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A Comprehensive Bibliometric Analysis of Objective Weighting Methods in Multi-Criterion Decision-Making

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ABSTRACT

Objective weighting methods have gained significant importance in the field of Multi-Criteria Decision Making (MCDM) due to their ability to determine criterion importance based on data-driven characteristics, thereby minimizing subjective bias. This study aims to examine the evolution, intellectual structure, and global research trends of objective weighting methods by conducting a comprehensive bibliometric analysis of 23,684 publications in the Web of Science (WoS) database from 1990 to 2025. The findings show significant and accelerating growth in scientific output, particularly after 2017, along with a rapid expansion of research interest in this area. Keyword analysis identified the Entropy method as the most dominant and frequently used approach, with 1,712 occurrences, significantly outperforming other methods. Co-authorship analysis reveals that China leads in both publication output (8,711 documents) and citation impact (127,032 citations), while the United States demonstrates the highest level of international connectivity, occupying a central position in global collaboration networks. At the institutional level, the Chinese Academy of Sciences stands out as the most influential organization. Citation analysis also highlights De Boer *et al.* (2005) pioneering work as the most cited publication in the field. Journal and publisher analysis shows that IEEE Access is the leading journal in terms of publication volume, while MDPI is the most prolific publisher. Furthermore, the results demonstrate a strong correlation between objective weighting studies and sustainability-focused topics, particularly Sustainable Development Goal 13 (Climate Action), followed by Sustainable Development Goals 3 and 11. Overall, this study provides a structured and comprehensive overview of the global research landscape of objective weighting methods in the field of MCDM, offering valuable insights for future research directions and methodological advancements.

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1. Introduction

MCDM involves evaluating and ranking alternatives for a given problem based on multiple criteria, making it sensitive to the influence of criterion weights. In MCDM scenarios, alternatives often produce similar utility scores, leading to uncertainty for the decision-maker and, potentially, indecision. This uncertainty may raise questions about the accuracy of the criteria weight assessment, as human judgment is inherently prone to error. Objective methods typically address this by considering either the variability introduced by the criteria or the conflicts that arise among them. A criterion conveys information about the level of data dispersion; when it assigns equal scores to all alternatives, it yields redundant information [1]. The optimal value, often called the best solution, is identified through the optimization process. These problems center on finding maximum or minimum values and can be classified as single- or multi-objective [2].

In many MCDM problems, assigning weights to criteria is a crucial step that requires careful consideration. Determining these weights represents one of the primary challenges within the MCDM process. In objective weighting methods, the weights assigned to each criterion are derived from data obtained through mathematical models, without incorporating any input from the decision maker [3]. Additionally, MCDM approaches are increasingly recognized for their effectiveness in identifying optimal solutions across a variety of fields, including economics, engineering, medicine, and education. Two critical components of MCDM are selecting appropriate methods to determine criterion weights and identifying the most suitable MCDM techniques for implementation. These choices play a significant role in influencing the ranking of various alternatives. Methods for establishing weights can be classified into three categories: subjective, objective, and combined (also known as hybrid). Among these, objective methods are the most widely used, as they help minimize the impact of decision-makers' subjective judgments on the allocation of criterion weights [4].

1.1. The Significance of Objective Weighting Methods in Decision Making

The objective method assigns weights based on available evaluation data using mathematical models, independent of the decision maker's preferences. These methods can be especially useful when the decision maker is unavailable or when the subjective weights derived from their input lack consistency [5]. The literature examines various objective weighting methods, including Entropy, CRITIC, MEREC, LOPCOW, CILOS, IDOCRIW, SD, and MPSI.

The Entropy method, initially developed in thermodynamics, was introduced into information theory by Shannon in 1948. Entropy measures the degree of disorder in a system. Higher entropy values indicate greater randomness, leading to less information being conveyed by the data. This method is valuable for evaluating uncertainties and assessing the potential value of the information that data can provide [6,7]. Furthermore, the Entropy method has become the most widely used objective approach for determining criterion weights.

The CRITIC method, introduced by Diakoulaki *et al.* [8] is a significant weighting technique for determining attribute objective weights. This approach uses both the standard deviation and the correlation coefficient between a specific criterion and other criteria to assess the importance of each feature, ultimately causing the respective attribute weights [8,9]. The CRITIC method is recognized as one of the most widely adopted objective approaches for determining criterion weights.

The MEREC method, introduced by Keshavarz-Ghorabae *et al.* [10] calculates criterion weights by evaluating the removal effects of each criterion on the overall performance of alternatives. In this approach, a criterion receives a higher weight if its exclusion significantly affects the aggregate performance of the other options. Additionally, MEREC has demonstrated greater efficiency as an objective weighting technique when compared to CRITIC and Entropy [10,11].

The LOPCOW method, developed by Ecer and Pamucar [12], offers several advantages, including eliminating discrepancies due to data size, producing more balanced weightings, and incorporating both positive and negative data into the weighting process. As an objective weighting technique, LOPCOW addresses the variances commonly observed in entropy-based approaches, causing criterion weights that are not only more reliable but also more acceptable [12,13].

The CILOS method, developed by Zavadskas and Podvezko [14], provides an objective framework that accounts for the diminishing importance or impact of criteria as they approach their optimal maximum or minimum values. In this method, a minor relative loss of effectiveness for a criterion results in a greater weight, while a larger relative loss leads to a lower weight. This approach contrasts with the ENTROPY method, which operates in the opposite direction. One of the key advantages of CILOS is its ability to overcome a limitation inherent in the ENTROPY method [14,15].

The IDOCRIW method, proposed by Zavadskas and Podvezko [14], combines the most effective aspects of the Entropy method with the CILOS approach. This integrated weighting technique addresses the issue of criterion weight disparity commonly associated with the Entropy method. Additionally, it eliminates the need for expert opinions, thereby resolving concerns about both consistency and inconsistency [14,16].

The standard deviation (SD) has recently emerged as a valuable validation tool for MCDM methods. A first study by Zaidan *et al.* [17] utilized the SD approach by normalizing the final MCDM scores and calculating SDs for comparative analysis. The authors underscored the significance of normalization in drawing robust conclusions from the varying scores produced by different criteria. Additionally, they recommended using a broader distribution, as indicated by a higher SD, to more effectively highlight the distinctions among the methods [18].

The MPSI method, developed by Gligorić *et al.* [19] provides a novel approach for objectively determining weight coefficients in various MCDM problems. This method builds on the traditional Preference Selection Index (PSI) by presenting a refined version that requires minimal modifications. These adjustments primarily focus on streamlining a specific step within the original PSI methodology. This subtle enhancement results in a significant improvement in the final values of the weight coefficients, bringing them closer to those produced by other objective weighting methods [19].

1.2. Objective of the Current Study

The objective of this study is to systematically investigate the intellectual framework, publication trends, and thematic developments encompassing objective weighting methods for MCDM, including ENTROPY, CRITIC, MEREC, LOPCOW, CILOS, IDOCRIW, SD, and MPSI. A comprehensive bibliometric analysis is conducted using data from the Web of Science database, with the evaluation aided by VOSviewer to explore key trends and insights across the relevant fields. Specifically, this research aims to:

Examine Trends: Examine and assess the evolution of objective weighting methods in MCDM, emphasizing techniques such as ENTROPY, CRITIC, MEREC, LOPCOW, CILOS, IDOCRIW, SD, and MPSI-consideration to their methodological advancements and the patterns of their application across various domains.

Assess Research Impact: Analyze the academic impact of key publications, notable authors, and leading journals that contribute to the literature on objective weighting techniques in MCDM. This analysis should include an exploration of citation trends, highly cited articles, and primary publication sources.

Map Research Networks: Investigate co-authorship, institutional collaborations, and national partnerships to reveal the intellectual framework and international research landscape surrounding objective weighting methods in MCDM. Highlight significant research clusters and collaborative connections within this field.

1.3. Novelty of the Current Study

This research offers a comprehensive bibliometric analysis of the utilization of objective weighting methods within the field of MCDM. It provides valuable insights into current trends and methodologies in this area. The novelty of the current study lies in its in-depth exploration of the evolution of objective weighting methods in MCDM, highlighting emerging trends, key research articles, and significant gaps in the existing literature. By employing advanced bibliometric tools and databases, this study examines a significant corpus of publications, revealing noteworthy patterns and shifts in research focus over time.

1.4. Organization of the Study

The rest of this paper is organized as follows: The second section offers a comprehensive review of the current research landscape. The third section describes the data and methodological framework employed in the study. In the fourth section, we present the findings obtained from a bibliometric analysis. Lastly, the fifth section concludes with a summary of our results, recommendations, and implications for future research.

2. Literature Review

In the last few decades, there has been a notable increase in bibliometric studies that systematically analyze the evolution, structure, and scholarly impact of MCDM research across various disciplines. These studies offer a comprehensive overview of intellectual advancements in the MCDM field by identifying key research themes, highly cited authors, foundational works, and emerging research directions. In this context, Table 1 summarizes significant bibliometric studies in the MCDM literature.

Table 1
 Summary of Previous Bibliometric Studies on MCDM

Author(s)	Research Title	Database	Software	Key Findings
[20]	Multi-criteria decision analysis (MCDA) in health care: A bibliometric analysis	Medline, PubMed, WoS, Biosis	Matheo Analyzer	The results indicate a significant increase in MCDA applications in healthcare, with healthcare resource allocation emerging as the most dominant research topic.
[21]	A bibliometric data analysis of multi-criteria decision-making methods in heritage buildings	Web of Science	VOSviewer	The findings reveal that AHP and fuzzy AHP, along with Delphi and fuzzy Delphi methods, are the most frequently used MCDM techniques for assessing cultural heritage value.
[22]	Bibliometric studies on multi-criteria decision analysis (MCDA) applied in personnel selection.	Scopus	Webibliomining	The analysis shows that fuzzy-logic-based approaches are the most widely used methodologies in personnel selection problems.
[23]	A bibliometric review on the application of fuzzy optimization to sustainable energy technologies	Web of Science	VOSviewer	The results indicate a substantial increase in publications on fuzzy optimization methods in sustainability and energy technology research.

Table 1
 Continued

Author(s)	Research Title	Database	Software	Key Findings
[24]	Bibliometric studies on multi-criteria decision analysis (MCDA) methods applied in military problems	Scopus, Web of Science	VOSviewer, R package	The findings demonstrate that the Analytic Hierarchy Process (AHP) is the most frequently applied MCDA method in military-related studies.
[25]	Bibliometric analysis of MCDM methods in the last decade: WASPAS, MABAC, EDAS, CODAS, COCOSO, and MARCOS	Scopus, Web of Science	R package	The results show that Türkiye and India rank among the top five countries in terms of publication output across the analyzed MCDM methods.
[26]	Sustainable supplier selection through multi-criteria decision making (MCDM) approach: A bibliometric analysis	Scopus	VOSviewer	The findings indicate that the literature primarily focuses on decision-making processes for sustainable supplier selection.
[27]	A bibliometric analysis of material selection using MCDM methods: Trends and insights	Dimensions.ai	VOSviewer	The results highlight a strong concentration of research activity in Asia and Europe, reflecting their leading role in advancing MCDM methodologies.
[28]	Multi-criteria decision making (MCDM) in diverse domains of education: A comprehensive bibliometric analysis for research directions	Scopus	VOSviewer, R package, Tableau	The study shows that researchers from China are highly active in this field, and publications originating from China receive a high number of citations, indicating strong research impact.
[29]	Sensitivity analysis in multi-criteria decision making: A state-of-the-art research perspective using bibliometric analysis	Scopus	RStudio, CiteSpace, VOSviewer	The findings reveal that China leads in publication volume, while India demonstrates the strongest performance in international research collaboration.
[30]	Bibliometrics analysis on economics and MCDM	Scopus	R package, VOSviewer	The results highlight China as the most collaborative country, frequently engaging in joint research with Saudi Arabia, the USA, India, and Türkiye.
[31]	A comprehensive and systematic review of multi-criteria decision-making (MCDM) methods to solve decision-making problems: Two decades from 2004 to 2024	Dimensions.ai	VOSviewer	The study demonstrates an exponential growth in MCDM applications, particularly in sustainable energy, urban planning, and healthcare optimization.
[32]	Trends in Capital Structure: A Bibliometric Analysis to Support the Construction of Decision-Support Methodologies	WoS & Scopus	Bibliometrix, VOSviewer, NVivo	Identifies two dominant research streams (theoretical vs. optimization-based approaches) and highlights the dominance of leading countries such as China and the USA, emphasizing the need for integrated decision-support frameworks.
[33]	Operational Research Pathways for Sustainable Fashion Supply Chains: A Bibliometric and TCCM Review	Web of Science	VOSviewer, RStudio	Reveals increasing adoption of MCDM and optimization techniques in sustainable supply chains, with strong emphasis on circular economy practices and digital technologies such as AI and blockchain.

Table 1
 Continued

Author(s)	Research Title	Database	Software	Key Findings
[34]	Multi-Criteria Analysis of Cybersecurity Maturity in the Largest Latin American Economies Using CRITIC-WISP	WoS & Scopus	Bibliometrix, VOSviewer	Demonstrates the effectiveness of objective weighting (CRITIC) in evaluating cybersecurity maturity, identifying economic and technological indicators as critical determinants.
[35]	Multi-Criteria Decision-Making in Soccer: A Bibliometric Analysis	Web of Science	Biblioshiny, VOSviewer	Shows a significant increase in MCDM applications, identifies TOPSIS and AHP as dominant methods, and highlights the growing integration of artificial intelligence with decision-support systems.

2.1. Research Gap

Previous bibliometric studies on MCDM have primarily examined a diverse range of application areas, including healthcare [20], cultural heritage [21], personnel selection [22], sustainable energy technologies [23], military decision-making [24], supplier selection [26], material selection [27], education [28], sensitivity analysis [29] and economics-related applications [30]. Additionally, several studies have explored the evolution of specific MCDM techniques and ranking methods, particularly those introduced over the last decade [25], alongside comprehensive reviews that assess the overall progress within the MCDM field [31]. More recent studies have further highlighted the increasing use of bibliometric approaches to analyze MCDM applications in various fields such as sustainability, cybersecurity, and sports analytics [32-35]. Despite the expanding body of bibliometric literature, existing studies have primarily concentrated on application areas, ranking-based MCDM methods, or general methodological advancements. In contrast, objective weighting methods have been ignored as a specific category within the methodology. So far, none of the bibliometric studies has conducted a systematic, comparative analysis specifically focused on objective weighting methods such as Entropy, CRITIC, MEREC, LOPCOW, CILOS, IDOCRIW, SD, and MPSI. To address this gap, the present study conducts a comprehensive bibliometric analysis of objective weighting methods employed in MCDM applications. This research builds on previous bibliometric investigations and introduces a novel methodological perspective to enhance our understanding of the evolution and importance of objective weighting techniques in the MCDM literature.

3. Data and Methodology

Bibliometrics is an important analytical approach that quantitatively examines scientific publications and reveals research trends in the literature. Pritchard [36] defined bibliometrics as the application of mathematical and statistical methods in the examination of written communication media and emphasized that this method is an effective instrument in analyzing the structure of scientific literature. Today, bibliometric analysis is considered a reliable quantitative method widely used to reveal the development process, research trends, and knowledge networks of a particular research field [37]. While traditional literature reviews generally cover a restricted number of studies, bibliometric analyses systematically examine large datasets, offering a more comprehensive and objective perspective on the overall structure of the research field [38]. This approach enables the analysis of large-scale bibliographic data using science-mapping techniques, allowing a more systematic examination of research trends, conceptual structures, and academic collaboration networks [39].

This study employs a bibliometric analysis method to systematically, transparently, and reproducibly examine the scientific literature on objective weighting methods in MCDM. The quality of the data source used in bibliometric analyses is critical to the reliability of the findings. Accordingly, the WoS database was chosen as the data source for this research. The Web of Science database is considered one of the most reliable data sources for bibliometric studies due to its strict indexing criteria for selecting academic journals and its comprehensive citation data. Furthermore, the WoS database offers significant methodological advantages for science mapping studies because it provides standardized bibliometric indicators, such as author, institution, keyword, and citation, in a consistent format [40].

VOSviewer (version 1.6.20) software was used to analyze and visualize the obtained bibliometric data. Developed by [41], VOSviewer is a widely used science mapping tool for creating and visualizing bibliometric networks. The software uses the Visualization of Similarities (VOS) technique. It enables the analysis of bibliometric relationships, such as co-authorship, keyword co-occurrence, citation relationships, and bibliographic matching, through network maps. VOSviewer is frequently preferred in bibliometric studies, especially because of its ability to efficiently analyze large datasets and present complex bibliometric relationships in understandable network visualizations. In line with the objectives of this study, the bibliometric analysis was structured to address the following research questions:

- i. What is the distribution of publications on objective weighting methods in MCDM fields in the WoS database from 1990 to 2025?
- ii. Which keywords are most frequently used in objective weighting methods in MCDM publications in the WoS database?
- iii. Which countries and researchers have the highest number of publications on objective weighting methods in MCDM fields in the WoS database?
- iv. Who are the countries, researchers, and institutions with the most co-authored works on objective weighting methods in MCDM fields in the WoS database?
- v. Which countries and publications are most cited in the WoS database on objective weighting methods in MCDM fields?
- vi. How are the objective weighting methods in MCDM publications distributed among various journals?
- vii. How are the objective weighting methods in MCDM publications distributed among different publishers?
- viii. How are the publications on objective weighting methods in MCDM categorized into Sustainable Development Goals (SDGs) in the WoS database?

Following the formulation of the research questions, Table 2 presents the thematic keyword groups used to guide the bibliometric search strategy, including terms related to objective weighting methods in MCDM fields to systematically capture the relevant literature.

Bibliometric analysis initiated with a search in the WoS database to identify publications focusing on the role of objective weighting methods in MCDM fields. Accordingly, the search strategy was structured around two main thematic keyword groups. The first group focused on objective weighting methods and the second on multi-criteria decision-making approaches. These two keyword groups were combined using Boolean Operators to ensure that only publications directly related to the research topic were included in the analysis. The search equation used in the search process is detailed in Table 3.

Table 2
 Thematic Keyword Groups

Topics	Keywords
Objective Weighting Methods	ENTROPY; Entropy weighting; Information entropy; CRITIC; Criteria Importance Through Intercriteria Correlation; MEREC; Method based on the Removal Effects of Criteria; LOPCOW; Logarithmic Percentage Change-driven Objective Weighting; IDOCRIW; Integrated Determination of Objective Criteria Weights; CILOS; Criterion Impact Loss; Standard Deviation; SD method; MPSI; Mean and Preference Similarity Index
MCDM	Multi-criteria decision analysis; Multi criteria decision analysis; MCDA; Multi-criteria decision making; MCDM; Multi criteria decision making; multi-attribute decision making; Multi attribute decision making; MADM; Decision making; Group decision making; Fuzzy decision making; Hybrid MCDM; Integrated MCDM

Table 3
 Search Equation

Database	Equation Search
WoS	("Entropy" OR "Entropy weighting" OR "Information Entropy") OR ("CRITIC" OR "criteria importance through intercriteria correlation") OR ("MEREC" OR "method based on the removal effects of criteria") OR ("LOPCOW" OR "logarithmic percentage change-driven objective weighting") OR ("IDOCRIW" OR "integrated determination of objective criteria weights") OR ("CILOS" OR "Criterion Impact Loss") OR ("standard deviation" OR "SD method") OR ("MPSI" OR "Mean and Preference Similarity Index") AND ("multi-criteria decision analysis" OR "multi criteria decision analysis" OR "MCDA" OR "multi-criteria decision making" OR "MCDM" OR "multi criteria decision making" OR "multi-criteria decision analysis" OR "multi attribute decision making" OR "multi-attribute decision making" OR "MADM" OR "decision making" OR "group decision making" OR "fuzzy decision making" OR "hybrid MCDM" OR "integrated MCDM") AND (LIMIT-TO (OA, "Open Access")) AND (LIMIT-TO (DOCTYPE, "Article" OR "Review Article")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (WOSINDEX, "SCI-EXPANDED" OR "SSCI" OR "ESCI")) AND (LIMIT-TO (WOS CATEGORIES, "Operations Research & Management Science" OR "Transportation" OR "Transportation Science" "Mathematics Applied" OR "Management" OR "Computer Science Information Systems" OR "Economics" OR "Business" OR "Automation and Control Systems"))))

4. Results

This section presents visual maps resulting from a bibliometric analysis of 23,684 articles and their inferences.

4.1. Annual Distribution of Publications

The bibliometric analysis was conducted on 23,684 articles. Figure 1 presents the annual publication number of these articles from 1990 to 2025. Figure 1 demonstrates the yearly distribution of publications related to objective weighting methods in MCDM fields in the WoS database.

The results indicate that publication output remained relatively limited during the early years but began to increase gradually after 2010. A significant rise is observed after 2017, with the highest number of publications documented in 2025.

4.2. Keyword Analysis

Keyword analysis is a widely used bibliometric technique that identifies the main research themes, conceptual structures, and emerging trends within a specific scientific field. By observing the frequency and co-occurrence of keywords used in academic publications, researchers can reveal the intellectual structure of a research domain and understand how topics are interconnected over time. This method enables the identification of dominant research topics, emerging themes, and the evolution of scientific knowledge within a discipline [38,39]. Furthermore, keyword co-occurrence analysis helps visualize relationships among research topics and provides insights into the

concept in literature, with 1,712 occurrences. It was followed by "Deep Learning" (522 occurrences) and "Machine Learning" (505 occurrences).

4.3. Co-Authorship Analysis

Co-authorship analysis is a widely used bibliometric technique for examining collaboration patterns among researchers, institutions, or countries within a specific scientific domain. The method is based on the principle that when two or more authors jointly publish a scientific article, a collaborative relationship is established, which can be represented and analyzed through network structures. By investigating these collaborative links, co-authorship analysis helps identify influential researchers, research groups, and collaboration clusters, thereby revealing the social and intellectual structure of a research field. Furthermore, co-authorship networks enable scholars to understand the extent of scientific cooperation and the development of knowledge through collaborative research activities [42]. In bibliometric visualization tools such as VOSviewer, these collaborative relationships are mapped as networks in which nodes represent authors, institutions, or countries, and links indicate co-authored publications, allowing researchers to analyze the intensity and structure of scientific collaboration within a discipline [41]. In this study, 178 countries, 2,101 institutions, and 1,179 authors with at least 5 publications and 5 citations were identified. Figures 3–5 demonstrate the countries, organizations, and researchers with the highest levels of co-authorship objective weighting methods in MCDM fields.

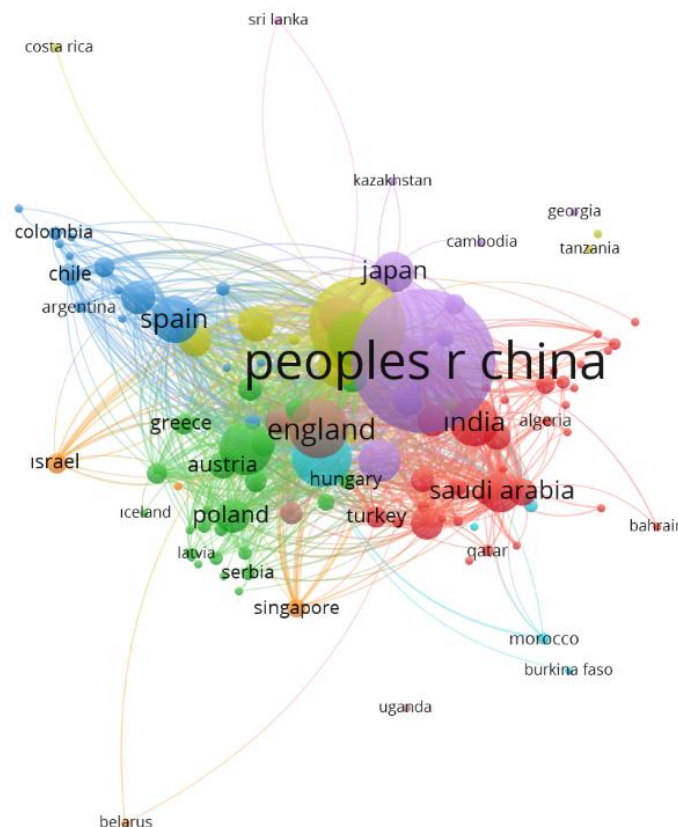


Fig. 3. Collaboration Network among Countries Based on Co-authored Publications

Figure 3 shows that China is the most productive country with 8,711 publications and 127,032 citations, followed by the United States with 4,029 publications and 122,058 citations. However, in terms of collaboration intensity, measured by total connectivity, the United States (3,662) is most centrally located in the international collaboration network, followed by China (2,925) and the United

Kingdom (2,327). Among European countries, France (1,488 publications), Germany (1,329 publications), and Italy (1,190 publications) stand out as significant contributors. Other countries, such as Spain, Canada, Australia, and India, also show considerable publication output and collaboration.

Figure 4 shows a map of the co-authorship network among institutions contributing to the research area. According to the findings, the Chinese Academy of Sciences stands out as the most productive and central institution in the network, with 792 publications, 15,830 citations, and 1,341 total link strength. This is followed by the University of Chinese Academy of Sciences (384 publications, 7368 citations, and 706 total link strength). Tsinghua University (187 publications, 4482 citations, and 305 total link strength), Peking University (146 publications, 4287 citations, and 261 total link strength), and Wuhan University (239 publications, 5000 citations, and 260 total link strength) are also among the significant research institutions based in China.

Figure 5 shows the co-authorship network among authors active in the research area. According to the findings, He occupies a central position in the Haibo collaboration network. With a total link strength of 46, the researcher stands out with 31 publications and 3,480 citations. He is followed by Schwartz, Joel (21 publications, 1,225 citations, total link strength 44), and Zavadskas, Edmundas Kazimieras (28 publications, 1,490 citations, total link strength 43).

4.4. Citation Analysis

Citation analysis is a fundamental bibliometric evaluation tool that measures the visibility and scientific impact of a researcher, article, or institution in the relevant literature through the reference networks that scientific publications establish among themselves [43].

Bornmann and Daniel [44] showed that the number of citations a study receives is an objective indicator not only of the publication's recognition but also of the extent to which it is accepted, validated, and used by the scientific community as an intellectual foundation for generating new knowledge.

The results of the bibliometric analysis of objective weighting methods in MCDM show that 114 of the 178 countries examined met the threshold of at least 5 publications and 5 citations, and were included in the analysis. Furthermore, it was determined that 14,315 of the 23,684 documents in the dataset received at least 5 citations. Figures 6 and 7 show the countries and documents with the highest citation impact in the field of objective weighting methods in MCDM, indicating the scientific impact of these studies in literature.

Figure 6 presents a density visualization of citations by country. Darker shades on the map indicate countries with higher citation impact in the literature. In this context, China has the most heavily shaded area, with 127,032 citations, making it the country with the highest impact in the literature. The United States follows China with 122,058 citations. Among European countries, the United Kingdom (40,462 citations), France (38,983 citations), and Germany (32,898 citations) stand out for their significant citation impact.

Figure 7 presents the density visualization of documents with the highest number of citations. On the map, denser shades near yellow indicate studies with higher citation impact, while lighter shades indicate lower citation density. In this context, De Boer *et al.* (2005) study has the highest number of citations, with 2,245 citations. This is followed by Diakoulaki *et al.* (1995) with 2,121 citations, Warren *et al.* (2011) with 1,888 citations, and Frenken *et al.* (2007) with 1,696 citations, respectively. When the density map is examined, it is evident that studies such as Benamou *et al.* (2015), Cockburn *et al.* (1991), Perthame *et al.* (2001), and Chen *et al.* (2003) also form distinct clusters in the literature, serving as important reference points in the development of the relevant research field.

Table 4
 Journals with the Highest Number of Publications

Journal Name	Number of Documents	H-Index (2024)	Subject Area and Category
IEEE Access	2,764	290	Electrical & Electronic Engineering; Computer Science; Multidisciplinary Engineering
Sustainability	1,703	207	Environmental Science; Sustainability Studies; Economics and Management
Remote Sensing	1,336	217	Remote Sensing; Environmental Science; Geosciences
International Journal of Environmental Research and Public Health	686	229	Public Health; Environmental Science; Health Policy
Electronics	527	110	Electrical Engineering; Computer Science; Electronic Systems
Water	496	123	Water Resources; Hydrology; Environmental Engineering
IEEE Transactions on Information Theory	463	304	Information Theory; Applied Mathematics; Electrical Engineering
Atmospheric Chemistry and Physics	339	267	Atmospheric Science; Environmental Chemistry; Climate Science
Ecological Indicators	333	204	Ecology; Environmental Monitoring; Sustainability Indicators
Discrete and Continuous Dynamical Systems	262	80	Applied Mathematics; Dynamical Systems; Mathematical Modeling

The findings show that certain journals stand out significantly in the literature. According to the analysis, IEEE Access has the highest number of publications in this field, with 2,764 publications and 45,556 citations. This is followed by Sustainability (1,703 publications, 17,834 citations) and Remote Sensing (1,336 publications, 24,945 citations).

4.6. Leading Publishers

Academic publishers are considered important actors in the production and dissemination of scientific knowledge, increasing the visibility of research outputs and shaping the institutional structure of scientific communication [47]. Accordingly, Table 5 presents the leading publishers of publications on objective weighting methods in MCDM, along with the distribution of their contributions to the literature.

Table 5
 Publishers with the Highest Number of Publications

Publisher Name	Country of Origin	Number of Publications
MDPI	Switzerland	5,678
IEEE	United States	3,654
Elsevier	Netherlands	3,409
Springer Nature	United Kingdom	1,768
Wiley	United States	866
American Institute of Mathematical Sciences (AIMS)	United States	701
Taylor & Francis	United Kingdom	518
Frontiers Media SA	Switzerland	370
Cambridge University Press	United Kingdom	344
Copernicus Publications	Germany	337

According to the findings, MDPI ranks first with 5,678 publications. IEEE follows this with 3,654 publications, and Elsevier with 3,409 publications. Springer Nature (1,768 publications) and Wiley (866 publications) are among the leading publishers with significant contributions to literature.

4.7. SDG-Oriented Research Trends

Measuring the tangible contribution of scientific knowledge to global sustainability goals has become a fundamental evaluation dimension of current bibliometric research. In this regard, the WoS database offers a dynamic classification module that matches scientific publications to their citation topics within the 17 SDGs outlined in the United Nations' 2030 Agenda. According to Armitage *et al.* [48] analyzing bibliographic data by SDG categories enables a macro-level assessment of the extent to which the research discipline under consideration is integrated into solving global ecological, socio-economic, and environmental problems. A bibliometric analysis was conducted to identify the main SDGs associated with studies on objective weighting methods in MCDM. Table 6 presents the SDGs ranked by publication count, revealing their relative importance in literature.

Table 6

SDG-Oriented Research Distribution

Sustainable Development Goals	Relevant Indicator	Number of Publications
Climate Action	SDG 13	4,681
Good Health and Well-Being	SDG 3	4,295
Sustainable Cities and Communities	SDG 11	3,594
Life Below Water	SDG 14	2,340
Clean Water and Sanitation	SDG 6	2,036
Life on Land	SDG 15	1,987
Industry, Innovation and Infrastructure	SDG 9	1,526
Affordable and Clean Energy	SDG 7	1,314
Decent Work and Economic Growth	SDG 8	1,204
Zero Hunger	SDG 2	1,128

The findings show that the most frequently addressed goal in the literature is SDG 13: Climate Action, with 4,681 publications. This is followed by SDG 3: Good Health and Well-Being, with 4,295 publications, and SDG 11: Sustainable Cities and Communities, with 3,594 publications.

5. Discussion and Conclusion

As highlighted by numerous researchers [27,28, 48], MCDM methods are extensively utilized across various fields. A significant challenge for many MCDM approaches is determining criterion weights. Consequently, considerable research effort over the past few decades has focused on examining trends and insights into the weighting methods used in MCDM applications across different domains [15,49,50]. Nevertheless, the category of objective weighting methods has received relatively limited attention in the MCDM literature. To date, no bibliometric studies have conducted a systematic comparative analysis of objective weighting methods, including Entropy, CRITIC, MEREC, LOPCOW, CILOS, IDOCRIW, SD, and MPSI. To the best of the author's knowledge, this research marks the first bibliometric analysis of objective weighting methods within the MCDM field, employing the WoS database. The aim is to evaluate the scientific output that has developed over the past three to four decades (1990-2025). In this context, a comprehensive review was carried out to identify the most prolific authors, landmark studies, leading organizations, countries, academic disciplines, and SDGs.

The publication trend indicates that research output was relatively low in the early 1990s but began to increase steadily after 2005. A significant upward trajectory is evident from 2017 onward, leading to the highest volume of publications anticipated by 2025. An analysis of the keyword co-

occurrence network reveals that "Entropy" is the most frequently used term in the literature, followed closely by "Deep Learning" and "Machine Learning," which rank second and third, respectively. Additionally, the country-level analysis indicates that China emerges as the most productive nation in this field, with the United States closely trailing. However, when assessing collaboration intensity through the total link strength within the international collaboration network, the United States assumes the most central position, underscoring its crucial role in global research partnerships. Following the United States are China and the United Kingdom. In Europe, France, Germany, and Italy also stand out as significant contributors to the field's advancement. A further examination of institutional productivity highlights the Chinese Academy of Sciences, the University of Chinese Academy of Sciences, and Tsinghua University as some of the most active and influential institutions. Furthermore, notable scholars such as He, Schwartz, and Zavadskas have made substantial contributions to the growth of academic literature.

Citation-based assessments indicate that China is at the forefront of research, with nearly 130,000 citations and significant influence in the field. The United States and the United Kingdom closely follow, solidifying their positions as key global research hubs with strong citation performance. Among the most impactful studies, De Boer *et al.* [45] stands out with approximately 2,250 citations, making it a crucial reference in the literature. It is closely accompanied by notable works from [8]. An analysis of journals indicates that IEEE Access is the leading publication venue in this research field, with Sustainability (MDPI) not far behind. Additionally, Remote Sensing also plays a significant role in the publication landscape. Among publishing entities, MDPI emerges as the dominant publisher, with nearly 6,000 publications, followed by IEEE and Elsevier. Furthermore, the findings highlight the growing importance of objective weighting methods for addressing research on the SDGs. Specifically, the literature emphasizes SDG 13 (Climate Action), SDG 3 (Good Health and Well-being), and SDG 11 (Sustainable Cities and Communities). Ultimately, the results indicate that climate action is the most frequently discussed theme, followed by public health and sustainable urban development.

Overall, this research offers a comprehensive assessment of global academic contributions related to objective weighting techniques within the context of MCDM. The study identifies key researchers and analyzes the distribution of scientific output across various countries and regions. By providing a structured overview of current knowledge on objective weighting methods in MCDM, this research aims to deepen understanding of the existing academic landscape and uncover new research opportunities in this rapidly advancing field. Based on these findings, several implications for both research and methodological implications are proposed:

- i. Identifying key authors, institutions, countries, and journals provides a structured overview of the intellectual and institutional landscape surrounding objective weighting methods within the MCDM literature. This mapping can help researchers identify influential research teams, potential collaborators, and appropriate publication venues for their upcoming studies.
- ii. The prominence of nations like China in publication output, coupled with the United States' critical role in the global research network, underscores the significance of international scientific collaboration. By strengthening partnerships—especially between emerging and established research institutions—we can advance methodological innovation and facilitate the dissemination of knowledge within the discipline.
- iii. The terminology associated with Entropy, Deep Learning, and Machine Learning highlights a growing trend of combining advanced computational and data-driven approaches with traditional MCDM techniques. As a result, future research is likely to focus on developing

hybrid frameworks that integrate objective weighting methods with artificial intelligence and machine learning technologies.

- iv. Determining research gaps through bibliometric patterns offers valuable insights for future investigations. Expanding the use of objective weighting methods in underexplored areas, along with their integration with novel analytical techniques, could greatly enhance both the methodological rigor and practical significance of MCDM research.

This research offers a comprehensive analysis of trends and insights within the relevant field; however, it is essential to recognize certain limitations. The study exclusively uses the WoS database, which, despite adherence to high-quality indexing standards, may introduce coverage bias by omitting significant publications found in other prominent databases such as Scopus, Dimensions, and Google Scholar. Consequently, regional journals, conference proceedings, and more recent research outputs may not be adequately represented. Additionally, the emphasis on English-language publications may lead to language bias, potentially neglecting important contributions in other languages. Furthermore, variations in indexing policies and citation practices across different databases could influence the visibility and citation impact of specific studies. Another limitation is the reliance on a single bibliometric tool, VOSviewer, which, although effective for visualization, may restrict analytical diversity. Therefore, the findings should be interpreted with caution concerning their generalizability. Future research could enhance the robustness of bibliometric analyses by integrating multiple databases and by employing complementary tools, such as R and CiteSpace, to achieve a more comprehensive perspective.

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Conflicts of Interest

The authors declare no conflicts of interest.

Declaration of Generative AI and AI-Assisted Technologies in the Manuscript Preparation Process

During the preparation of this work, the authors used Grammarly to enhance readability and improve language structure. This tool is not used to generate scientific content, analyses, or conclusions. After using Grammarly, the authors reviewed and edited the content as needed and take full responsibility for the final manuscript. No generative AI tools were used to create or modify the study figures or artwork.

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