

Trends and Networks in the Application of MCDM Methods in Computer Science: Analysis of the Web of Science Database

Review Paper

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Abstract – This paper presents a comprehensive bibliometric analysis of scientific output in the field of Multi-Criteria Decision-Making (MCDM) within the context of computer science, focusing on the period from 2019 to mid-2025. Using data from the Web of Science Core Collection, a total of 302 relevant papers were identified based on criteria such as publication year, language, document type, open access status, and research area. The analysis covers publication dynamics, the most influential authors and institutions, thematic directions, and collaboration structures. Special emphasis is placed on citation analysis of the most impactful works, as well as the visualization of co-authorship networks using the PRISMA methodology and tools such as RStudio and Biblioshiny. The results reveal a growing trend in publications, high activity by certain authors (e.g., Akram M and Liu Y), and strong collaboration within research clusters. Dominant topics include decision-making models, alternative selection, aggregation operators, and priority evaluation. This study provides insights into the structure and dynamics of the scientific community engaged in MCDM methods in computer science and may serve as a guide for future researchers, practitioners, and scientific development strategies.

Keywords: Multi-Criteria Decision-Making (MCDM), Bibliometric Analysis, Computer Science, AHP, TOPSIS, VIKOR, Fuzzy Logic, Web of Science

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1. INTRODUCTION

In today's world, strongly shaped by digital transformation, information technologies, and pervasive automation, computer science plays a crucial role in solving complex problems that require systematic decision-making [1]. Decisions are increasingly made in contexts marked by uncertainty, resource limitations, and the presence of multiple conflicting criteria [2]. Under such

conditions, Multi-Criteria Decision Making (MCDM) emerges as a necessary methodological framework that enables analytical ranking, selection, and evaluation of alternatives based on clearly defined criteria [3]. Due to its flexibility and applicability, MCDM methods have found a solid foundation in various areas of computer science, from algorithm optimization and software evaluation to technology selection, resource planning, and large-scale data system management [4].

With the rapid development of artificial intelligence methods, machine learning, IoT technologies, natural language processing, and decision support systems, there is a growing need for structured and transparent decision-making approaches [5]. In this context, MCDM methods such as the Analytic Hierarchy Process (AHP), TOPSIS, VI-KOR, ELECTRE, PIPRECIA, and SWARA provide formal models that integrate both quantitative and qualitative criteria, allowing for a balance between technical performance, functional requirements, and system constraints [6]. These methods not only enable multidimensional problem analysis but also provide a basis for objectively comparing complex alternatives in real-time, with minimal risk of subjectivity [7].

Alongside methodological advancements, scientific output in the field of MCDM has seen a significant increase, indicating growing interest from the academic community [8]. However, due to its wide application and fragmented terminology, there is a need for mapping, systematizing, and critically analyzing the existing research to identify key trends, influential authors, institutions, journals, and thematic focuses. In this regard, bibliometric analysis emerges as an effective tool for quantitatively mapping scientific production and gaining insight into the structure, dynamics, and evolution of a specific research domain.

This study aims to provide a comprehensive overview of research activities related to the application of MCDM methods within computer science through bibliometric analysis. The focus is on analyzing publication trends over the past seven years (2019–2025), identifying the most influential authors and institutions, detecting key research topics, and evaluating collaboration networks. Using data from the Web of Science database and tools such as Biblioshiny, RStudio, and Excel, this paper offers an empirically grounded view of the state of the field and highlights directions for its future development [9].

The significance of this analysis lies not only in its descriptive representation of scientific output but also in its ability to offer researchers a clear orientation regarding strategic positioning within the research community, the selection of relevant journals, and the identification of thematic niches with innovation potential. Furthermore, the results of this study can serve as a foundation for meta-research syntheses, strategic research management, and the promotion of interdisciplinary and international collaboration in decision-making within computer science.

1.1. BACKGROUND AND IMPORTANCE OF THE TOPIC

Multi-Criteria Decision Making (MCDM) represents a class of quantitative methods that enable structured problem-solving in situations requiring the simultaneous consideration of multiple, often conflicting, criteria [3]. In today's information-driven society, simple

analyses are increasingly insufficient for making high-quality decisions, particularly in fields such as system design, risk management, algorithm selection, and performance evaluation [10]. MCDM methods have become essential in computer science because they offer the capability for precise, transparent, and replicable evaluation of alternative solutions' qualities that are especially critical in software engineering, computational intelligence, automation, and other related disciplines [4].

In this context, particular attention is given to methods such as AHP, TOPSIS, ELECTRE, VIKOR, PIPRECIA, and SWARA, which allow for the evaluation and ranking of alternatives based on weighted criteria [11, 12]. This makes them suitable for complex engineering and information technology applications. Their use in computer science spans a wide range from the selection of computer networks, algorithms, and system architectures to the analysis of security, energy efficiency, and user experience. The growing complexity of information systems and the need for decisions that integrate technical, functional, and operational factors further emphasize the value of the MCDM approach [4].

The significance of this topic is also reflected in the increasing volume of global scientific output. The large number of publications in recent years demonstrates not only the academic maturity of this field but also the expanding application of MCDM methods in real-world and interdisciplinary contexts. Therefore, a comprehensive bibliometric analysis is necessary to map the research landscape, identify major research streams, and provide a foundation for future strategic directions.

1.2. OBJECTIVES AND RESEARCH QUESTIONS

The main objective of this paper is to identify and analyze scientific publications related to the application of MCDM methods in computer science through bibliometric analysis, focusing on the period from 2019 to 2025. By applying quantitative methods of scientific production analysis, the study aims to present the main thematic directions, influential authors, institutions, and sources, as well as collaboration patterns that shape this field.

The specific research objectives are to:

- Map the volume and dynamics of scientific production related to MCDM methods in computer science
- Identify the most influential authors, institutions, and journals in the field
- Detect the most common research topics and key terms associated with the use of MCDM methods
- Analyze the citation impact of individual publications
- Examine the structure of collaborative networks among authors and institutions
- Based on these goals, the following research questions have been formulated

- What are the trends in publishing scientific papers on MCDM methods in computer science between 2019 and 2025?
- Which authors, institutions, and journals have the greatest influence in this field?
- What are the most common research topics and terms associated with the application of MCDM methods?
- Which papers have the highest citation impact, and how has their influence evolved?
- How are collaboration networks among researchers structured, and what are the key nodes of connection within these networks?

Answers to these questions will enable a deeper understanding of the current state of research and serve as a foundation for future studies and applications of MCDM methodology in computer science.

2. FUNDAMENTAL DEFINITIONS AND CONCEPTS OF MCDM METHODS

MCDM is an approach used for making decisions in situations where multiple options must be evaluated based on several criteria [13]. MCDM methods enable systematic analysis and comparison of different alternatives by taking into account their strengths and weaknesses with respect to defined evaluation criteria [14]. The core concepts include identifying relevant criteria, assigning weights to each criterion, and applying mathematical or heuristic models to rank or select the best options [15]. MCDM methods are widely used in fields such as management, engineering, and economics because they provide an objective and transparent basis for decision-making [16].

2.1. ANALYTIC HIERARCHY PROCESS (AHP)

The Analytic Hierarchy Process (AHP) is an MCDM method developed by Thomas L. Saaty in the 1970s [17]. The first significant work that formally describes AHP is "A scaling method for priorities in hierarchical structures", published in 1977 in the *Journal of Mathematical Psychology* [18]. AHP facilitates structural analysis of complex decisions by decomposing a problem into hierarchical levels, which typically include the overall goal, criteria, and alternative options [19].

Users first construct a hierarchy of the problem and then perform pairwise comparisons of the elements at each level of the hierarchy using a relative importance scale [18]. These comparisons allow for the calculation of weights for the criteria and for the alternatives. The outcome is a ranked list of alternatives based on their overall weighted scores.

AHP is particularly useful in decision-making scenarios that require the integration of subjective judgments and intuitive preferences, making it a valuable tool when both qualitative and quantitative data must be considered.

2.2. PIPRECIA METHOD

The PIPRECIA (Pivot Pairwise Relative Criteria Importance Assessment) method is an advanced technique for determining the weights of criteria through pairwise comparisons [20]. This method is relatively recent compared to other MCDM methods. The first work describing the PIPRECIA method is "A novel multi-criteria decision-making method: pivot pairwise relative criteria importance assessment (PIPRECIA)", authored by R.K. Pamučar and M. Čirović and published in 2015 in the journal *Operational Research in Engineering Sciences: Theory and Applications*. PIPRECIA involves iterative comparisons of criteria, where the relative weights are gradually adjusted based on mutual relationships. This method is especially useful in situations that require flexibility and adaptability in assigning criteria weights during the decision-making process.

2.3. TOPSIS METHOD

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is an MCDM method developed by Hwang and Yoon in 1981. [21]. The foundational work that describes this method in detail is the book "Multiple Attribute Decision Making: Methods and Applications", published in the same year [22]. The TOPSIS method is based on identifying a positive ideal solution (the best values for all criteria) and a negative ideal solution (the worst values for all criteria) [23]. Alternatives are ranked according to their distance from these ideal solutions. This method is particularly useful in scenarios where it is important to balance multiple criteria and choose the option that represents the most optimal combination of characteristics.

2.4. ELECTRE METHOD

ELECTRE (ELimination and Choice Expressing Reality) is a family of MCDM methods developed by Bernard Roy and collaborators [24]. The foundational work introducing the ELECTRE method is "Classement et choix en présence de points de vue multiples (La méthode ELECTRE)", published in 1968 [25]. ELECTRE methods use the principles of concordance and discordance to evaluate alternatives by establishing outranking relationships based on multiple criteria and eliminating those that do not meet specific thresholds [26]. ELECTRE is often applied to problems with conflicting criteria and where compromise solutions need to be identified. It is particularly valuable in situations characterized by high levels of uncertainty and complexity.

2.5. VIKOR METHOD

VIKOR (ViseKriterijumska Optimizacija i Kompromisno Rešenje - Multicriteria Optimization and Compromise Solution) is an MCDM technique developed by Opricovic and Tzeng [27]. The first significant publication describing the VIKOR method is "Compromise solution by MCDM methods: A comparative analysis of

VIKOR and TOPSIS”, published in 2004 in the European Journal of Operational Research [23]. VIKOR focuses on identifying a compromise solution that best satisfies the conflicting criteria. The method uses linear programming to rank alternatives based on their proximity to an ideal solution, taking into account both the weights of criteria and the degree of compromise. VIKOR is especially helpful in decision-making scenarios where finding a balanced trade-off among criteria is critical, particularly when there is uncertainty in setting criteria priorities [28].

2.6. SWARA METHOD

SWARA (Step-wise Weight Assessment Ratio Analysis) is an MCDM method developed by Kersuliene, Zavadskas, and Turskis [29]. The first significant work describing the SWARA method is “Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis (SWARA)”, published in 2010 in the Journal of business economics and management [29]. The SWARA method involves an iterative

assessment of the relative importance of criteria through a series of pairwise comparisons and successive adjustments of weights based on the outcome of each iteration [30]. SWARA supports decision-making processes that require accounting for changes in priorities and the importance of criteria over time [31]. This method is particularly useful in situations where criterion weights need to be dynamically adjusted to reflect evolving decision contexts.

3. RESEARCH METHODOLOGY

To achieve a systematic and comprehensive analysis of scientific output in the field of Multi-Criteria Decision Making (MCDM) within the domain of

computer science, this study applies a bibliometric methodology, with a particular focus on scientometric techniques and PRISMA (Fig. 1) guidelines [32]. This approach enables the quantitative mapping of scientific publications, identification of key researchers and themes, as well as the visualization of research networks and trends.

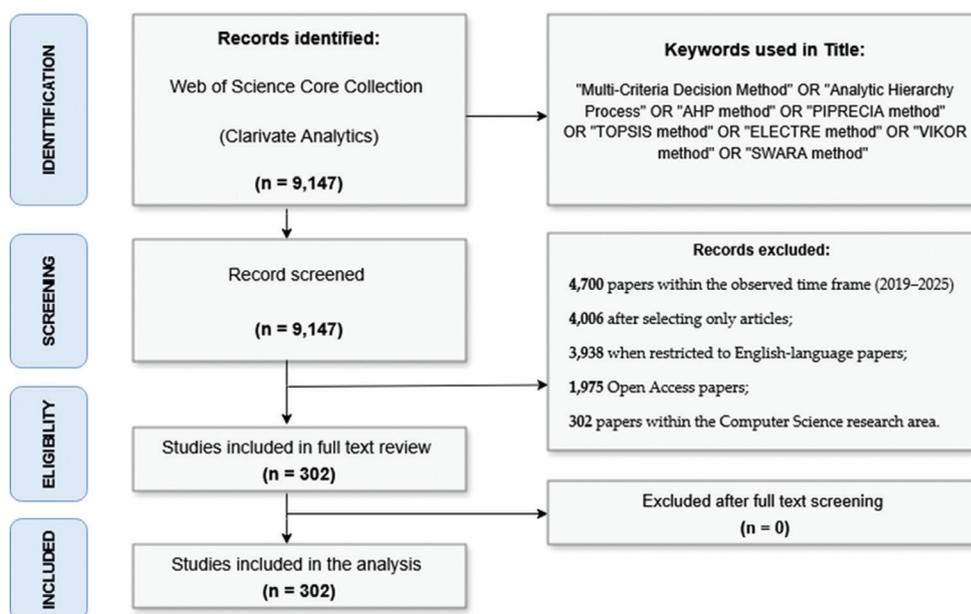


Fig. 1. PRISMA flowchart

3.1. DATABASE SELECTION

For the purpose of this study, the Web of Science Core Collection (Clarivate Analytics) was used as the primary database [33]. It is considered one of the most relevant sources for tracking scientific output in technical and engineering disciplines.

The search was conducted on June 15, 2025, and the selection of the WoS database is justified by its high relevance, standardized bibliographic records, and rich metadata necessary for conducting bibliometric analyses (including authors, institutions, citations, keywords, journals, etc.), as illustrated in Fig. 2.

3.2. DATABASE SELECTION

The search was conducted in line with the predefined thematic orientation, focusing specifically on MCDM methods within the field of computer science. The following terms were used in the search query:

"Multi-Criteria Decision Method" (Title) OR "Analytic Hierarchy Process" (Title) OR "AHP method" (Title) OR "PIPRECIA method" (Title) OR "TOPSIS method" (Title) OR "ELECTRE method" (Title) OR "VIKOR method" (Title) OR "SWARA method" (Title) All terms were searched within the titles of the papers to ensure specificity and to exclude publications that mention these methods only incidentally. The initial search yielded 9,147 results.

3.3. FILTERING CRITERIA AND RESULT REFINEMENT

Following the initial search, the following filtering criteria were applied to narrow down the focus to the most relevant publications:

- Publication years: 2019–2025.
- Document type: Articles only.
- Language: English only.
- Access type: Open Access only.
- Research area: Computer Science.

- After applying these filters, the number of results was successively reduced as follows:
- 4,700 papers within the observed time frame (2019–2025).
- 4,006 after selecting only articles.
- 3,938 when restricted to English-language papers.
- 1,975 Open Access papers.
- 302 papers within the Computer Science research area.

As shown in Fig. 3, these 302 papers comprise the final dataset analyzed in this study.

Completeness of bibliographic metadata - 302 documents from ISI

Metadata	Description	Missing Counts	Missing %	Status
AB	Abstract	0	0.00	Excellent
C1	Affiliation	0	0.00	Excellent
AU	Author	0	0.00	Excellent
CR	Cited References	0	0.00	Excellent
RP	Corresponding Author	0	0.00	Excellent
DI	DOI	0	0.00	Excellent
DT	Document Type	0	0.00	Excellent
SO	Journal	0	0.00	Excellent
LA	Language	0	0.00	Excellent
PY	Publication Year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total Citation	0	0.00	Excellent
DE	Keywords	32	10.60	Acceptable
ID	Keywords Plus	46	15.23	Acceptable
WC	Science Categories	302	100.00	Completely missing

Fig. 2. Completeness of bibliographic metadata



Fig. 3. Main data information

3.4. ANALYSIS FLOW ACCORDING TO THE PRISMA FRAMEWORK

The selection and screening process was conducted in accordance with the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), which require transparent reporting of the inclusion and exclusion flow of publications [33]. The PRISMA flow diagram (Fig. 1) illustrates the complete search and selection process, providing a clear overview of the steps taken from initial identification to the final inclusion of articles.

3.5. TOOLS AND ANALYTICAL APPROACH

The following tools were used for processing and visualizing bibliometric data:

- RStudio 2023.12.1 (Build 402) and Biblioshiny 4.1.4 – for conducting quantitative analyses, mapping thematic clusters, and generating network visualizations.
- Microsoft Excel v2407 – for additional data processing, tabular presentations, and the creation of summary diagrams.

- VOSviewer and Gephi (optional) – for advanced visualization of collaboration and citation networks.

This methodological framework ensures a comprehensive and reliable approach to identifying key research actors, thematic clusters, collaborative structures, and emerging trends in the domain of MCDM methods in computer science.

3.6. LIMITATIONS OF THE SEARCH AND METHODOLOGY

Although the search was carried out systematically and meticulously, with clearly defined criteria and adherence to the PRISMA framework, there are several important limitations to consider when interpreting the results:

- The analysis is based exclusively on the Web of Science database, thereby excluding relevant papers indexed in other databases such as Scopus, Google Scholar, IEEE Xplore, and Dimensions. As a result, some influential papers or authors may not be captured.
- The search query was limited to article titles, meaning studies that apply MCDM methods but do not mention them explicitly in the title (only in the abstract or body text) might have been omitted.
- The filtering by research area (Computer Science only) and language (English only) excludes potentially relevant interdisciplinary work or research published in other languages.
- The focus on Open Access publications may also affect the representativeness of the dataset, as some significant contributions may be found in subscription-based journals.
- Finally, data for the year 2025 only includes the first half (up to June 15), and the number of publications for that year is not final and should be interpreted with caution.

Despite these limitations, the applied methodological approach provides a solid foundation for conducting a reliable bibliometric analysis and enables the identification of key trends, influential contributors, and thematic directions within the dynamic field of MCDM methods in computer science.

4. RESULTS

This section provides a detailed overview of the key findings of the research, focusing on the analysis of the number of publications, influential authors, journals, and institutions in the field of Multi-Criteria Decision Making (MCDM). The analysis of publication trends and patterns contributes to a better understanding of the dynamics of research activity and identifies the main contributors to the advancement of this field.

4.1. GENERAL PUBLICATION TRENDS

The overview of general trends includes an analysis of the publication dynamics during the observed peri-

od, identification of key research areas, and prominent journals. The focus is on recognizing shifts in research interest and potential factors influencing fluctuations in publication volume, providing essential context for deeper result interpretation.

4.1.1. Publications

The number of publications per year reveals the dynamics of research activity in the field of MCDM in computer science over the past seven years. The analysis highlights oscillations in publishing intensity resulting from a combination of global events, institutional policies, resource availability, and evolving research interests.

From 2019 to 2022, a stable growth in publication volume was recorded:

- 2019: 40 papers.
- 2020: 37 papers.
- 2021: a notable increase to 53 publications.
- 2022: 53 publications again.

This continuity indicates a strong academic interest in applying MCDM methods to address complex problems in computer science. In 2023, a slight decline to 48 publications was observed, which may be attributed to a redistribution of research priorities or a delay between research execution and publication. However, 2024 marks a recovery, reaching a peak of 54 publications, suggesting a regained momentum and increasing interest in the topic.

For 2025, 17 publications were recorded by the data extraction date (June 15), representing only the first half of the year. This preliminary figure suggests continued researcher engagement, although results for this year must be interpreted with caution.

Fluctuations in publication volume may stem from factors such as reduced research funding, shifting funding priorities, or global crises such as the pandemic. On the other hand, a temporary decrease may prompt deeper and more focused studies with higher scientific contribution. Such a qualitative shift in research practice can enhance theoretical frameworks and promote the development of new methodological approaches in MCDM.

Despite annual variations, the overall trend remains positive, and the analysis confirms that MCDM in computer science continues to be a vital and relevant field, maintaining consistent research interest and potential for future development.

4.1.2. Number of Publications by Year

The year-by-year breakdown provides a detailed view of the trajectory and intensity of research activity in the field of MCDM methods within computer science. Changes in annual publication numbers reflect the impact of global conditions, evolving priorities, and availability of research resources.

2019: A total of 40 papers marked a strong start, indicating growing interest in applying MCDM methods in computing, largely driven by digital transformation and increasing system complexity.

2020: Publications slightly dropped to 37, likely influenced by the COVID-19 pandemic, which disrupted research cycles and publication dynamics.

2021: A sharp increase to 53 papers signals recovery from pandemic-related constraints and a growing reliance on quantitative and data-driven methodologies.

2022: The same total of 53 papers suggests stability and maturity in the application of MCDM techniques across various computing subfields.

2023: A modest drop to 48 papers may reflect a temporary reallocation of research funding or a shift toward emerging topics such as AI ethics and sustainable digital solutions.

2024: A new peak is reached with 54 publications, indicating renewed momentum and broader MCDM adoption in industry and academia, possibly aided by open data and increased global collaboration.

2025: 17 papers recorded by June 15. Although partial, this count points to a sustained interest, with expectations for a significant increase by the end of the year.

The overall publication trend (illustrated in Fig. 4) shows gradual growth between 2019 and 2025, with peak years in 2021 and 2024. While minor fluctuations are natural, the trend is overall stable and positive, affirming the relevance of MCDM in contemporary research and its necessity for further application and refinement.

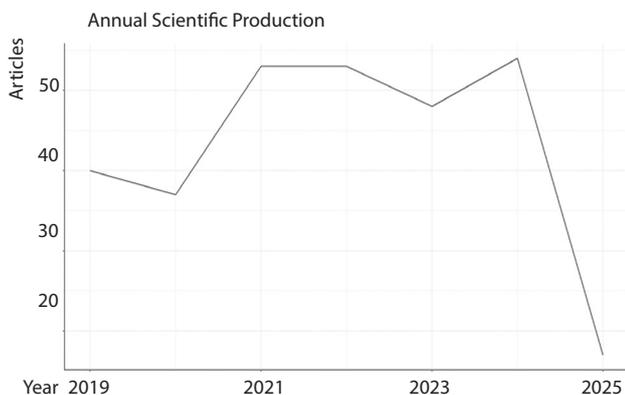


Fig. 4. Number of Publications by Year

4.1.3. Most Influential Journals

The analysis of publication sources provides insight into the most represented journals in which papers related to Multi-Criteria Decision Making (MCDM) in computer science are published (as shown in Table 1). This analysis helps identify the platforms that serve as the main channels for disseminating research findings and advancing the field. Below is an overview of the ten most represented journals based on the number of published papers:

Table 1. Top 10 leading publishers

No.	Journal	Number of Publications
1.	IEEE Access	74
2.	International Journal of Intelligent Systems	14
3.	Complex & Intelligent Systems	13
4.	Expert Systems with Applications	13
5.	ISPRS International Journal of Geo-Information	9
6.	Mobile Information Systems	9
7.	Soft Computing	9
8.	International Journal of Computational Intelligence Systems	8
9.	Scientific Programming	8
10.	Algorithms	7

IEEE Access, with 74 published papers, stands out as the most represented journal in the field of MCDM methods. Its broad thematic scope, open access policy, and fast peer-review process contribute to its popularity within the research community. This journal is particularly suitable for interdisciplinary studies that integrate decision-making methods with contemporary challenges in engineering and information technology.

International Journal of Intelligent Systems, Complex & Intelligent Systems, and Expert Systems with Applications rank among the leading journals by publication volume, with similar numbers of papers (13–14). These journals are known for their focus on artificial intelligence, computational intelligence, and the application of intelligent methods to real-world problems, making them ideal for publishing research that applies MCDM approaches.

In addition, a significant number of publications come from journals such as ISPRS International Journal of Geo-Information, Mobile Information Systems, and Soft Computing, indicating the broader application of MCDM methods in areas such as spatial information, mobile systems, and soft computing algorithms.

It is important to note that data on total citations and average citations per paper are currently unavailable, which somewhat limits a comprehensive assessment of these journals' impact. Nevertheless, the number of publications provides a clear picture of which journals serve as dominant platforms for research in this domain. Identifying the most prominent publication sources can help researchers choose appropriate journals for submitting future work and staying informed about current research trends. Focusing on these journals can contribute to greater visibility, wider readership, and stronger positioning of research findings within the global scientific community.

4.2. GENERAL PUBLICATION TRENDS

This section focuses on identifying the most influential authors and institutions shaping the development

of the Multi-Criteria Decision Making (MCDM) field. Analyzing research productivity, citation impact, and inter-institutional collaboration provides insight into the key factors contributing to scientific advancement, defining research trends, and disseminating results within this domain.

4.2.1. Key Author Analysis

Based on updated bibliometric data, two authors stand out as the most influential and productive in the MCDM field: Liu Y and Akram M (as shown in Fig. 5). Their research spans a wide range of MCDM applications, with a focus on integrating traditional decision-making techniques with modern approaches such as fuzzy logic, optimization, geoinformation technologies, and artificial intelligence.

Liu Y consistently appears as one of the most prolific researchers in this domain. His most cited work from 2019, "Distance Measure for Fermatean Fuzzy Linguistic Term Sets Based on Linguistic Scale Function: An Illustration of the TODIM and TOPSIS Methods" [34], published in the International Journal of Intelligent Systems, has garnered 76 citations, averaging 10.8 citations per year, confirming his strong influence in the area of fuzzy MCDM models.

Another 2019 publication on landslide susceptibility assessment using GIS and the AHP method (published in ISPRS International Journal of Geo-Information) has received 42 citations (6.0 per year), highlighting his contribution to spatial decision-making and the application of MCDM methods in geographic contexts. In the past three years, Liu Y has also published several

works applying extended MCDM approaches, including PSO-VIKOR, topological optimization, and AHP in the design of electric trucks and energy-efficient buildings. However, his 2024 article in Engineering Reports has not yet been cited, which is expected due to its recent publication.

Akram M stands out as the leading author in 2023 in terms of citation intensity. His article, "Enhanced ELECTRE II Method with 2-Tuple Linguistic M-Polar Fuzzy Sets for Multi-Criteria Group Decision Making" [35], published in Expert Systems with Applications, already has 35 citations, averaging 11.6 citations per year.

Two other works from the same year also show high impact:

- One on applying fuzzy ELECTRE for water system management (32 citations).
- Another on the selection of rehabilitation centers using M-polar fuzzy N-soft information (20 citations).
- Overall, Akram M demonstrates a very high annual citation rate, indicating not only the relevance of his research but also its strong practical applicability, especially in group decision-making and AI applications in healthcare.

Considering their publication output, annual citation rates, and multidisciplinary scope, these authors represent the core of contemporary MCDM research. Their contributions expand the theoretical foundation of decision-making methods and open new research directions through integration with intelligent systems, optimization, and applied statistics.

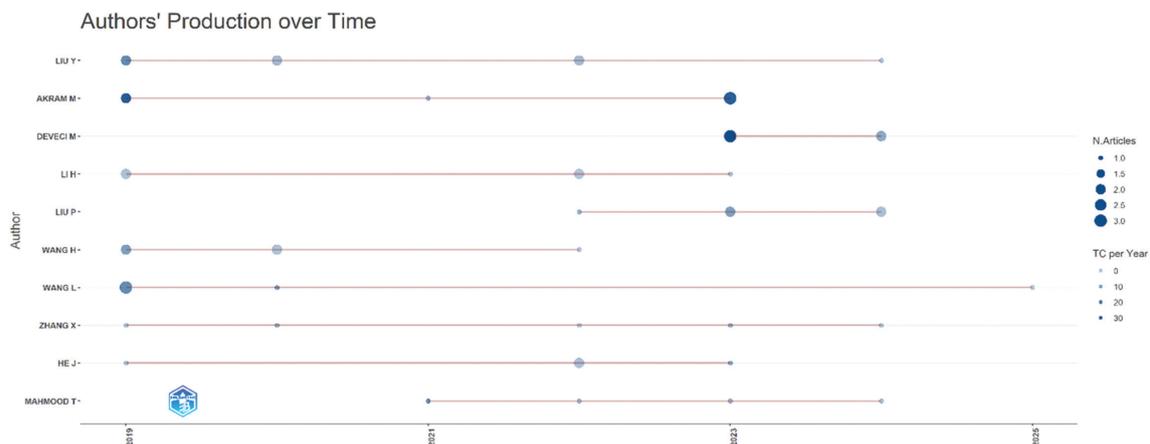


Fig. 5. Key Author Analysis

4.2.2. Key Author Analysis

The analysis of institutional research productivity in the field of MCDM indicates a clear increase in global interest (as shown in Table 2), with several universities contributing a significant number of publications. Based on the latest data, the ten most active institutions in terms of the number of published papers during the observed period are presented in the table below.

Three institutions share the top position in terms of publication count (11 papers each): King Mongkut's University of Technology Thonburi (KMUTT) from Thailand, National Defense University, and Sichuan University from China. Their leading positions indicate significant and ongoing dedication to research in decision theory, with particular emphasis on the application of MCDM methods in contexts such as engineering, security, and analytical systems.

Table 2. Top 10 leading publishers by publications

No.	Institution (Affiliation)	Number of Publications
1.	King Mongkut's University of Technology Thonburi (KMUTT)	11
2.	National Defense University	11
3.	Sichuan University	11
4.	University of the Punjab	10
5.	University of Salamanca	10
6.	Air Force Engineering University	9
7.	International Islamic University Islamabad	9
8.	Islamic Azad University	9
9.	Jiangxi University of Finance and Economics	9
10.	Budapest University of Technology and Economics	8

University of the Punjab (Pakistan) and University of Salamanca (Spain), each with 10 publications, highlight the geographical diversity of research and point to the wide international dissemination of knowledge in this field. Both institutions demonstrate consistent productivity, likely supported by multidisciplinary research teams and international collaborations.

Other notable institutions on the list include Islamic Azad University, International Islamic University Islamabad, and Air Force Engineering University, which have previously been recognized as key contributors in this field. Their continued presence among the most productive institutions reflects a stable research strategy and a sustained focus on the development and implementation of MCDM methods.

Although Jiangxi University of Finance and Economics and Budapest University of Technology and Economics, with 9 and 8 papers respectively, have slightly fewer publications, their inclusion in the list signals a growing interest in applying multi-criteria analysis in economic and technical domains.

It is important to note that this analysis covers only the quantitative aspect (number of publications), while qualitative metrics such as citation count and research impact are not included. Nevertheless, these figures offer a reliable insight into the institutions that contribute the most to advancing knowledge and promoting the use of MCDM approaches in computer science.

4.3. ANALYSIS OF MAIN RESEARCH TOPICS AND APPLICATION AREAS

The analysis of keyword frequency in titles and abstracts allows for the identification of the most frequently studied topics in the MCDM field (shown in Fig. 6), as well as insight into their evolution over time. Based on the analysis of term frequency and their occurrence quartiles (Q1 – initial presence, Q2 – peak frequency year, Q3 – end of active phase), several thematic focuses emerge:

The most frequent terms include model (47 occurrences), selection (36), sets (31), decision-making (30), AHP (29), and aggregation operators (23). These terms

represent the core foundations of current MCDM research, indicating the prevalent use of decision-making models in alternative selection, work with various data sets, and a theoretical-operational base grounded in methods like AHP and aggregation theory.

Terms such as ranking (14), criteria (11), and weights (6) have become more prominent during the 2022–2024 period, suggesting a growing interest in sophisticated ranking techniques and weight optimization in the evaluation of alternatives. The relevance of expressions like multicriteria decision-making and priorities, which appear predominantly between 2022 and 2024, reflects a focus on formalizing priorities and the importance of criteria in increasingly complex problem domains.

Interestingly, terms such as extension (20) and aggregation operators have been active since as early as 2019, indicating that extending existing methods and developing new aggregation functions were among the top research priorities even in the early stages of the observed period. Methods such as VIKOR (9) and concepts like information (11) also hold a stable position within the thematic network, reaffirming the importance of multi-criteria compromise decision-making and the growing integration with information systems and data management.

The analysis of key terms confirms that MCDM research has evolved from foundational structural models and classical methods (such as AHP and VIKOR) toward more complex approaches involving criteria prioritization, weight management, and extended versions of existing methods. The increased frequency of terms related to selection, ranking, and aggregation points to a high level of practical application in domains such as engineering decision-making, system performance evaluation, and intelligent informatics frameworks.

These findings confirm that the field of multi-criteria decision-making is continuously expanding and adapting to the demands of modern problems, relying on mathematical formalization, heuristic approaches, and intelligent models to support decision-making under conditions of complexity and uncertainty.

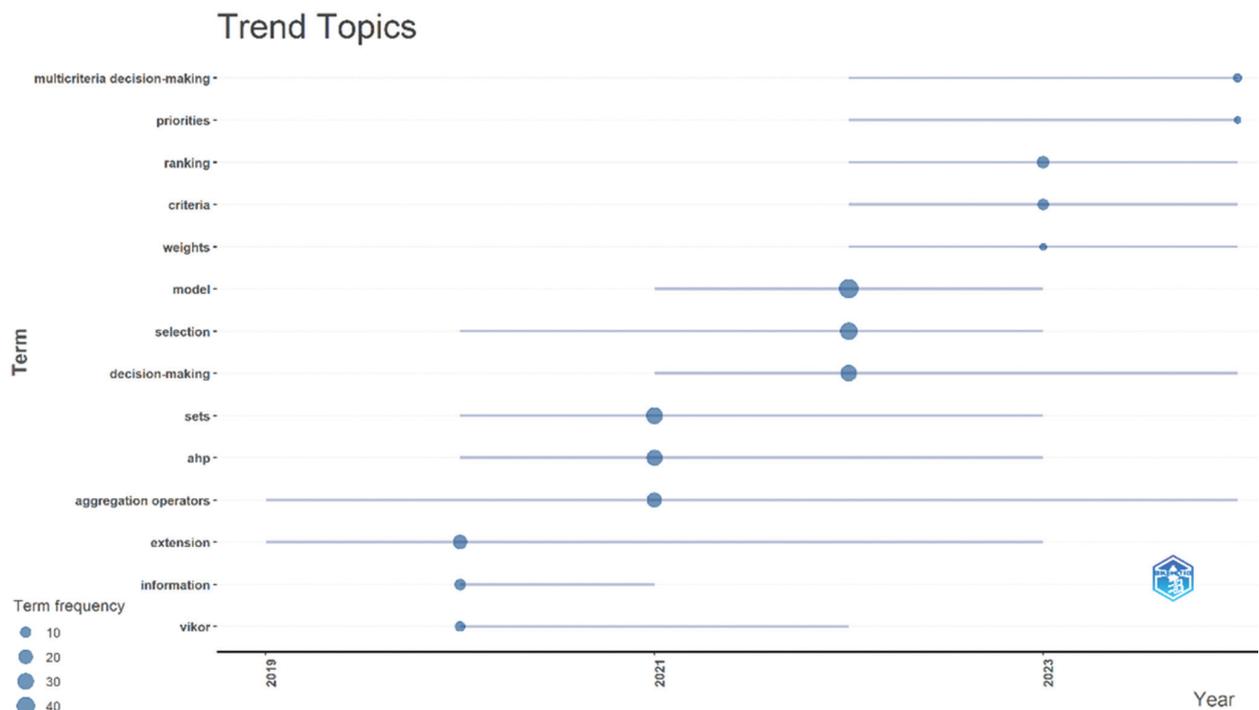


Fig. 6. Trend topics

4.4. CITATION ANALYSIS: IDENTIFYING THE MOST INFLUENTIAL PAPERS AND AUTHORS

Citation analysis is a key element in identifying the most influential authors and publications in the MCDM field. By using metrics such as total citation count, average citations per year (TC/year), and normalized citation count (Normalized TC), it is possible to highlight the papers that have a long-term and global impact on the development of this discipline (as shown in Fig. 7).

According to the analysis, the most cited paper in the dataset is a 2019 article by Akram M, published in the International Journal of Intelligent Systems (DOI: 10.1002/int.22103), with 172 total citations and an average of 24.5 citations per year, confirming its sustained relevance. Moreover, its normalized citation value (5.54) indicates that this work is widely used as a reference in numerous studies.

Another standout publication is the 2024 paper by Moslem S, published in Engineering Applications of Artificial Intelligence, which, despite its recency, has already reached 85 citations in less than two years (averaging 42.5 per year) with a normalized TC of 18.14, making it the most intensely cited work over a short timeframe. This reflects its high relevance and rapid integration into ongoing research.

Other significant papers include:

- Chan HK (2019) – Decision Support Systems (DOI: 10.1016/j.dss.2019.113114): 120 citations, 17.1 per year, Normalized TC: 3.86.
- Mohammed MA (2020) – IEEE Access: 115 citations, 19.1 per year, Normalized TC: 5.21.

- Alkan N (2021) – Applied Soft Computing: 94 citations, Normalized TC: 4.35.
- Al-Shami TM (2023) – Two papers in Complex & Intelligent Systems and Information with high normalized citation counts: 5.59 and 4.94, respectively.

Among authors with multiple influential publications, Liu D stands out with two papers in the International Journal of Intelligent Systems, published in 2019 and 2020 (with 76 and 69 citations, respectively), confirming his consistent contribution to the fields of fuzzy logic and intelligent systems.

Additionally, a considerable number of high-impact papers are published in journals such as IEEE Access, Expert Systems with Applications, Engineering Applications of Artificial Intelligence, and Applied Soft Computing, underlining their central role in disseminating MCDM research results.

Beyond total citations, the normalized citation count is a crucial metric for comparing the impact of papers published in different years, as it adjusts for the time advantage older publications have. Hence, papers from 2023–2024 with high normalized values can be considered emerging references in the coming years.

In conclusion, the citation analysis reveals that the most influential papers cover a wide spectrum of topics from group decision-making and fuzzy logic to artificial intelligence applications and real-world solution evaluation. These works are shaping the theoretical foundations, methodological innovations, and practical implementations of MCDM approaches in modern research.

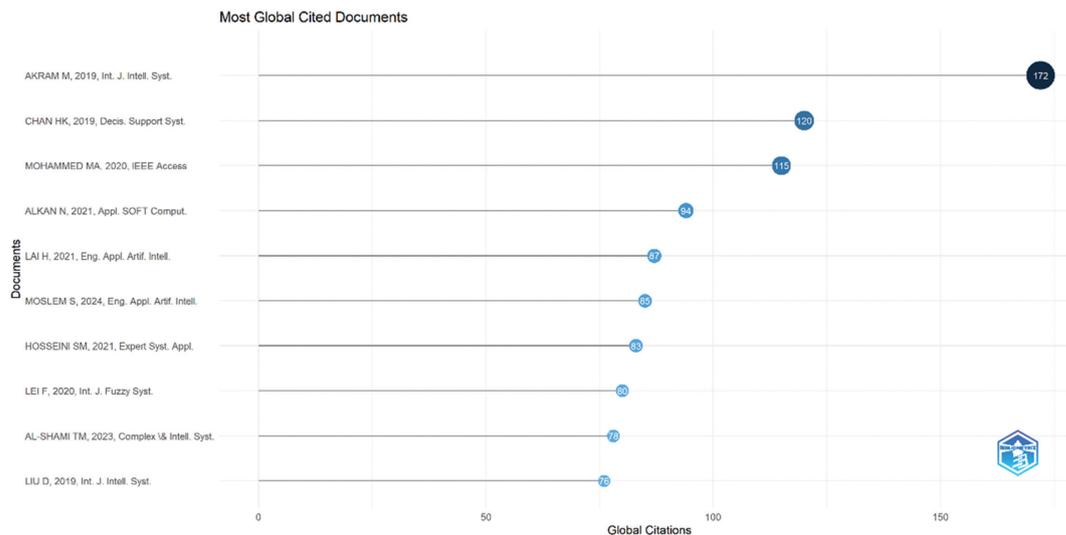


Fig. 7. Most Global Cited Documents

4.5. NETWORK ANALYSIS: COLLABORATION AMONG AUTHORS AND INSTITUTIONS

Network analysis enables the identification of collaboration patterns among researchers, highlighting key authors and institutions that act as connectors and hubs of influence in the MCDM field (as shown in Fig. 8). The analysis was conducted using network metrics such as betweenness centrality (intermediary importance), closeness centrality (network proximity), and PageRank (influence based on connectivity).

Based on cluster analysis, several research groups have been identified as shaping the global MCDM community:

Cluster 1 – “Li-Wu-Xu-Chen” Network

This group is led by authors such as Li F (betweenness: 69), Li J, and Wu Y, known for their high interconnectedness and strategic network positioning. This cluster likely represents strong regional collaboration within Chinese institutions, with a focus on applications of AHP and GIS in decision-making. Their proximity in the network reflects frequent co-authorship and mutual citation.

Cluster 2 – “Wang-Li-Xu-Zhang” Network

The largest cluster by number of authors includes some of the most influential figures, such as Wang Y (betweenness: 124.46, closeness: 0.017), Wang Z (120), Li Q, Xu J, Zhang C, and Wang Q. These authors form a dense collaboration network with high centrality, indicating their key role in bridging various research subgroups. Their high PageRank and closeness values further affirm their visibility and role in knowledge dissemination within the community.

Cluster 3 – “Liu-Zhang” Group

Led by Liu Y, Liu P, Liu D, Zhang X, and Li Y, this cluster exhibits strong internal collaboration, especially through work linking MCDM with fuzzy logic, heuristic methods, and complex decision-making models.

Notably, Zhang X has a high PageRank (0.0356), while Liu Y plays a crucial intermediary role (betweenness: 60.52), positioning him as a central figure in the global research network.

Cluster 4 – “Akram-Deveci-Alcantud” Network

Dominated by Akram M, who has a high closeness centrality (0.0417) and a solid PageRank (0.0265), this cluster highlights his role as a key actor in international collaborations. Alongside Deveci M, Mahmood T, Al-Kenani AN, and Alcantud JCR, the group focuses on group decision-making, fuzzy sets, and the application of ELECTRE and VIKOR methods in practical domains such as healthcare and resource management.

Cluster 5 – “Moslem-Duleba”

This smaller cluster includes Moslem S and Duleba S, with relatively lower centrality values but recognizable contributions in applied studies, likely in the areas of urban planning and spatial analysis using MCDM techniques.

Clusters 6 and 7 – “Kumar-Agrawal” and “Salabun-Watroski”

These clusters include authors like Kumar R, Agrawal A, Salabun W, Wieckowski J, and Kizielewicz B, with high closeness centrality (up to 1.0 for Cluster 6 and 0.333 for Cluster 7), but lower PageRank and betweenness values. This suggests that they are positioned in peripheral yet internally cohesive research groups, likely working on specialized methodologies within national or institutional research projects.

The network analysis reveals that the MCDM research community is structured around clearly defined centers of influence and strong collaborative links, with key hubs connecting different knowledge clusters. Authors with high betweenness centrality play a critical role in knowledge transfer across groups, while those with high PageRank values indicate greater global visibility and impact on research directions.

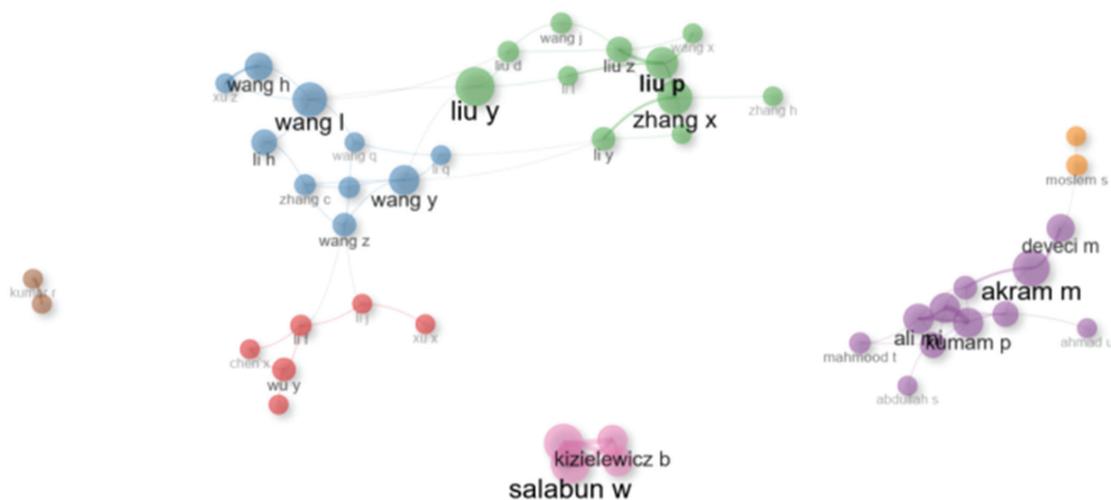


Fig. 8. Collaboration Among Authors and Institutions

5. DISCUSSION

The discussion of recent findings in the MCDM field reveals several important trends and insights that shed light on the dynamics of scientific activity during the period from 2019 to mid-2025. Quantitative data on publication output indicate steady growth in research interest, with peaks in 2021 and 2024, and slight declines in 2020 and 2023. Notably, even in the first half of 2025, there is evident research activity with 17 published papers, suggesting that the current year will also be productive. This trend shows that the MCDM domain remains highly relevant despite global challenges such as the COVID-19 pandemic, economic uncertainty, and shifts in research priorities.

Citation analysis further confirms the importance of specific authors and publications. Akram M stands out with the most cited paper from 2019 (172 citations), while Moslem S demonstrates an exceptionally high citation rate (42.5 citations per year) for his 2024 publication and holds the highest normalized citation value (18.14), despite the short time since publication. These findings confirm that high research impact can be achieved in a short time when the topics are innovative and practically relevant. The cited works span diverse applications of MCDM approaches from healthcare, energy efficiency, and urban planning to soft computing systems and intelligent platforms, highlighting the transdisciplinary nature of the methodology.

In terms of research topics, the analysis of key terms reveals a shift in researchers' focus over time from classical methods such as AHP and VIKOR toward extended models, complex aggregation operators, and strategies for ranking, criteria weighting, and option selection. Dominant terms like model, decision-making, and selection confirm the practical orientation of research toward the development of methodological frameworks for solving real-world decision problems. Newer terms like priorities and multicriteria decision-making, especially prevalent during 2023–2024, reflect a grow-

ing need to formalize decision hierarchies in increasingly complex systems.

Similar conclusions are supported by the analysis of key institutions. KMUTT, National Defense University, and Sichuan University emerge as leading research institutions, each with 11 publications. Their top rankings suggest systemic support for decision-making research and well-organized research teams. Other highly active institutions include the University of the Punjab, Islamic Azad University, and University of Salamanca, highlighting global coverage and collaboration in this scientific domain.

Additional insights into collaboration are provided by the network analysis of authors and institutions, which identified key collaboration clusters. For instance, the “Wang–Li–Zhang” cluster demonstrates strong internal connectivity and a high degree of centrality, enabling effective knowledge transfer within the network. Wang Y shows the highest betweenness centrality (124.46), positioning him as a “bridge” between different research groups. Akram M, in a separate cluster, also has a high closeness centrality and PageRank, confirming his role as a central figure in the global MCDM network. The presence of authors with high local centrality (e.g., Moslem S, Zhang X, Liu D) points to highly influential micro-clusters generating specialized knowledge.

This comprehensive analysis demonstrates that the MCDM field is dynamic and expanding, with stable growth in publication volume, high citation levels for key works, and increasingly diverse geographic and thematic coverage. Despite fluctuations caused by global events, it is evident that MCDM methods remain essential tools for solving complex problems in computer science and beyond.

For future research, it is recommended to:

- continue monitoring normalized citation scores of newer works;
- identify emerging topics through trend analysis of key terms;

- conduct expanded network analyses with a focus on international projects and co-authorship networks.

Additionally, integrating qualitative approaches, such as content analysis and assessments of methodological quality, could complement quantitative findings and contribute to a deeper understanding of the impact and relevance of MCDM research.

6. CONCLUSIONS

This bibliometric analysis provides a comprehensive overview of research activity in the field of Multi-Criteria Decision Making (MCDM) in computer science from 2019 to mid-2025. Based on the analysis of 302 publications extracted from the Web of Science database, key trends, authors, institutions, research topics, and collaboration networks shaping the field have been identified. The total number of publications indicates a steady and growing interest from the research community, with notable peaks in 2021 and 2024, while preliminary data for 2025 already demonstrate continued productivity. This quantitative trend reinforces the increasing use of MCDM methods in solving complex problems, especially in areas such as artificial intelligence, resource optimization, urban planning, and information security.

The citation analysis highlights the most influential papers and authors, notably Akram M, Moslem S, and Liu D, whose works combine classical MCDM techniques with advanced approaches such as fuzzy sets, group decision-making, and hybrid models. Papers published in 2023 and 2024 are already achieving high citation rates, suggesting rapid recognition of quality and relevance in recent research. The most frequently studied themes include terms such as model, decision-making, selection, aggregation operators, AHP, and ranking, reflecting a focus on practical applications and algorithmic frameworks for complex system evaluation. The rising use of terms like multicriteria decision-making and priorities in the last two years reflects a deepening of both theoretical and operational aspects of the field.

Key institutions KMUTT, National Defense University, Sichuan University, University of the Punjab, and Islamic Azad University, emerge as regional centers of expertise and collaboration. Network analysis further illuminates the structure of academic cooperation, with authors such as Wang Y, Zhang X, and Akram M occupying central positions within interconnected clusters.

The findings of this study not only confirm the steady growth of the MCDM field but also point to the key contributors, thematic directions, and institutional hubs that are likely to shape its future development. This analysis serves as a reference point for researchers and institutions aiming to position themselves within the global MCDM community, and as a foundation for strategic planning in scientific projects and international collaborations.

6.1. SIGNIFICANCE AND SCIENTIFIC CONTRIBUTION

The significance of this study lies in its ability to map the entire research structure of MCDM methods through quantitative indicators. The analysis highlights the most active authors, most cited papers, key institutions, and leading journals, offering a valuable tool for researchers seeking to understand thematic and network flows in the field. The work also contributes to the identification of dominant thematic trends, including AHP, VIKOR, fuzzy sets, aggregation operators, and alternative evaluation.

Beyond academic value, the results offer practical insights for researchers and decision-makers, helping them identify reliable sources of knowledge, high-potential research niches, and valuable collaborators. In this way, the study not only reflects the current landscape but also encourages strategic planning, resource optimization, and increased international visibility for both domestic and regional scholars.

6.2. RESEARCH LIMITATIONS

Despite its comprehensive approach, this study has several methodological limitations. The analysis relies solely on the Web of Science database, which may exclude important contributions indexed in Scopus, Google Scholar, or Dimensions. Additionally, data for 2025 covers only the first half of the year, making results for this period incomparable to full-year data from previous years.

The study is predominantly quantitative, lacking a deeper qualitative evaluation of the most cited papers, which could enhance the understanding of their scientific contributions and methodological rigor. Moreover, citation normalization does not account for disciplinary differences in citation behavior, which may impact the objectivity of comparisons between authors from different domains.

6.3. RECOMMENDATIONS FOR FUTURE RESEARCH

Future studies should consider incorporating data from multiple databases to gain a more comprehensive view of global scientific output. Combining quantitative bibliometrics with qualitative content analysis would provide deeper insights into the impact and value of the most cited works. Researchers are also encouraged to follow emerging interdisciplinary trends, such as the application of MCDM in AI, cybersecurity, energy efficiency, and smart cities.

Time-series analyses of keyword trends and thematic shifts can help detect new research niches early. Particular attention should also be given to network dynamics to identify authors with key intermediary roles in connecting different research communities. Lastly, fostering international and interdisciplinary collaboration remains one of the most critical factors for the continued growth and evolution of the MCDM field.

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