

A REVIEW ON APPLICATION OF MULTI-CRITERIA DECISION MAKING (MCDM) APPROACHES

Poonam S Kadapure^{a*}, Dr. Pralhad P Rathod^{b*}, Dr. Roopa K^{c*}

^{a*} Research Scholar, Department of Management Studies, Visvesvaraya Technological University (VTU), Belagavi, Karnataka, 590008, India,

Department of MBA, Tatyasaheb Kore Institute of Engineering and Technology, Warana University, Warananagar, [Maharashtra](#), 416113, India; puunamsantoshkadapure@gmail.com

^{b*} Department of MBA, Visvesvaraya Technological University (VTU), Belagavi, Karnataka, 590008, India, pprathod77@gmail.com

^{c*} Department of MBA, Cambridge Institute of Technology and Management, Bangalore, roopaanandkn@gmail.com

Abstract: In academics and business, multi-criteria approaches are becoming more popular for efficient decision-making. This systematic study explores multi-criteria techniques and provides an overview of them. Finding various uses for MCDM techniques is one of the primary goals of this effort. Multi-criteria decision-making (MCDM) strategies have shown to be useful tools when handling complex decision-making problems requiring numerous, often conflicting criteria. This review research fully examines the implementation of MCDM approaches in several domains, including environmental science, engineering, management, and public policy. The paper looks at the theoretical foundations of popular MCDM techniques, such as Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) etc. This analysis highlights the advantages and disadvantages of each tactic.

Key Words: Multi-criteria decision-making, AHP, TOPSIS

1. Introduction:

Multi-Criteria Decision Making (MCDM) is a discipline that assists in making decisions when multiple, often conflicting criteria are involved. This approach is essential in complex decision-making scenarios where a single criterion, such as cost or time, is insufficient to determine the best course of action. MCDM integrates various criteria into the decision-making process to provide a more comprehensive and balanced evaluation of alternatives.

1.1 The key Features of MCDM:

Multiple Criteria: MCDM involves evaluating several criteria simultaneously. These criteria can be quantitative, such as financial costs, time, or energy consumption, and qualitative, such as customer satisfaction, environmental impact, or safety. Each criterion represents a different aspect of the decision problem, contributing to a more holistic understanding of the alternatives.

Conflict among Criteria: Often, the criteria in MCDM are conflicting. For example, a decision alternative that minimizes cost might not maximize quality. MCDM approaches are designed to handle these trade-offs, helping decision-makers to identify and understand the compromises involved in choosing one alternative over another.

Various methods are utilized in MCDM to aid in the evaluation and ranking of alternatives. Some prominent techniques include as shown in figure 1:

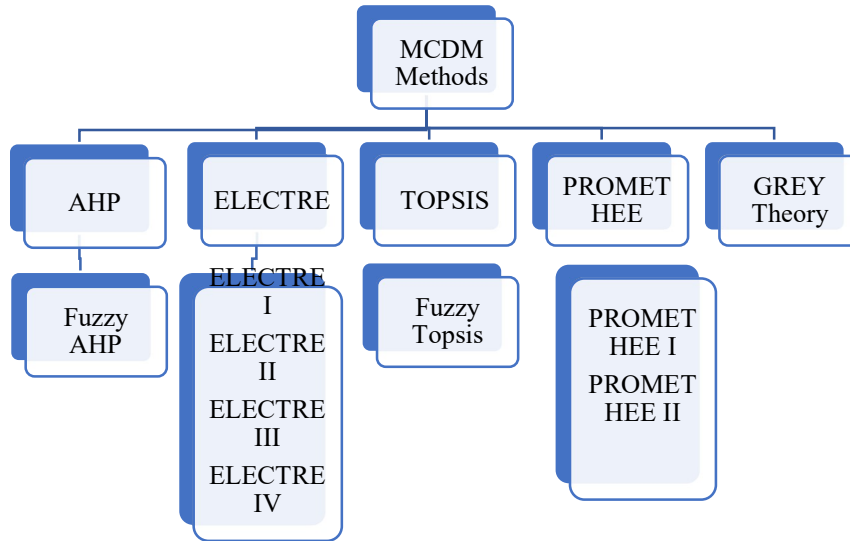


Figure 1: Different techniques of MCDM

Advantages		Disadvantages
➤ Easy to understand and use	HAW & WSM	➤ Attribute weights are assigned arbitrarily ➤ Difficult to adopt in case of numerous criteria ➤ Common numerical scaling is used to calculate the final score
➤ Can eliminate any element to be measured and utilize proportional values instead of real (actual) ones	WPM & MEW	➤ Do not provide any solution with equal decision matrix (DM) weight.
➤ Considers all criteria/attribute ➤ Offers simple calculation ➤ Makes decisions intuitively	SAW	➤ Does not commonly discover the real situation ➤ All criteria values must be positive and maximum.
➤ Allows the DMs to structure the decision-making problem into a hierarchy tree ➤ Facilitates understanding of the problem ➤ Presents high time consumption because of the number of pairwise comparisons and requires mathematical calculations that increase as the number of attributes and alternatives increase or change. ➤ Is significantly restrained by the human capacity for information processing; thus, 7±2 is regarded as the ceiling for comparison.	AHP	➤ Scoring and ranking in AHP depends on the alternatives considered for evaluation. ➤ The removal or addition of alternatives may change the final ranking (rank reversal problem).
➤ Offers a full understanding of the importance level that an attribute could take on the basis of its correlation with other attributes ➤ Allows for measurement of the judgments' consistency, which is impossible to evaluate in methods that specify weights by compromise. ➤ Assists specifying weights by breaking up the problem into smaller parts; consequently, a group of experts could have a manageable discussion because only two attributes are compared in specifying judgments	ANP	➤ The offered proper network structure among attributes is complex even for experts, and different structures lead to various results. ➤ The formation of a super matrix needs to be the pairwise comparison of all attributes with all other attributes, a step that is both complex and unnatural.
➤ TOPSIS and VIKOR are applied to discrete alternative challenges and they are the most significant approaches to solve real-world problems. ➤ TOPSIS and VIKOR have the ability to immediately recognize the proper alternative. ➤ TOPSIS and VIKOR decreases the pairwise comparisons required, and the capacity limitation may not significantly control the process. ➤ TOPSIS and VIKOR usable for situations with many alternatives and attributes. ➤ TOPSIS and VIKOR are appropriate to utilize when quantitative or objective data are offered. ➤ TOPSIS and VIKOR are based on an aggregating function representing 'closeness to the ideal', which originated in the compromise programming method.	TOPSIS & VIKOR	➤ TOPSIS and VIKOR lack provision to weigh elicitation and check the consistency of judgments. ➤ TOPSIS does not consider the relative importance of distances.

Figure 2: Strengths and Weaknesses of Multi-Criteria Decision-Making Approaches

MCDM has a wide range of applications across various fields, reflecting its versatility and utility in addressing complex decision problems. In business, MCDM is used for strategic planning, project selection, resource allocation, and supplier evaluation. It helps managers to balance different objectives such as cost, quality, and risk. Engineers use MCDM for design optimization, systems engineering, and infrastructure planning. It aids in selecting materials, processes, and technologies that meet multiple performance criteria. Environmentalists and policymakers employ MCDM in environmental impact assessments, resource management, and sustainability planning. It helps balance ecological, economic, and social objectives. MCDA methods are used to solve decision-making problems in several areas, including the information and communication technology; business intelligence; environmental risk analysis; environmental impact assessment and environmental sciences; water-resource management; solid-waste management; remote sensing; flood-risk management; health-technology assessment; healthcare; transport; nanotechnology research; climate change; energy; international law and policy; human resources; financial management; performance and benchmarking; supplier selection; e-commerce and m-commerce; agriculture and horticulture; chemical and biochemical engineering; software evaluation; network selection; education and social policy; heating, ventilation, and air conditioning and small-scale energy management systems; and public security.

Multi-Criteria Decision Making is a powerful approach for tackling complex decision problems involving multiple, conflicting criteria. By incorporating various criteria into the decision-making process, MCDM provides a more comprehensive and balanced evaluation of alternatives, leading to more informed and rational decisions. Its applications span numerous fields, demonstrating its broad relevance and effectiveness in addressing diverse decision-making challenges.

1.2 STEPS IN MCDM Approach

By weighing several criteria, the Multi-Criteria Decision-Making (MCDM) methodology offers an organized strategy for making decisions. This is a condensed description of the general MCDM procedure:

- 1. State and Define the Problem Domain:** Define the decision-making problem, including alternatives, attributes, and constraints. The information gathered will guide the selection of the appropriate MCDM technique.
- 2. Elicit the Criteria:** Identify and define the evaluation criteria that will influence the decision. Avoid using too many criteria, as this increases complexity and computational cost.
- 3. Screen the Alternatives:** Use dominance methods to eliminate alternatives that are inferior in some attributes. Apply cutoff values to remove alternatives that don't meet the necessary thresholds.
- 4. Define Preferences on Evaluation Criteria:** Prioritize the evaluation criteria based on their importance to the decision-making process. This helps focus on the most critical criteria for decision-making.
- 5. Choose MCDM Method for Selection:** Select the most appropriate MCDM method, such as WSM (Weighted Sum Model) for simplicity or more complex techniques for complicated problems.

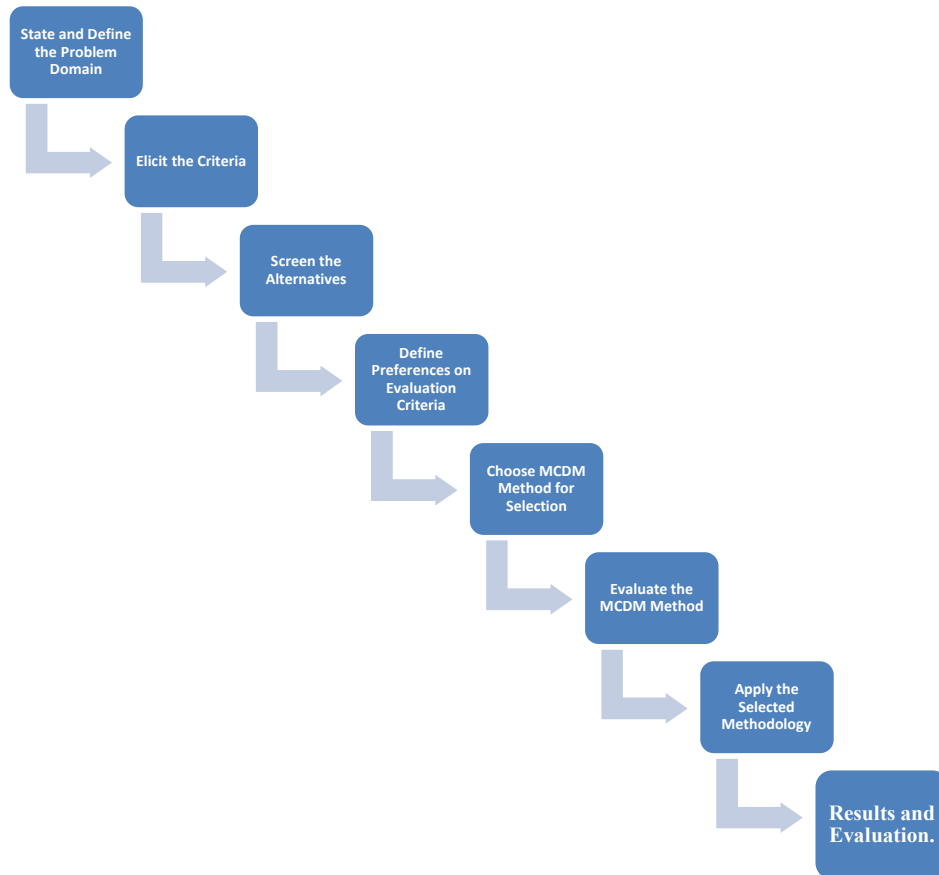
6. Evaluate the MCDM Method: Use the Appropriateness Function (AF) to rank and evaluate the selected MCDM methods. The method with the highest AF is recommended for solving the decision problem.

7. Apply the Selected Methodology: Perform the necessary mathematical computations specific to the chosen MCDM technique (e.g., WSM, AHP, TOPSIS).

8. Results and Evaluation: Analyze the results and evaluate them for robustness through sensitivity analysis to understand how parameter variations affect the outcome.

This flow (Figure 3) ensures a systematic approach to decision-making by combining various criteria and methods to achieve an optimal solution.

Figure 3: Flowchart for MCDM Process



1.3 Flowchart for MCDM Process

This flowchart represents the iterative steps involved in evaluating alternatives using MCDM techniques, making the decision-making process structured and comprehensive.

2. Literature Review:

The field of multi-criteria decision-making (MCDM) encompasses various methodologies designed to evaluate and rank options based on multiple criteria. The selected research papers provide a broad overview of MCDM applications across different sectors, such as stock indices evaluation, construction, airline performance, portfolio management, banking, material selection, and financial management. This review synthesizes the key findings, methodologies, strengths, and limitations of these studies.

Dev Gupta et al., (2021) employs the Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to rank sectoral indices of the NSE, considering criteria such as return, risk, liquidity, and market capitalization. The study's comprehensive approach using robust MCDM -- techniques offers practical implications for investors. However, it relies on historical data and may present potential complexity for individual investors. A study conducted by **Daniel Jato-Espino et al., (2014)** addressed a variety of decision-making scenarios, such as material selection, project management, and sustainability assessments and also investigated the use of MCDM methods in the construction industry. **Pedro Jose Gudiel Pineda et al., (2018)**, combined several MCDM techniques, such as AHP and Data Envelopment Analysis (DEA), to improve the operational and financial performance of airlines. The comprehensive methodology of the analysis integrates financial and operational viewpoints. Nevertheless, integrating many MCDM techniques is difficult and requires a lot of data. A study was undertaken by **H. S. Hota et al., (2018)** which suggests a three-tier architecture that integrates goal programming (GP) and AHP for the best possible stock portfolio management. The creative way in which AHP and GP are integrated in the research works well for portfolio optimization. But the model is complicated and needs a lot of processing power.

Sanjay Gupta et al., (2021) applies MCDM techniques to measure the performance of private sector banks in India by taking into account factors like operational efficiency, customer satisfaction, and financial performance. The report offers thorough benchmarking and is realistically relevant to the banking industry. Nevertheless, it has problems with sensitive data and might miss some performance elements. **Anojkumar, L et al., (2014)** explained the problem of pipes material selection in the sugar sector is solved by the application of four Multi-Criteria Decision Making (MCDM) techniques. The techniques employed are: FAHP-VIKOR, FAHP-TOPSIS, FAHP-ELECTRE, and FAHP-PROMETHEE. Tensile strength, yield strength, percentage of elongation, hardness, cost, corrosion rate, and wear rate are the seven criteria that will be used in the study to determine which of the five classes of stainless steel (J4, JSLAUS, J204Cu, 409 M, and 304) is the best. It contrasts both approaches' efficacy and performance, paying special attention to the VIKOR method's adaptability. **Kujawski, E et al., (2003)** illustrates the drawbacks and difficulties of multi-criteria decision analysis (MCDA) using the women's figure skating competition from the 2002 Winter Olympics as a case study. It contrasts a number of well-liked approaches for integrating various characteristics into a single score. Conflicting rankings can be produced by MCDA models even when same data is used. Selecting the appropriate analysis approach and accurately interpreting the results are the two key issues faced by analysts. Users may also be misled by the availability of software applications that offer quantitative scores. These findings are intended to encourage improved MCDA techniques and are applicable to a variety of domains, including systems engineering. **Marqués, A.I et al., (2020)** have suggested two of the best techniques for assisting analysts and decision-makers in this discipline in producing consistent assessments and precise forecasts are value-based and outranking relations approaches. This study offers a thorough analysis of the applications of the TOPSIS and ELECTRE methodologies to

significant financial issues between 2000 and 2018, emphasizing new findings, unanswered issues, and difficulties that call for more investigation. Choosing stocks to invest in is a multiple criteria decision-making (MCDM) problem because it incorporates several factors. Conflicting rankings can frequently be produced by various MCDM techniques.

Through use of a hybrid MCDM approach based on Spearman's rank correlation coefficient, **Poklepović, T. et al., (2014)** has addressed the disparities. The criteria weights for the five MCDM methods—COPRAS, linear assignment, PROMETHEE, SAW, and TOPSIS—are established using the AHP approach. Taking into account stock returns, traded volumes, and important market indicators, the study looks at 19 equities that were traded on the Croatian capital market between March 2012 and March 2014. Although the five strategies yield different beginning rankings, the hybrid approach generates final rankings. The results demonstrate that while the greatest stocks fluctuate marginally when industry profitability is taken into account, the worst stocks stay constant regardless of industry. **Janic, M. et al., (2002)** has presented the application of three Multiple-Criteria Decision-Making (MCDM) techniques—SAW, TOPSIS, and AHP—in the process of choosing a new hub airport for a fictitious EU airline that operates in the liberalized EU aviation market. These techniques are used on a predetermined group of airports, with the selection of criteria based on the performance that is important to the airline in making decisions. The article evaluates each method's value as an additional tool for making decisions in the actual world in addition to providing an example of how it operates.

Basciani, F. et al., (2023) presented a general and extendable mechanism in this work that enables the aggregation and prioritization of quality attributes. The capacity of mutual funds (MF) to diversify risk while providing prospective returns has made MF investing more and more popular among investors. Mutual funds are overseen by a regulatory body and are actively managed by fund managers. Because fund performance varies based on a number of risk-return factors, it is imperative that individual investors evaluate it before making an investment. **Biswas, S., et al., (2019)** presented a two-phase method for ranking and choosing mutual funds. DEA (Data Envelopment Analysis) is first used to examine the performance of open-ended equities large-cap funds in India for first selection. Then, using weights derived from the Entropy technique, the MABAC method is used to rank the funds according to risk and return. **Kassaei, M., et al., (2013)** used a fuzzy technique in order to manage this ambiguity and get more accurate outcomes. Traditional decision models have trouble addressing the intricate interactions that exist between criteria and sub-criteria. This article suggests a hybrid multi-criteria decision-making (MCDM) approach that makes use of the Analytic Network Process (ANP) to ascertain the linkages and give each sub-criterion the proper weight. Next, options are ranked according to their overall performance using the TOPSIS approach. Because of its benefits, TOPSIS has gained popularity in MCDM studies as a method for rating options. A case study of an Iranian automaker is used in the research to show how this model might enhance vendor selection. The objective of **Alias, M.A., et al., (2008)** is to present a methodical analysis of the use of Multi-Criteria Decision Making (MCDM) techniques in material selection. The analysis reveals that the most popular approach for material selection is hybrid methods, which combine two or more MCDM techniques. In order to ensure that travellers are satisfied, choosing tourist attractions is a multi-criteria decision-making challenge that needs to be carefully considered based on particular human requirements at a given time. With the help of this research, **Bire, C., et al., (2021)** has adopted fuzzy analytic hierarchy process (AHP) decision support system for choosing tourist destinations in Kupang City will be developed. The algorithm will suggest appropriate tourism spots based on the user's priorities for nine human need qualities. The study also examines the differences between the original AHP and

the fuzzy AHP approaches, concluding that although both are useful for multi-criteria decision-making, the fuzzy AHP offers a better option when comparisons are ambiguous. Corporate performance evaluation is one of the most important and crucial processes for any business, regardless of the field it works in. Financial performance is the most important and noticeable aspect of corporate performance evaluation. A methodological framework is required to address such difficult decision problems since appropriate performance analysis is crucial for decision-makers in a variety of financial performance aspects. Thus, **Kaya, A., et al., (2024)** has studied the Turkish enterprises that are part of the sustainability index (banks excluded) based on their financial performance.

Using the full **consistency** approach (FUCOM), the weights of the criteria were established by taking into account the opinions of four experts. Nine different multi-criteria decision-making techniques were used to rate the companies. The Copeland technique was used to make sure that all nine rankings agreed upon anything. Financial information is included in the decision matrix. **Singh, K. et al., (2020)** examined the causal connections between the sectoral and Nifty-Fifty indexes, as well as their trends and patterns. The paper investigates these correlations using the Granger-causality test and unit root test. The results show that the banking and financial services industries outperformed the other indices, with the pharmaceutical and real estate sectors performing poorly. Compared to other sectoral indexes, the Nifty-Fifty was found to be less volatile, with the Realty sector exhibiting the highest volatility across the study period. Comparable to the Second World War's economic crisis, the COVID-19 pandemic has killed over six million people worldwide, disrupted every facet of life, and instilled widespread dread of a catastrophic economic collapse. In order to handle the intricate, multifaceted problems **Sotoudeh-Anvari, A., (2022)** presented multi-criteria decision making (MCDM) techniques. This study, which focuses on the application of MCDM techniques to COVID-19-related problems. According to the PRISMA protocol, 35 countries participated to this study, with India leading the way, followed by Turkey and China. Notably, foreign cooperation was included in half of the studies. "Journal of Infection and Public Health" and "Applied Soft Computing" are the two leading journals in the discipline. **Wu, H.Y., et al., (2012)** The primary goals of this paper is to rank 12 private universities in Taiwan and to weigh performance evaluation criteria in order to assess the performance of higher education institutions. A hybrid multi-criteria decision-making (MCDM) model is employed in the study. The weights of the evaluation criteria are established using the Analytic Hierarchy Process (AHP), and the universities are ranked using the VIKOR technique in accordance with the AHP findings. Additionally, the study contrasts its rankings with these colleges' official rankings. The findings are intended to assist universities in effectively enhancing their performance and to serve as a model for other educational establishments seeking to better assessment, performance, and policy-making. The complexity of real-world issues makes decision-making difficult. Techniques that are efficient are required to identify the optimum option.

The development of e-learning, which businesses today employ as a substitute for traditional training methods because of its flexibility, cost-effectiveness, and time savings, has been aided by the internet's impact on all industries. Evaluating the efficacy of e-learning is vital, but current models sometimes don't take a holistic approach that takes into account the fuzziness of subjective impressions as well as the linkages between criteria. To tackle these problems, a novel hybrid MCDM model is presented by **Tzeng, G.H., et al., (2007)**. DEMATEL is used to manage dependent criteria relationships, whereas factor analysis is used to account for independent criteria relationships. Subjective perceptions are aligned with the assessment of overall efficacy through the application of fuzzy integral and AHP methodologies. The outcomes of the experiments

demonstrate that this model evaluates e-learning programs well, particularly when the criteria are intricate and related. **Dymowa, L. and Dymowa, L., (2011)** examines typical issues with multiple criteria decision making (MCDM) and suggests fresh approaches. It makes use of a straightforward subset hood measure based on fuzzy values to address the problem of determining a common scale for both objective and subjective criteria. The chapter employs type 2 and level 2 fuzzy sets to enhance aggregation techniques; as a result, final evaluations are shown as fuzzy membership functions. We compare these imprecise evaluations using a probabilistic method. A new approach to hierarchical investment evaluation is also presented in this chapter; it differs from the conventional fuzzy analytic hierarchy process (AHP). Using MCDM and fuzzy optimization, these developed techniques are used to handle stock ranking and budgeting challenges. **Cetin, M.K. and Cetin, E.İ., 2010** There are numerous studies measuring banks' performances in Turkey in the literature. For instance, **Aydogan and Booth (1996)** looked into the performance characteristics of Turkish commercial banks that were owned by the state and those that were privately owned during the 1986–1990 era. Turkish banks' comparative financial performance from 1989 to 1999 was evaluated by **Mercan et al. (2003)** using financial ratios in data envelopment analysis (DEA). **Özkan-Güney and Tektaş (2006)** evaluated nonpublic commercial banks' technical efficacy using the DEA model from 1990 to 2001. Using the VIKOR technique, **Ertuğrul and Karakaşoğlu (2008)** assessed and ranked the branches of a single bank. **Seçme et al. (2009)** assessed the top five commercial banks in the Turkish banking sector using the TOPSIS and Fuzzy AHP techniques. In their analysis, they made use of both financial and non-financial indicators. Smartphones that have been outfitted with cutting-edge mobile applications—like quick and simple Internet access—have emerged as indispensable devices for the multitasking era, or "M-era, **Hu, S.K., Lu, M.T. and Tzeng, G.H., (2014)** suggesting to use a hybrid MCDM model—a combination of VIKOR and DANP, or DEMATEL-based ANP—to promote the product value and meet customer needs through smart phone enhancement. Using the DEMATEL technique, the DANP may create an INFLUENTIAL NETWORK RELATIONSHIP MAP (INRM) to examine the relationships between dimensions and criteria, and then measure. With a generalist approach, it is challenging to consistently make profits in the stock market due to its volatility and unpredictability. **Ullah, A.K.M., (2021)** have concentrated on determining the optimal features for certain time periods, despite the fact that many have attempted to construct machine learning models for profitable trading in the US stock market. To determine whether to go long or short on stocks, the model employs ensemble learning with four classifiers: stochastic gradient descent, decision tree, logistic regression with L1 regularization, and Gaussian Naive Bayes. Using daily trading, the model produced a 54.35% profit between July 2011 and January 2019. Additionally, a brand-new model is suggested that weighs. **Zavadskas, E.K. and Turskis, Z., (2011)** presents an overview of these approaches in economics, emphasizing the most significant findings and applications over the past five years. The agricultural economy depends heavily on the storage and post-harvest conservation of agricultural products. Choosing the ideal site for an agricultural warehouse is crucial and involves a number of considerations, including cost, accessibility, and distance from consumers and growing regions. For resolving such issues, Multi-Criteria Decision Making (MCDM) techniques like rating and ranking work well. The complexity and ambiguity in these criteria are addressed by **Shukla, G., et al., (2017)** in this work through the use of a Fuzzy Analytical Hierarchy Process (Fuzzy AHP). The study uses Fuzzy AHP to rank three possible locations for a rice storage warehouse based on their suitability by arranging the criteria into a hierarchy. Multicriteria methods have become increasingly popular in both academia and industry for effective decision-making. The Systematic Investment Plan (SIP) is a popular choice in the

Indian equity market because it makes disciplined investing easy, even in volatile markets. This research by **Majumdar, S., P et al.,(2021)** looks at the returns of Indian companies from 2010 to 2019, identifying top-performing stocks based on market capitalization and sectors. Value Averaging (VA) beat SIP, with 352 out of 359 companies yielding higher returns under VA; this advantage was most pronounced in the consumer goods, financial services, and industrial manufacturing sectors, especially for small-cap companies. However, the study also highlights the importance of risk factors for VA strategy and should not be disregarded in favor of concentrating solely on excess return. **Alias, M.A., et al (2008)** have reviewed two primary methodologies of Artificial Intelligence MCDM (AIMCDM) and Classical MCDM (CMCDM) in this study along with contemporary techniques in Multi-Criteria Decision Making (MCDM) and their applications. To find out which strategy is more popular and where it is utilized, recent articles from international journals published in 2008 are examined. The results demonstrate that in MCDM, AIMCDM and CMCDM are equally prevalent.

2.1 Outcome of literature study

The literature study emphasizes the use of Multi-Criteria Decision-Making (MCDM) strategies including AHP, TOPSIS, VIKOR, and others, have been successfully handled complicated decision-making scenarios, including material selection in industries, stock portfolio management, and bank performance evaluation etc. and has recognized problems such as reliance on historical data, model implementation complexity, data sensitivity, and the possibility of inconsistent rankings amongst various MCDM techniques are typical obstacles.

3. Research Gap & Scope for further Research

There are still a lot of unmet needs in Multi-Criteria Decision-Making (MCDM) systems, especially in terms of usability and complexity. The complexity and high computational demands of various MCDM models make them difficult for individual investors and smaller enterprises to execute, which emphasizes the need for more straightforward and user-friendly models. Subsequent investigations may concentrate on crafting hybrid MCDM tactics that proficiently tackle problems such as competing ranks by amalgamating the advantages of diverse methodologies. Furthermore, investigating the use of MCDM techniques in situations involving real-time decision-making, particularly in industries with rapid technological advancements and financial services, may provide insightful information. Enhancing accessibility via user-friendly interfaces and effective processes is essential, as is carrying out sensitivity analyses to comprehend how changes in input data impact results, which eventually results in stronger MCDM models.

4. Conclusion:

This review of the literature highlights the adaptability and potency of Multi-Criteria choice-Making (MCDM) techniques in handling complex choice issues by offering a thorough overview of their use in a variety of industries. AHP, TOPSIS, VIKOR, and other MCDM techniques have been effectively used in a number of fields, including the evaluation of stock indexes, construction, airline performance, portfolio management, banking, material selection, and financial management. These studies show that MCDM techniques are useful instruments for decision-makers who have to weigh several factors, frequently at odds with one another. According to the reviewed research, hybrid models—which incorporate many MCDM techniques or pair MCDM with other methods like fuzzy logic and DEA—are very useful for enhancing the resilience and accuracy of decision-making. These methods resolve uncertainty and provide a more thorough investigation.

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