

COMPARATIVE ANALYSIS OF MULTI-CRITERIA DECISION MAKING APPROACHES: A COMPREHENSIVE EVALUATION

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Abstract

Multi-Criteria Decision Making(MCDM) approaches are vital in working complex decision- making problems where multiple disagreeing criteria must be considered. These approaches help in assessing and prioritizing druthers to make informed opinions. This paper presents a relative analysis of several prominent MCDM ways, including Analytical Hierarchy Process(AHP), Analytical Network Process(ANP), Technique for Order Preference by Similarity to Ideal Solution(TOPSIS), and VlseKriterijumska Optimizacija I Kompromisno Resenje(VIKOR). Each system is assessed grounded on its theoretical foundations, operation disciplines, strengths, and limitations. The study highlights how these approaches differ in terms of structure, complexity, and the type of decision terrain they best serve. likewise, the paper explores the practical counteraccusations of opting an applicable MCDM fashion, considering factors similar as data vacuity, the nature of the decision problem, and stakeholder involvement. The comparison aims to give decision- makers with perceptivity into the advantages and disadvantages of each approach, enabling further effective and customized decision- making in colorful fields, from business to environmental operation and engineering.

Keywords : Multi-Criteria Decision Making Approach, Analytical Hierarchy Process(AHP), Analytical Network Process(ANP), Technique for Order Preference by Similarity to Ideal Solution(TOPSIS), VlseKriterijumska Optimizacija I Kompromisno Resenje(VIKOR).

1. Introduction

In an increasingly complex world, decision-making processes often involve multiple, conflicting criteria, requiring robust methods to support effective evaluation and choice. Multi-Criteria Decision-Making (MCDM) approaches have been developed to address such complexities, offering systematic frameworks for analyzing diverse alternatives based on a set of predefined criteria. Over the years, a wide range of MCDM techniques—such as AHP, ANP, TOPSIS and VIKOR have been introduced and widely applied across various domains including engineering, business, environmental management, and healthcare. However, the diversity of these methods, each with unique assumptions, computational structures, and decision rules, often presents a significant challenge for practitioners in selecting the most appropriate technique for a given context.

This paper presents a comprehensive comparative analysis of prominent MCDM approaches, evaluating their performance, strengths, and limitations through detailed case studies and a unified set of evaluation criteria. The study aims to bridge the gap between theoretical development and practical application by offering a critical synthesis of methodological differences and application outcomes. Special emphasis is placed on factors such as consistency, sensitivity to input variations, ease of use, computational efficiency, and the ability to handle uncertainty.

By systematically comparing multiple MCDM methods under identical decision scenarios, this work provides valuable insights for researchers and decision-makers, helping them make informed choices regarding the selection and application of MCDM tools. Additionally, the paper contributes to the growing body of literature by identifying trends, challenges, and opportunities for future research in the evolving field of decision science. Ultimately, the findings aim to foster a deeper understanding

of how different MCDM approaches can be leveraged to enhance decision quality in multi-faceted environments.

2. Literature Review

Recent research has increasingly focused on Comparative Analysis Of Multi-Criteria Decision Making Approaches: A Comprehensive Evaluation, highlighting its significance in multiple fields of study. The following are the list of Recent works on the Multi-Criteria Decision Making Approach: Ersoy, N., & Keleş, N. (2024), study examines how different MCDM methods—WASPAS, SECA, SAW, OWA, CODAS, MARCOS, PSI, and WPM—perform when applied with a consistent linear normalization process. It also assesses the impact of three weighting methods: Entropy, Equal Weighting (EW), and LOPCOW. The analysis is grounded in three real-life applications, highlighting how normalization and weighting choices influence ranking outcomes[1]. Steffen, V., de Oliveira, M. S., & Trojan, F. (2024), paper explores the application of MCDA methods—specifically Entropy Weight Method (EWM), Analytic Hierarchy Process (AHP), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)—to classify and rank research papers within a systematic literature review. It distinguishes between compensatory and non-compensatory approaches, emphasizing the importance of method selection based on dataset characteristics[2].

Yingfang Li(2024), study categorizes MCDM methods into three groups based on their ranking techniques and examines why different methods can yield identical solutions. It delves into the effects of normalization procedures and distance measures, offering insights into the relationships and characteristics of various MCDM methods. Kumar, R., & Pamucar, D. (2024), extensive review analyzes 3,655 peer-reviewed articles over two decades, tracing the evolution of MCDM methods from foundational techniques like AHP and TOPSIS to hybrid models incorporating artificial intelligence and fuzzy logic. It identifies publication trends, leading contributors, thematic clusters, and collaborative networks, highlighting gaps and opportunities for future research[3]. Villalba, P., Sánchez-Garrido, A. J., & Yepes, V. (2024), literature review focuses on the application of MCDM methods in the context of building assessment and retrofitting. It highlights the prevalent use of AHP for criteria weighting, SAW for constructing vulnerability indices, and TOPSIS for retrofitting decisions. The study provides recommendations for integrating safety and sustainability considerations in building renovations[4]. Saeed Khojaste Effatpanah(2024), case study evaluates clean energy technologies using five MCDM methods: SAW, TOPSIS, ELECTRE, VIKOR, and COPRAS. It examines how different weighting scenarios—technical, economic, environmental, and social-policy— affect the prioritization of energy options, providing insights into the robustness and sensitivity of each method[5].

Ashish Soni(2023), evaluates the performance of three MCDM methods—MOORA, TOPSIS, and COPRAS—in selecting filler-reinforced thermoplastic composites. The Analytic Hierarchy Process (AHP) is employed to determine criteria weights. The rankings obtained from these methods are compared using Spearman's rank correlation coefficient, providing insights into the consistency and reliability of each technique in material selection[6]. Nazlı Ersoy(2023), presents a multidimensional framework to measure corporate sustainability in the energy sector. The sustainability performance of energy companies operating in Asia and Europe is assessed using a hybrid MCDM approach, combining Entropy for criteria weighting with PIV, ROV, GRA, and MARCOS methods for ranking alternatives[7]. Karolina Ogrodnik(2023), identifies and compares the most commonly used MCDM/MCDA methods—TOPSIS, AHP, and PROMETHEE—in creating city rankings. The paper

provides a comparative analysis of these methods, focusing on their algorithms, data selection processes, and integration possibilities with other methods[8].

These studies offer a diverse range of perspectives on MCDM method comparisons, covering various applications and methodological approaches. They can serve as a solid foundation for your literature review, providing insights into the strengths, weaknesses, and applicability of different MCDM methods in real-world scenarios.

3. Comparative Analysis Of Multi-Criteria Decision Making Approaches: A Comprehensive Evaluation

3.1 Difference between TOPSIS, AHP, ANP and VIKOR

In the domain of Multi-Criteria Decision Making (MCDM), several methods have been developed to assist decision-makers in evaluating and selecting the best alternative from a set of options, considering multiple criteria. Among the most widely used methods are the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), the Analytic Hierarchy Process (AHP), the Analytic Network Process (ANP), and the VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR). These methods differ in their approach, complexity, and the types of decision problems they are best suited for. Below is a detailed comparison based on key attributes.

3.1.1 Analytic Hierarchy Process (AHP)

Concept: AHP is a hierarchical decision-making process where the problem is structured in multiple levels: goal, criteria, sub-criteria, and alternatives. It involves pairwise comparisons of criteria and alternatives to derive their relative importance.

Methodology: The decision-maker makes pairwise comparisons of alternatives and criteria using a scale of preference. These comparisons are used to calculate a priority vector (weights) and rank the alternatives.

Strengths:

- Simple to understand and use.
- Widely applicable across various industries (e.g., healthcare, manufacturing, supply chain).
- Can handle both qualitative and quantitative data.

Weaknesses:

- Subjectivity in pairwise comparisons.
- Prone to inconsistencies in judgment, which can affect results.
- Cannot handle interdependencies between criteria.

Applications: Used in cases where the decision-maker needs to compare alternatives based on a set of hierarchical criteria (e.g., supplier selection, project evaluation).

3.1.2 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

Concept: TOPSIS is based on the idea that the best alternative is the one closest to the ideal solution (i.e., the best performance on all criteria) and farthest from the negative ideal solution (i.e., the worst performance on all criteria).

Methodology:

- Identify the ideal and negative ideal solutions.
- Calculate the Euclidean distance of each alternative from the ideal and negative ideal.
- Rank the alternatives based on their distance to the ideal solution.

Strengths:

- Simple to implement and understand.

- Effective when alternatives are quantitatively measurable.
- Computationally efficient, especially for a large number of alternatives.

Weaknesses:

- Sensitive to the normalization of data, which can affect the results.
- Assumes the independence of criteria.
- May struggle when dealing with qualitative or ambiguous data.

Applications: Suitable for problems where alternatives can be quantitatively assessed, such as environmental management, financial investments, and product evaluations.

3.1.3 Analytic Network Process (ANP)

Concept: ANP is an extension of AHP that incorporates interdependencies among criteria, sub-criteria, and alternatives. It is particularly useful in more complex decision-making environments where criteria are not independent but influence each other.

Methodology: Similar to AHP, ANP uses pairwise comparisons, but it also includes feedback loops and interdependencies between decision elements (e.g., criteria, sub-criteria, and alternatives). ANP uses a network model to represent relationships between elements and computes priority vectors accordingly.

Strengths:

- Can handle complex interrelationships between criteria and alternatives.
- More accurate in situations where there are feedback effects between criteria.
- Flexible and adaptable to dynamic decision-making scenarios.

Weaknesses:

- More complex and computationally intensive than AHP.
- Requires more data and expertise for constructing the network and conducting the pairwise comparisons.
- May become difficult to manage as the number of interdependencies grows.

Applications: Suitable for complex decision-making problems such as strategic planning, risk analysis, and multi-dimensional project management.

3.1.4 VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR)

Concept: VIKOR is designed for multi-criteria optimization and focuses on ranking and selecting alternatives that are closest to the ideal solution. The goal is to find a compromise solution that is the best for the majority of criteria.

Methodology:

- VIKOR uses a multi-criteria decision-making approach to rank alternatives by calculating a composite index that measures the proximity to the ideal solution, considering both the "group utility" and "individual regret" of each alternative.
- The VIKOR method combines a compromise programming approach with a ranking index that reflects both the ideal and non-ideal solution.

Strengths:

- Effective in handling decision problems with conflicting criteria.
- Allows for compromise between the best and worst alternatives.
- Can handle both qualitative and quantitative data.

Weaknesses:

- Requires normalization of data, which could affect the consistency of results.

- Assumes that there is a clear compromise among alternatives, which may not always be the case.
- More complex than simpler methods like AHP or TOPSIS.

Applications: VIKOR is typically used for problems involving decision-making in fields like environmental management, engineering design, and policy formulation, where a compromise solution is necessary.

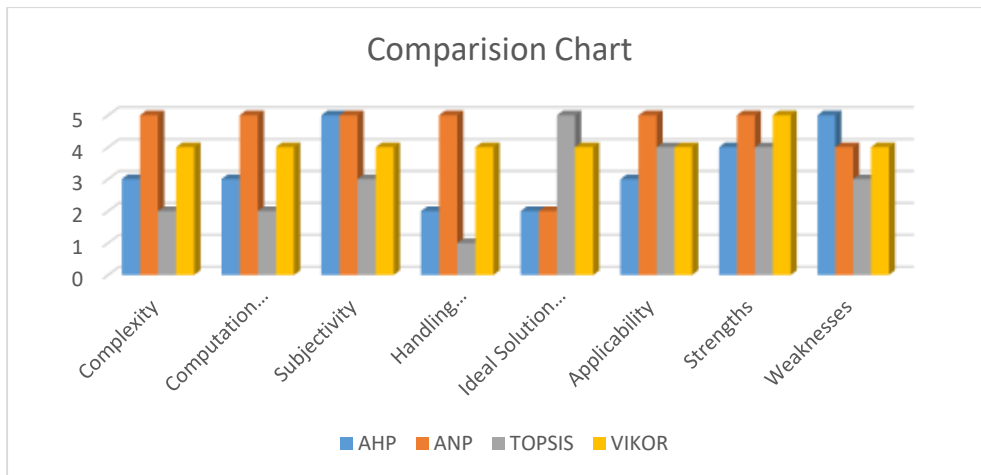
4. Key difference between Multi-Criteria Decision Making Approach and Comparison Chart

The following table 4.1 is the comparison key difference table for the traditional Multi-Criteria Decision Making Approach .

Table 4.1 Comparison table

Feature	AHP	TOPSIS	ANP	VIKOR
Method Type	Hierarchical	Ranking-based	Network-based	Compromise-based
Interdependencies	Does not handle interdependencies	Assumes independence of criteria	Handles interdependencies	Handles conflicting criteria
Data Requirements	Qualitative and quantitative	Quantitative	Qualitative and quantitative	Quantitative
Complexity	Moderate	Low	High	Moderate
Computation Complexity	Medium	Low	High	Medium
Subjectivity	High (pairwise comparisons)	Medium (dependent on normalization)	High (pairwise comparisons)	Medium (compromise)
Ideal Solution Focus	No specific focus	Ideal and negative ideal solutions	No ideal solution	Compromise between ideal and non-ideal
Applicability	Suitable for simpler decision problems	Suitable for problems with clear alternatives	Suitable for complex, interdependent systems	Suitable for problems needing a compromise solution
Strengths	Simple, widely used	Simple, computationally efficient	Can handle complex interdependencies	Compromise solution between alternatives
Weaknesses	Subjective, lacks handling of interdependencies	Sensitive to normalization, limited to measurable data	Complex, computationally intensive	Assumes compromise exists, sensitive to data normalization

The following chart figure 4.1, provides the give you a side-by-side comparison of the MCDM methods based on their attributes, where each bar represents how each method performs in terms of the specific attribute.

FIGURE 4.1 CHART ON MCDM METHODS

5. CONCLUSION

Each of these MCDM methods—AHP, TOPSIS, ANP, and VIKOR—has its own strengths and weaknesses, making them more suitable for different types of decision-making problems:

- **AHP** is best suited for simpler problems with hierarchical structures, where criteria and alternatives are relatively independent.
- **TOPSIS** is ideal for problems where alternatives are quantitatively comparable, and a straightforward ranking is required.
- **ANP** is more suitable for complex systems where criteria are interdependent and feedback effects exist.
- **VIKOR** excels in situations where a compromise solution is needed, particularly when criteria are in conflict.

The selection of the appropriate MCDM method should depend on the nature of the problem, the relationships between criteria and alternatives, and the decision-maker's priorities.

ACKNOWLEDGEMENT

I M KRITHIKA sincerely thank my supervisor, colleagues, and institution for their valuable support and guidance throughout this research. I also acknowledge the funding and resources provided, which significantly contributed to the successful completion and publication of this journal paper.

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