., 2011; Khoshnevisan et al., 2020; Tilman et al., 2011; Zhou et al., 2018) among other things. In the quest to improve one's quality of life, there is a massive devastation of the environment that cannot be expected. There is a concern that arises: Can future development be both economically and environmentally sustainable? This question cannot be answered without considering the future Vision, and any planning scheme should prioritize environmental sustainability. Following the United Nations Conference on Environment and Development in 1992, many countries attempted to follow the guidelines outlined in that report, namely, reducing carbon emissions (Salimifard & Raeesi, 2014) and implementing policies like GSCM & SSCM (Kannan et al., 2014; Muduli & Barve, 2013; Muduli et al., 2013a; Muduli et al., 2013b; Govindan et al., 2015a; Rostamzadeh et al., 2015) that prioritize environmental factors over economic, fiscal, social, agricultural, and energy considerations. The use of GSCM and SSCM principles by companies and industries, results in reverse logistics ideas like recycling (Alshamsi & Diabat, 2015; Jia et al., 2015; Mudgal et al., 2009; Govindan et al., 2015b), boosting the concept of reusing which cuts down the utilization of virgin resources (Diabat & Al-Salem, 2015; Garg et al., 2015), are all advantageous in reducing pollution. GSCM and SSCM concepts have received much interest from scholars and practitioners in the recent decade because of these benefits. The MCDM technique has been widely applied in the fields of environmental Pollution remediation, resource planning & management (Miettinen & Salminen, 1999; Salminen et al., 1998). In this study, selected literature is aligned with the stated vision, and the AHP approach is used to address the problem (Figure 8). For further reference please refer Table 3.

Table 3. Literature review on environmental pollution & sustainable manufacturing.

Decision Problem: Environmental Pollution					
Reference	**Decision Area**	**Measure Focus**	**Country Origin**	**Criteria considered**	**Technique used**
Zhang et al. (2021)	Evaluation	Determining the most effective nitrogen application rate in order to prevent fertilizer-related pollution.	China	Economic (1 s.cr), environmental indicator (5 s.cr), ecological indicator (3 s.cr)	AHP, Meta-heuristic method
Zhang et al. (2022)	Assessment	Environmental risk assessment of marine micro-plastics.	China	Pressure index (7 s.cr), Response index (3 s.cr), State index (5 s.cr)	AHP
Karimi et al. (2011)	Selection	Choosing the best technique for treatment of waste water.	Iran	TEC, ENV, ECO	AHP
Borza & Petrescu (2016)	Assessment / selection	This research is to find out where the least and most contaminated sections are on the Olt River, using data from different sample stations.	Romania	Boita, Govora barrage, Caineni, Babeni barrage, Cornet barrage, Dragasani barrage	AHP, TOPSIS, GIS
Abba et al. (2013)	Assessment	Assessing stakeholder perspectives and judgements on the environmental implications of Johor Bahru's municipal solid waste disposal	Malaysia	Noise, vibration, visibility, habitat depletion, flora & fauna, LULC, stream ecology, air quality	AHP, ANP
Bottero et al. (2011)	Selection	The study depicts a genuine selection dilemma for small cheese companies in terms of selecting the most sustainable wastewater treatment (WWT) method.	_	ECO aspect (5 s.cr), TECH aspect (6 s.cr), ENV aspect (5 s.cr)	AHP, ANP
Ruiz-Padillo et al. (2016)	Assessment	In each of the road segments covered in the Noise action plans, this report presents a variety of viable alternatives to reduce traffic noise.	Spain	Effect on infrastructure (3 s.cr), Functional (4 s.cr), ECO (3 s.cr), ENV (3 s.cr), social (4 s.cr)	Weighted sum, AHP, ELECTRE, TOPSIS

Table 3 continued…

Majid & Mir (2021)	Selection	The goal of this research is to find viable dump locations in Srinagar, India	India	Built-up-area, elevation, water bodies, residential area, agricultural & allied area, road network, railway line, size, airport, slope	GIS, AHP, MCE (multi-criteria-evaluation)
Besharati Fard et al. (2022)	Selection	Selection of the best dump location in Guilan Province, which has a moderate and humid environment.	Iran	Distance from surface water, Geology, distance from aquifers, winds, DFF, rainfall, distance from protected areas, LULC, temperature, SL, DFR, distance from rural areas, digital elevation model	FAHP, Game theory, GIS, BW Method (best worst)
Hassan (2013)	Management	Waste management during manufacturing process in industries.	USA	Man (4 s.cr), Method (3 s.cr), ENV (3 s.cr), Material (2 s.cr), Machine (3 s.cr)	Lean six sigma (LSS), AHP
Decision Problem: Sustainable practices in Manufacturing					
Ameen & Mourshed (2019)	Ranking	A stakeholder-driven structured technique is provided using Iraq as a case study, which discovers and ranks context-relevant indicators as well as sets weights for aggregating indicator scores.	Iraq	Ecology, jobs & business, water, local economy, energy, housing, waste, layout, hazard, urban space, LULC, local culture, Infrastructure & transportation, management & construction, safety, innovation, well-being, governance	AHP
Mathiyazhagan et al. (2015)	Evaluation/ management	Identifying major pressures among all offered pressures for GSCM deployment in industries	India	Regulation, Financial, external resource, production and operation	AHP
Govindan et al. (2014)	Assessment	Analysis of GSCM barriers in Indian industry	India	Outsourcing category (6 cr), knowledge (11 cr), involvement and support (12 cr), technology (8 cr), financial (9 cr)	AHP
Thanki et al. (2016)	Assessment	Analysis the impact of lean and green paradigms on overall small & medium enterprises performance.	India	Cost, cycle time, quality, timely delivery	AHP
Mangla et al. (2017)	Prioritization / evaluation	Identify and prioritize the obstacles to achieving SCP trends in a supply chain framework. SCP – Sustainable Consumption Production	India	Govt. regulation & policies barrier (5 s.cr), supply chain member related barrier (4 s.cr), organizational barrier (6 s.cr), behavior barrier (5 s.cr), sustainability related barrier (4 s.cr), strategic barrier (6 s.cr)	FAHP
Lee et al. (2013)	Assessment	Highway designs' financial and ecological sustainability are assessed during their whole life cycle.	USA	Mandatory screening (3 s.cr), Judgement (9 s.cr)	AHP, life cycle assessment (LCA)
Song et al. (2021)	Assessment	The technique of safety assessment in chemical manufacturing is demonstrated in this paper.	China	Organization (4 s.cr), Operator characteristic (3 s.cr), Information (5 s.cr), workplace design (4 s.cr), job design (3 s.cr), task environment (5 s.cr), human system interface (5 s.cr)	Fuzzy-AHP, Cloud model

As per a literature analysis on environmental pollution and sustainable manufacturing, it must have been observed that the environment is the most widely used indicator, with many sub-indicators. Secondary and tertiary indicators that are widely employed in the evaluation and selection decision problem include economic and technical indicators.

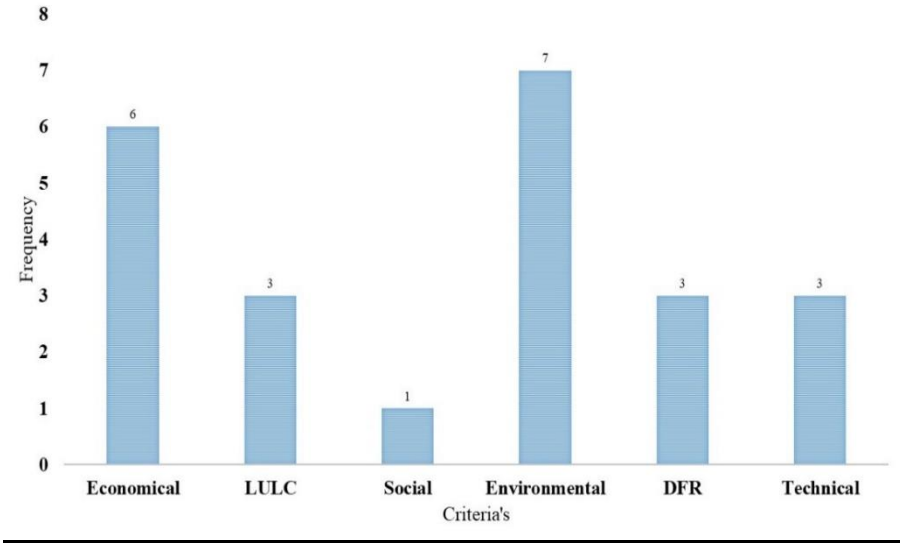


Figure 8. Frequency distribution of important criteria's related to environmental pollution and sustainable manufacturing.

4.4 AHP Studies Related to the Health Care

Improving health care and medical decision-making is critical for the country's progress. The unpredicted COVID-19 epidemic has just broken the backbone of all nations and has also become a big menace. The government must establish the most effective plan for the construction of a sophisticated health-care system (Sharma et al., 2022a, b, c). Health care professionals (HCP) must consistently combine information from many domains into medical decision making in order to optimize the efficacy of healthcare treatments. Improving health care and medical decision-making is critical for the country's progress. The unpredicted COVID-19 epidemic has just broken the backbone of all nations and has also become a big menace. The government must establish the most effective plan for the construction of a sophisticated health-care system. Health care professionals (HCP) must consistently combine information from many domains into medical decision making in order to optimize the efficacy of healthcare treatments (Tonelli, 2001). To assist with health care and medical decision-making, a range of decision-making strategies and tools are available. In this selected review, a well-established & commonly used MCDM technique AHP is used to examine & evaluate the major challenges in medical & health-care decision making. This research looked at the topic of site selection for new healthcare infrastructure such as hospitals and clinics, as well as the assessment of strategic healthcare service quality (HSQ) and many more topics. Please refer Table 4 for further description.

Table 4. Literature review on medical field.

Decision Problem: Medical field					
Reference	**Decision area**	**Measure Focus**	**Country origin**	**Criteria considered**	**Technique used**
Nilashi et al. (2016)	Assessment	To give greater insight into the various reasons that are driving or limiting for HIS (Hospital Information System) adoption.	Malaysia	TECH (4 s.cr), Human (4 s.cr), Organizational (4 s.cr), ENV (4 s.cr)	AHP

Table 4 continued…

Pauer et al. (2016)	Assessment	Assess the information requirements of patients with uncommon diseases and to compare the effects of various AHP techniques	_	Medical questions, social counselling, research, current events, self-help, diagnostic, psychological counselling, therapy, legal-advice, disease pattern, registers, new study, study results	AHP
Rajabi et al. (2020)	Prioritization	Determine and prioritize strategies to prevent violence against health care employees / workers (HWs)	_	Safety, acceptance from staff, efficiency, non-interference in the work process, possibility of implementation, durability, comprehensiveness, cost	Fuzzy additive ratio assessment (ARAS-F), Fuzzy AHP
Cabrera-Barona & Ghorbanzadeh (2018)	Assessment	Development of a multiple criteria deprivation index for the city of Quito in order to assess health disparities	Equador	long-term disability population %, without health insurance population %, without formal education, work without wages population %, minimum distance between primary health care facility, four or more people per dormitory homes %, deprived from garbage collection service homes %, deprived from drinking water facility homes %, without sewage system home %, without access to electricity system houses %	Interval-AHP
Chatterjee & Mukherjee (2013)	Selection	Site selection for a possible hospital in rural India.	India	Cost (4 s.cr), Location (4 s.cr), characteristic of population (3 s.cr)	F-AHP
Ijzerman et al. (2012)	Comparison	Compare the effectiveness of given methods in eliciting patients' preferences for stroke rehabilitation therapy options.	USA, Europe	Clinical outcome, Impact of treatment, Ease of use, complication, cosmetic, comfort	Conjoint Analysis (CA), AHP
Büyüközkan & Çifçi (2012)	Assessment	In the healthcare business, a strategic examination of electronic service quality.	Turkey	Information quality (3 s.cr), Tangibles (4 s.cr), empathy (3 s.cr), responsiveness (3 s.cr), assurance (3 s.cr), reliability (4 s.cr)	FAHP, FTOPSIS
Büyüközkan et al. (2011)	Assessment	In Turkey's healthcare, a strategic study of service quality was conducted.	Turkey	Assurance, Tangibles, Professionalism, responsiveness, reliability, empathy	FAHP
Cancela et al. (2015)	Selection / assessment	Identification of most critical variables to build & assess a telehealth system for Parkinson's illness.	_	Performance (4 s.cr), Clinical practice (4 s.cr), TEC issue (3 s.cr), user experience (3 s.cr), ECO (3 s.cr)	AHP
Chiu & Tsai (2013)	Evaluation / selection	Evaluation process for determining the best location for a regional teaching hospital.	Taiwan	Demand (2 s.cr), Transportation (3 s.cr), Future development (2 s.cr), Construction cost (2 s.cr), supporting industry (3 s.cr)	AHP
Dehe & Bamford (2015)	Selection	This research analyses and contrasts two MCDA modelling approaches for determining the locations of healthcare infrastructure.	UK	Environmental & safety (4 s.cr), Cost (4 s.cr), Design (5 s.cr), Population profile (3 s.cr), Size (4 s.cr), Accessibility (4 s.cr), Risk (4 s.cr),	Evidential Reasoning (ER), AHP

Table 4 continued…

Chen (2021)	Evaluation	Develop a strategy for determining effective mid-term occupational healthcare measures for a plant dealing with the COVID-19 outbreak.	Taiwan	Effectiveness to prevent spread of COVID-19, Cost, Low interference Integration of functional activities, High acceptability to worker	FAHP, FTOPSIS
Nguyen et al. (2021)	Prioritization	A unique hybrid SF-AHP with WASPAS-F model is suggested in this study to assist stakeholders in prioritizing governmental measures for the COVID-19 epidemic.	Vietnam	Cost, high acceptability to citizen, effectiveness for preventing COVID-19 spread-ness, ease of implementation, irreplaceability by other measures	Spherical Fuzzy SF-AHP, WASPAS-F (fuzzy weighted aggregated sum product assessment)
Gul et al. (2017)	Ranking	A case study conducted using a fuzzy MCDM technique, which produces superior DM consistency along with acceptable ranking of hazardous class.	Turkish	Severity, Undetectable, non-utilization, occurrence, sensitivity to maintenance non execution & personal protective equipment	FAHP, FVIKOR

4.5 AHP Studies Related to the Ecotourism Site Assessment

Ecotourism is a form of sustainable tourism that must be commercially effective, eco-friendly, culturally appropriate and socially acceptable (Wall, 1997). Generally, it adheres the principle of sustainability (Fennell, 2001; Garrod & Fyall, 1998; Mondino & Beery, 2019; Rinzin et al., 2007; Wood, 2002). The notion of ecotourism is now generally accepted all around world. Earlier, traditional tourism had a detrimental influence on society, culture, and the environment, consequently, the concept of ecotourism arose in order to save the environment and improve the well-being of the local population (Dwyer et al., 2010; Western, 1993). The multi-criteria evaluation approach used to identify ecotourism-friendly natural places. AHP has been identified as an appropriate MCDM technique for integrating contemporary scientific concepts and processes based on SD with tourism resource management. Description of review papers given in Table 5.

Table 5. Literature review on ecotourism.

Decision Problem: Ecotourism site selection					
Reference	**Decision area**	**Measure Focus**	**Country origin**	**Criteria considered**	**Technique used**
Chaudhary et al. (2022)	Selection	Identify viable ecotourism locations in the Garhwal Himalayan area.	India	Vegetation, SL, geological group, DFR, visibility, biological richness index, elevation, temperature, proximity to settlement, protected areas	GIS-RS (remote sensing), AHP
Sahani (2020)	Selection	Discover possible ecotourism sites in Kullu District, Himachal Pradesh, India.	India	SL, elevation, vegetation, climate, DFR, soil, geology, visibility, protected areas, surface water accessibility, topographic roughness, ground water, village proximity	AHP, GIS
Bunruamkaew & Murayama (2011)	Selection / prioritization	Identification and prioritization of a possible ecotourism location in Thailand's Surat Thani Province.	Thailand	Visibility, DFR, reserved areas, elevation, proximity to cultural sites, SL, settlement size, LULC, species diversity	GIS, AHP
Ghamgosar et al. (2011)	Management	With the support of AHP, a systematic strategy and analytical methods for tourist revival marketing plan.	Iran	LULC, soil, SL, aspect, rock, elevation	AHP, GIS
Mobaraki et al. (2014)	Evaluation	Evaluation of site appropriateness for ecotourism in the Isfahan Townships, Iran.	Iran	Geology, Topology, hydrology, LULC, climate, Access	AHP, GIS

AHP appears to be used independently or in conjunction with other strategies throughout the process. Figure 9 clearly depicts the percentile distribution of different approaches that are combined with AHP. GIS and fuzzy logic come out as a leading integrated approach utilized with AHP. In various articles, AHP is extended to fuzzy AHP that is a blend of fuzzy logic and traditional AHP. On the other part, frequency distribution of decision issue areas is display in Figure 10. Major problem of decision making is related to ranking, management, selection, prioritization, assessment etc., among them selection and assessment if found to be most centralized.

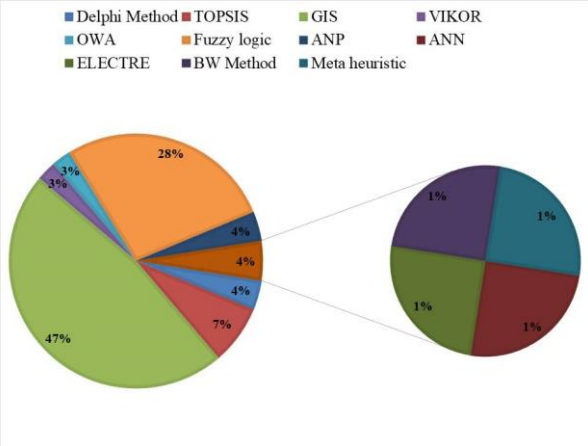


Figure 9. Percentile distribution of integrated method along with AHP.

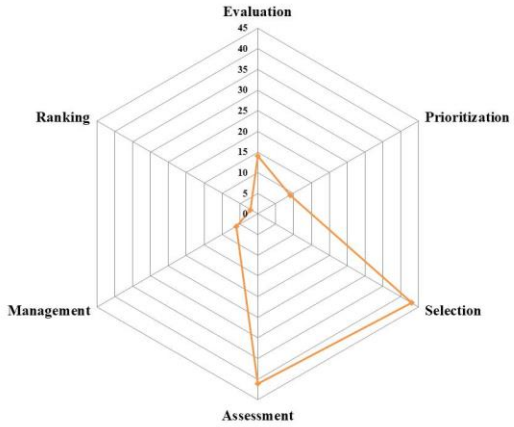


Figure 10. Distribution of published paper according to decision area.

5. Research Gaps & Recommendation

The documented AHP applications in RE appear to be limited to a few RES sectors, such as wind and solar energy; however, there may be scope to expand the usage of AHP to other RES. In the Indian context, there hasn't been much research done on ranking or prioritizing the pressures for GSCM implementation in eco-friendly companies. For estimating the priority vector, the majority of the papers examined in this study uses the Perron-Frobenius eigen vector (EV) approach. It can be expanded to a variety of different other methods for priority computation in the future, such as the geometric mean technique also known as logarithm least square method (LLS) (Crawford, 1987; Crawford & Williams, 1985), the least square method (LS) (Saaty & Vargas, 1984), the additive normalization approach (AN) (Srdjevic, 2005) and many others (Barzilai, 1997; Chu et al., 1979; Chandran et al., 2005; Joseph, 1999; Sugihara et al., 2004).

Numerous consistency indices and methodologies have been presented to measure the level of inconsistency in a PCM (Aguarón & Moreno-Jiménez, 2003; Barzilai, 1998; Crawford, 1987; Kou & Lin, 2014; Golden & Wang, 1989; Gass & Rapcsák, 2004; Koczkodaj, 1993; Kumar et al., 2022a, b; Peláez & Lamata, 2003; Stein & Mizzi, 2007), but the majority of publications in this literature review employed only Saaty's (Saaty, 1977) consistency index associated with the EV approach. Other consistency indices could be employed in the future to analyze PCM's inconsistency in various decision-making challenges (For example, After Salo (Salo & Hämäläinen, 1995), Pietro Amenta (Amenta et al., 2020) provides threshold to the Ambiguity Index is well suited for energy generation DM problem).

6. Conclusion

This paper attempt to review and critically analyze the existing literature based on the applications of AHP to support SD, published in various peer-reviewed journals between 2011 – 2022. This document summarizes a collection of 100 AHP-based publication reviews. Papers are further classified according to their application field, which ranges from RES to Ecotourism. In comparison to past AHP reviews, this study identifies the most significant criteria that should be prioritized. This study reflects the contribution of different MCDM methodologies with AHP in support of conventional and contemporary DM challenges. Based on the findings, it is clear that each of the DM areas discussed in this work will require greater attention in future research in order to achieve the intended SDG. Additionally, it has been discovered that AHP is adaptable and may be applied alone or in combination with other tools to thoroughly address SD DM issues. Moreover, descriptive analysis of the examined studies revealed that AHP is widely used in Asia and countries like Iran & India are progressing in this field. The widespread acceptance of AHP is due to the fact that is doesn't need a large sample size, can attain high degree of consistency, and simple to execute.

Researchers and practitioners from various Academic Institutes and Research Organizations can employ the outcomes of this study as a stimulant for framing DM concerns around AHP. It also helps them to gain a better understanding of the DM problem area aligned with SDG and the criteria's involved, methods (other than AHP) that have been utilized to address it, so that they can quickly classify or adopt the appropriate methodology. Furthermore, results show crucial insights into the technique's applicability and benefits, they may be motivated to frame SD DM challenges around the AHP.

Conflict of Interest

The authors confirm that there is no conflict of interest to declare for this publication.

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