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Review Article

Bibliometric Analysis on the Distributed Decision, Decentralized Decision, and Fuzzy Logic

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This study aims to survey the bibliometric properties of distributed decisions, decentralized decisions, and fuzzy articles published between 1995 and 2023 in the Web of Science (WoS) database. During the analysis process, the keywords "distributed decision, decentralized decision, and fuzzy" were scanned in all languages, both in the titles and the content of all publication types. As a result of the analysis, 79 articles in all fields comprised the dataset. The most used keywords in the articles were related to the distributed decision, decentralized decision, and fuzzy logic, and the most frequently cited publications were examined using the social network analysis method, which uses VOSviewer (version 1.6.19) to visualize the relationships. The study's goal on "active researchers, active journals, journal metrics, title document type, active countries, and active institutions" was to look at the words most frequently used in articles on distributed, decentralized, and fuzzy logic. The social network analysis represented the relationships between these keywords and the most frequently cited publications. The findings demonstrated a significant correlation between using these keywords in academic literature and their contribution to this field's research. These results can assist researchers in finding potential partners and keeping up with current research trends. Overall, this study offers important new perspectives on the state of research on fuzzy logic, distributed decision making, and decentralized decision making.

1. Introduction

In today's complex and interconnected world, decision making plays a significant role in various domains, ranging from engineering systems to business operations [1]. Traditional decision-making approaches, centered around centralized control and deterministic logic, often face challenges when dealing with uncertain, dynamic, and distributed environments.

Distributed decision making refers to the process of making decisions collaboratively among several autonomous entities. To achieve a consensus or reach optimal decisions, it uses the collective intelligence and expertise of these entities, which can be individuals, organizations, or intelligent agents. The participants in distributed decision making share information and the decision-making authority is distributed among them. In addition to enhancing scalability, fault tolerance, and decision quality, this approach offers several advantages. Furthermore, distributed decision making facilitates the efficient utilization of resources and can be adapted to dynamic and uncertain environments.

The importance of distributed decision making lies in its ability to harness the collective intelligence and diverse expertise of multiple agents. The distributed decision-making approach aims to encourage the sharing of information and collaboration to ensure integrity in the problem, thereby leading to improved decision-making outcomes. Additionally, distributed decision making reduces the burden on a single decision maker, resulting in more efficient and faster problem solving in domains that require immediate responses.

One of the important points of the decentralized decision procedure is the distribution of decision-making authority among different organizational units [2]. In contrast to centralized decision making, where decisions are made by a single entity with authoritative control, decentralized decision making allows multiple autonomous units to make decisions [2]. While operating independently, these units are aligned with a common objective. In addition to facilitating faster decision making, decentralization promotes the utilization of local knowledge and allows effective coordination between distributed units [3]. In addition, it enhances the agility and responsiveness of an organization by enabling local entities to make timely decisions based on their specific contexts.

The importance of decentralized decision making is derived from its capacity to address problems involving a high degree of complexity, uncertainty, and scalability. By decentralizing decision-making authority, this approach allows for efficient problem solving in large-scale systems, such as supply chains, traffic management, or multiagent systems. Furthermore, decentralized decision making ensures robustness and resilience to failures or disruptions in individual units, since the system can continue to function even if some units become compromised.

The fuzzy logic framework extends traditional binary logic by incorporating degrees of truth and uncertainty. By allowing intermediate values between true and false, it can deal with vague and imprecise information. By using fuzzy logic, fuzzy or qualitative concepts can be represented and manipulated, thereby providing a more realistic and flexible method of making decisions. With fuzzy logic, complex systems can be modeled, incomplete or ambiguous data can be handled, and human-like reasoning processes can be captured. This makes it particularly suitable for solving decision-making problems involving subjective or uncertain inputs.

Fuzzy logic is valuable in the modeling of real-life problems because it can handle and address the inherent uncertainties and complexities of human decision making. Using fuzzy sets, fuzzy logic, fuzzy rules, and fuzzy inference systems allows the representation and analysis of qualitative and subjective factors that often influence decision-making processes. This methodology can be implemented in different manufacturing industries, image processing, expert systems, and optimization.

Fuzzy logic, decentralized decision making, and distributed decision making are alternative paradigms to conventional centralized decision making and address the challenges posed by distributed, dynamic, and uncertain environments and provide more flexible and adaptive decision-making frameworks. Distributed decision making harnesses collective intelligence, whereas decentralized decision making empowers local entities, while fuzzy logic is capable of handling uncertainty and imprecision. Combining these concepts can enhance decision-making processes across a wide range of domains and open avenues for further research and practical applications.

With the rapid technological change, the increase in population, and how business and business conduct are carried out in all areas, the world is becoming more complex and dynamic daily. Thus, the importance of the decision-making mechanism in different problems that await solutions in many different areas of life increases. Supply chain and energy have complex and dynamic decision-making processes [4, 5], including management, scheduling, energy systems, optimization, network management, control systems, and many others. Therefore, decentralized decision making and distributed decision making are the particular ways of accomplishing in this field.

Distributed decision making takes place by distributing the decision-making procedure among the various decision makers. Also, every decision is related to each other due to affecting the outcome of different decisions. There is also uncertainty in the dynamic and variability of real life. Therefore, in real-life problems, several uncertainties occur. The uncertainty in these decision-making mechanisms gives rise to fuzzy logic.

Distributed decision making, decentralized decision making, and fuzzy logic offer alternative paradigms to conventional centralized decision-making approaches. They address the challenges posed by distributed, dynamic, and uncertain environments and provide more flexible and adaptive decision-making frameworks. While distributed decision making harnesses collective intelligence, decentralized decision making empowers local entities, and fuzzy logic handles uncertainty and imprecision. The combination of these concepts can significantly enhance decision-making processes in various domains and open avenues for further research and practical applications.

This paper is organized as follows. In Section 2, the novelty and motivations of this investigation are discussed. In Section 3, we illustrate the dataset and methodology. The analysis result is examined in Section 4. In Section 5, discussion and limitations are explained. In Section 6, implication of the study is included. In Section 7, the conclusions and future research are presented.

2. Structure, Novelty, and Motivations of This Investigation

In this article, bibliometric analysis is carried out to facilitate the acquisition of formal and quantitative data on the current state of the field in which the specified topics are studied and to monitor academic trends through visualization articles. The ultimate goal here is to obtain quantitative data and numerical measurement indicators about the research performance. Comments on these indicators should be inspired by the researchers' experiences and knowledge in the field. Through bibliometrics, quantitative findings were achieved from various types of analysis such as co-authorship, organization, citation, and most used keywords.

As a result, alternative paradigms have emerged to address these limitations and provide more flexible and adaptive decision-making frameworks. This paper explores three prominent concepts in this regard: distributed decision making, fuzzy logic, and decentralized decision making. In conclusion, these three concepts play vital roles in modeling and addressing real-life problems. These methodologies offer powerful tools to handle complex, dynamic, and uncertain scenarios that traditional approaches may struggle to capture. By leveraging collective intelligence, autonomy, and fuzzy reasoning, these techniques enhance decision-making processes, improve problem-solving capabilities, and enable more accurate and adaptable models for real-life applications.

In this study, the VOSviewer software tool (version 1.6.19) was utilized for knowledge visualization. This software structures networks of linguistic elements extracted from scientific articles, encompassing articles, authors, countries, citations, and keywords, and the flowchart is demonstrated in Figure 1.

We surveyed the bibliometric properties of distributed decisions, decentralized decisions, and fuzzy articles published between 1995 and 2023 in the WoS database.

All studies except a few were published in different journals. The quarterly percentages of these journals are shown in Figure 2. According to the quartile analysis, 51% were published in Q1 journals; 12% in the Q2 journals; 20% in Q3 journals; and 17% in Q4 journals, and H-Index of publications is 17.

As a result of the bibliometric analysis, 79 studies in all fields comprised the dataset, and these data are presented in the tables and figures. The data in the tables and figures, published papers in years, were analyzed under the titles of active researchers, active journals, active countries, and active institutions in the following sections.

3. Dataset and Methodology

Today, many databases can be used to obtain data and to conduct bibliographic or bibliometric research. WoS covers many journals in the field of science and is widely used in bibliometric studies because it provides great convenience for researchers to analyze [4–6].

It can be said that scientific developments are experienced continuously, and scientific publications are increasing every year. This situation has made it very difficult for researchers to dominate the field, and so the requirement of bibliometric methods has emerged, which deals with the direction in which the developments in the scientific field have evolved, how the dynamics and structure of the field are, and which are the most important fields of study through various filters.

Bibliometric methods undoubtedly continue to develop day by day thanks to the systematic knowledge in the field. The concept of bibliometrics, which dates back to the 1920s, was first used by Alan Pritchard [6]. The "impact factor" put forward by Garfield [7] and the "Hirsch index" developed by Hirsch [8] contributed significantly to the development of bibliometrics. Bibliometrics is based on analysis with various statistical and mathematical methods using data obtained from various databases.

Bibliometric methods are based on obtaining bibliographic data from databases and obtaining an image of the field of interest [9] and are generally performed for two purposes which are various types of analysis and scientific mapping. While type analysis refers to an author's or citation's performance in scientific publications, scientific mapping attempts to reveal the dynamics and structure of the scientific field [10].

The scientific mapping method is quite new among bibliometric methods, and it represents a spatial representation of the interrelationship of documents, disciplines, authors, specialties, and fields. The scientific mapping method is expressed as discovering useful information from data [10]. Scientific mapping analysis is done widely through keywords such as authors, countries, and publications and finds a wide application area [11].

In May 2023, 81 results were reached in the research conducted by selecting "all fields" with the keywords "x." In the obtained data, author-citation-keyword and summary analyses were examined. Content indexed in Web of Science was taken as a database. This search is determined to detect articles that contain the given keywords together. First of all, 81 publications (documents) of different types were found due to the primary search. According to the years, 57 articles, 25 proceeding papers, 1 book chapter, 1 review article, and 1 early access article from 112 different disciplines/areas, the oldest being 1995 and the newest 2023, were reached. To reach the sample to be used, some restrictions were made in the search, and the writing language was chosen as English. As a result of this secondary search, 79 documents were found.

The bibliometric analysis aims to summarize a large amount of bibliometric data showing the knowledge of any research topic or field and their change over the years [12]. VOSviewer software version 1.6.19 was used to sort and visualize the bibliometric data. VOSviewer provides three types of visualization, namely, network visualization, layer visualization, and density visualization.

4. The Analysis Result

4.1. Publication Output's Bibliometric Analysis. The keywords searched on the WoS were analyzed into categories. In this part, the keywords searched on the WoS contain the main findings about categories, citation topics, publication years, document types, publishers, and research areas. These documents have been created in 36 different categories, and the percentages are demonstrated in Table 1 as the top 10 categories. As seen clearly in Table 1, CSAI, EEE, and CSTM are the most studied categories.

With the increase in the topic of the supply chain, fuzzy sets, and unconstrained optimization in the world, studies on these issues have increased the number of studies in the fields of EEE, OPMS, and M. Moreover, the most cited topics list is demonstrated in Table 1.

It is seen in Table 1 that the keywords are used in different fields. The reason for this can be attributed to the concept of distributed decision, decentralized decision, and fuzzy being subjects of interdisciplinary studies and being handled in various sectors. Moreover, the citation topics that are the most researched and affecting issues of the research areas are given in Figure 3.

The research areas of distributed decision, decentralized decision, and fuzzy logic have been broadly studied and researched in recent years. Figure 3 provides a comprehensive

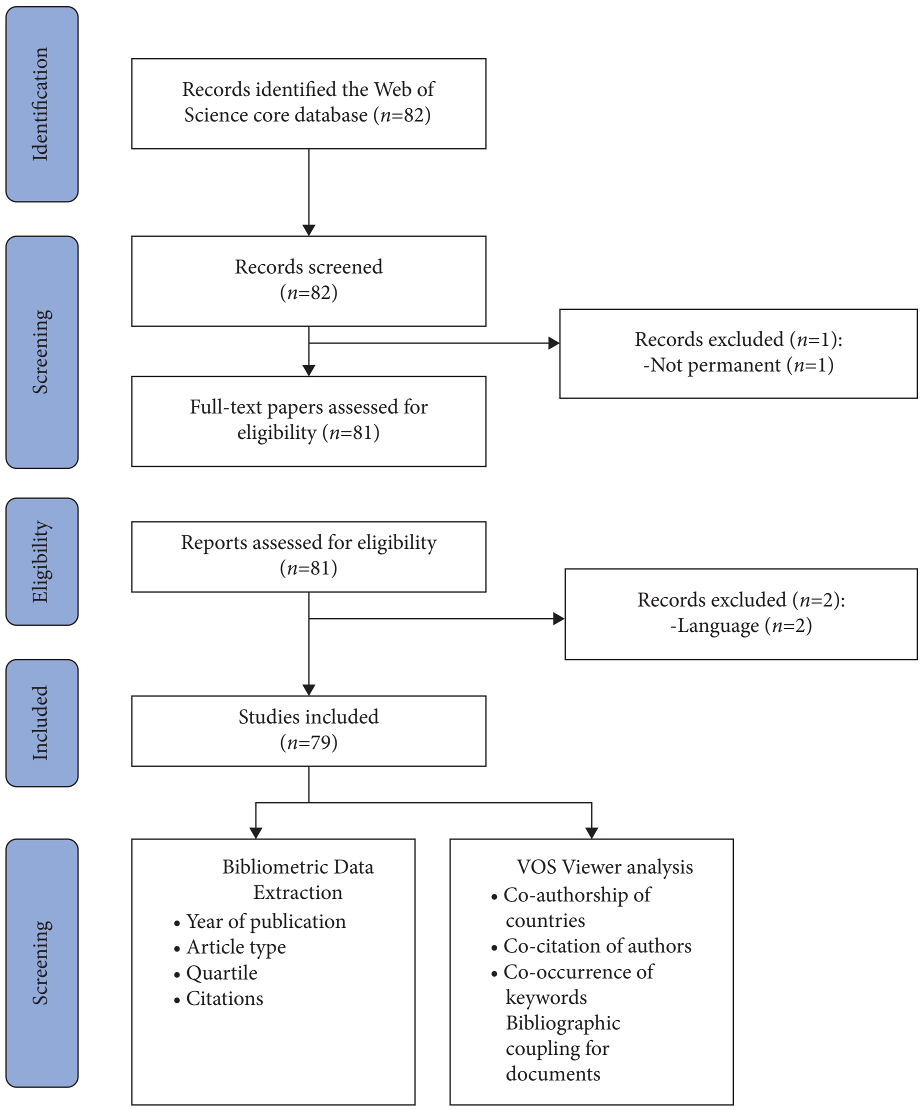

Figure 1: Flowchart of the study.

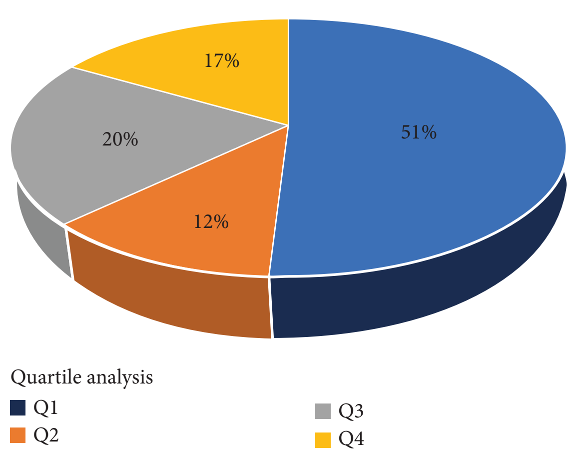

Figure 2: Quartile analysis.

Table 1: Category list.

Web of Science categories	Definition	Record count	% of 79
CSAI	Computer science artificial intelligence	32	40.5
EEE	Electrical electronic engineering	17	21.5
CSTM	Computer science theory methods	11	13.9
CSIA	Computer science interdisciplinary applications	9	11.4
ACS	Automation control systems	8	10.1
CSIS	Computer science information systems	8	10.1
ORMS	Operations research management science	8	10.1
EI	Engineering industrial	7	8.8
M	Management	6	7.6
EM	Engineering multidisciplinary	5	6.3

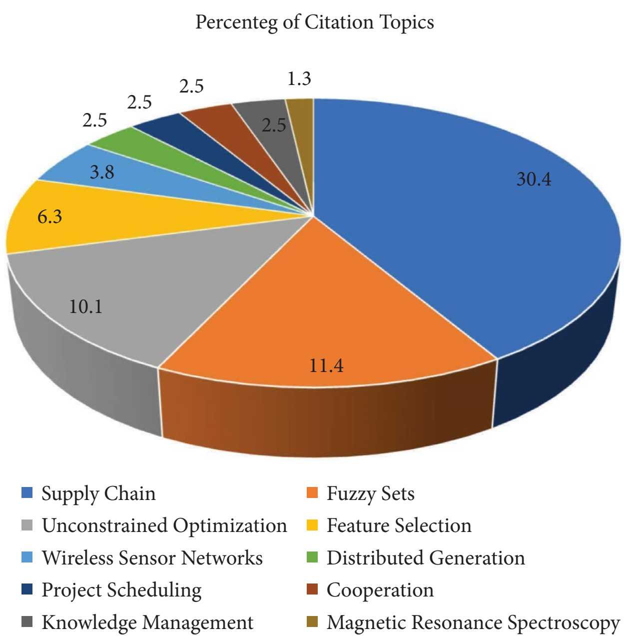

Figure 3: Percentage of citation topics.

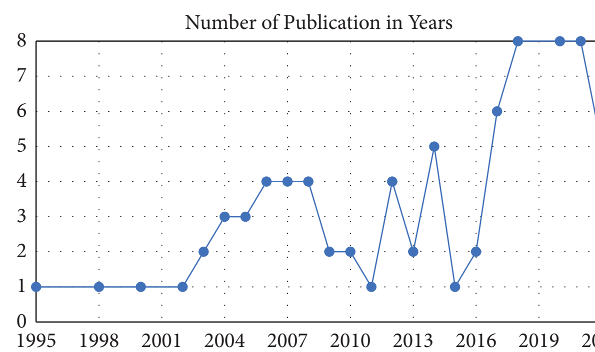

Figure 4: Number of publications in years.

overview of these fields' most researched and affecting topics. To carry out significant studies in the field, attention should be paid to the studies in the literature and the citations to these studies. Researchers can identify the most influential journals for publishing their work by doing so.

One of the most significant topics within these fields is decision making in complex systems, which has been explored through various approaches such as game theory and artificial intelligence. Another important area of research is the development of decentralized algorithms for decision making, which has potential applications in fields such as finance and transportation. Additionally, fuzzy logic has emerged as a powerful tool for handling uncertainty in decision-making processes. As these research fields increase and develop, the contribution of researchers to the field will gain maining with the appropriateness of the latest developments.

The number of studies carried out between 1995 and 2023 is given in detail in the graphic. According to this information, it is seen that there were very few studies until the 2000s and that the studies carried out in the following years increased, which is shown in Figure 4.

When the productivity of the countries is examined according to the number of publications, it is seen that 32 countries publish in this field. Figure 5 shows the ten most productive countries as follows. China has the most publications on the researched subject, with 34 articles. Iran follows this with 12 articles and the USA with ten articles. It can be said that China and Iran have made significant contributions to the development of literature.

4.2. Knowledge Visualization. To develop a complete analysis, it is necessary to consider the main factors influencing the results. Moreover, co-authorship analysis has three main units of analysis: authors, their affiliations, and countries. A total of 32 elements (countries) fulfilled the threshold requirement, which stipulated a minimum of three documents per country. The software identified 15 links, 18 clusters, and 16 total link strengths. Partnership mostly involved China with 34 documents and 458 citations, and then the country that follows it closest is Iran with 12 documents 77 citations.

Scientists collaborate with other researchers because of the need to combine different types of knowledge and skills to discover new knowledge and specialize in the field [13]. Scientific collaboration can also help expand the scope of a research project and encourage innovation as it provides access to different disciplines [14].

The co-citation analysis, which represents a quantitative bibliometric technique, classifies articles or comparable written scholarly communications based on matching sources in a publication's reference list. This type of analysis assumes that a pair of articles cited together is highly

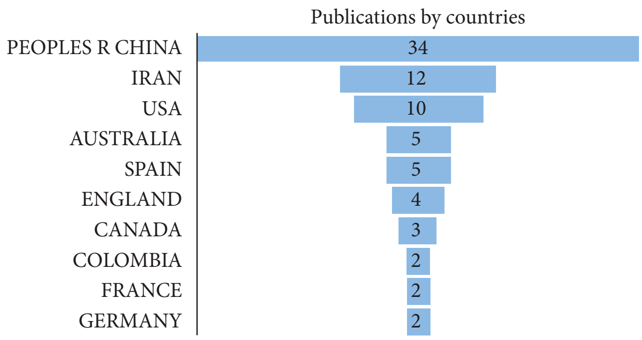

Figure 5: Publications by countries.

correlated in the network [15]. The co-occurrence of two or more sources defines the strength of similarity in content between publications. Figure 6 presents the network visualization obtained from the analysis of the authors' joint citations in the distributed decision, decentralized decision, and fuzzy logic, and also in Table 2 connections of the authors are demonstrated, for example, Jie Wei and Jing Zhao have the strongest connections in the network. For the analysis of the co-citation of authors, the number of total authors is 1942, and the software found 8 clusters of scientific collaboration, 183 links. In the clustered cooperation network, research sharing the same color indicates similar clusters. The curved lines represent the strength of connections. The closer the distance between two nodes, the stronger the scientific connections between authors. The relationship between authors and the highest citation counts is demonstrated based on the network connection shown in Figure 5. The software indicated 121 items, 185 links, and 215 total link strengths. For instance, due to Wei having 638 citations, the size of the node in the network visualization is larger compared to other authors. Gaz has the second-highest citation count and a total connection strength of 329.

In the network visualization, each node in the network symbolizes the researcher, and the connections indicate the relations between the authors. The distance between these two authors on the network visualization shows almost the degree of closeness of the two authors regarding common citations. The larger node of the author's name demonstrates the greater weight. Moreover, the weight of each node is decided by the total power of all connections connected to the node. Figure 7 shows the analysis of the co-citation of authors.

Bibliographic coupling is the most commonly used citation type in citation analysis. Moreover, the bibliographic coupling is two different sources finding an impression of the same source. As seen in the network visualization (Figure 8 and Table 3), it can be mentioned that there is an intense and complex relationship between documents. However, the relationship between the documents has been clarified through coloring. In this relationship, red, blue, and green colors interact with each other, as well as different colors interact with each other. The software found 6 clusters of scientific collaborations, 160 links, and 519 total strengths.

The analysis of the relationship among authors, publications, and countries is achieved through author citations and bibliographic matching analysis. It is clear that the prominent ones are authors such as Zhao [16, 17], Wei [18], Gao [19, 20], and Song [21].

The category, document type, publication year, and research area information of the 79 articles examined in the WoS database are shown in Table 4. Some abbreviations used in this table are given in Table 5. When analyzing the document types of all the studies examined in Table 4, it is observed that 73.41% are articles, 31.64% are proceeding papers, 1.26% are early access, and 1.26% are review articles.

Figure 9 depicts the results of the bibliometric analysis, which identified 431 of the most related keywords and their connection power to one another. In addition, the keywords are chosen according to link strength. The rate of occurrence is demonstrated by the volume of nodes. The analysis yielded a total of 456 keywords, out of which 38 met the threshold criteria (requiring a minimum occurrence of 3 for each keyword), 207 links, and 296 total link strengths. It has been determined that the keywords consist of 5 clusters, and they are expressed in different colors. For example, the cluster with a green model is related to distributed decision making, group decision making, multiagent systems, neural networks, agent technology, allocation, and aggregation. In summary, the elements of fuzzy, decentralized, and distributed decision-making are as follows: model, coordination, fuzzy, algorithm, fuzzy optimization, system, optimization, and decision-making. The cluster with the green model is a complex system that encompasses various aspects of decision making. Its relevance lies in its ability to facilitate distributed decision making, group decision making, and multiagent systems. Using neural networks and agent technology enables the system to allocate resources and aggregate data efficiently. The decentralized nature of the model allows for a more coordinated approach to decision making, with algorithms and fuzzy optimization playing a key role in the process. The system's ability to optimize decisions in real time is a significant advantage, allowing for quick responses to changing circumstances. In summary, the components of this model include coordination, distributed decision making, algorithm development, fuzzy optimization techniques, and overall decision-making capabilities. This system represents an important advancement in decision-making technology and has numerous applications across various industries.

5. Discussion and Limitations

A bibliometric analysis offers a valuable chance to pinpoint potential literature gaps. As far as we are aware, this constitutes the inaugural bibliometric analysis encompassing "distributed decision, decentralized decision, and fuzzy" across all fields. Consequently, these findings hold promise for guiding future research endeavors in this domain. The outcomes of the bibliometric inquiries suggest that research

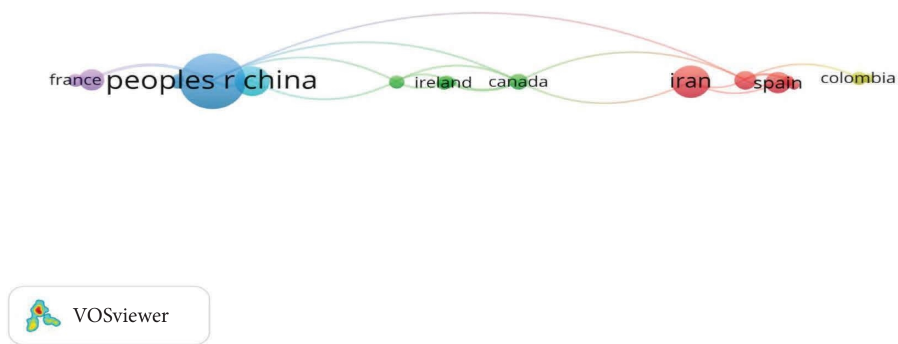

Figure 6: The analysis of the country of co-authorship.

Table 2: The authors of total link strength.

Author	Total link strength
Wei, Jie	30
Zhao, Jing	30
Gao, Jw	17
Liu, Bd	17
Li, Yong Jian	8
Hafezalkotob, Ashkan	7

incorporating these keywords spans various scientific domains. Additionally, fostering collaborations among researchers is recommended.

Analyzing keywords proves to be a beneficial method for delineating predominant themes and establishing a document framework within a research field. The knowledge visualization utilizing VOSviewer demonstrated a satisfactory correlation among the terms (keywords). Through network analysis, eight clusters were identified, showcasing a diverse dispersion of utilized keywords, indicative of a broad spectrum of covered topics. Conversely, the knowledge mapping indicated that primary scientific collaborations among researchers or institutions are primarily centered around China and Iran. The constituents of most related keywords analysis comprise coordination, distributed decision making, algorithm development, fuzzy optimization techniques, and comprehensive decision-making abilities. This system signifies a significant stride in decision-making technology and holds multifaceted applications across diverse industries. Additionally, the topics in which these words are most citation topics are supply chain, fuzzy sets, unconstrained optimization, feature selection, and wireless sensor networks. Moreover, the co-authorship analysis of authors indicates a deficiency in collaborative efforts among them. With limited group characteristics observed in the cooperative networks, authors tend to publish independently. Consequently, there exists an imbalance in research development across different countries, emphasizing the essential need to bolster partnerships. The reasons behind these gaps necessitate further analysis.

This analysis has various limitations. The search and methods were confined to articles extracted and analyzed solely from the WoS database. Although it encompasses all SCI and SSCI listed journals, this strategy also includes articles present in other datasets (for instance, Scopus and ProQuest). Additionally, the citation search within WoS may lack comprehensiveness (e.g., certain subject areas might be inadequately covered, and authors' keyword selection might not be appropriate). Nevertheless, this approach is widely utilized in bibliometric research. Moreover, our principal aim in this study was to encourage research development and address existing scientific gaps. In-depth bibliometric investigations will be necessary to focus on different indicators. We chose VOSviewer due to its focus on aggregate-level visualizations. The string we used for bibliometric analysis ("distributed decision (All Fields), decentralized decision (All Fields) and fuzzy (All Fields)") resulted in a nonexhaustive number of articles by specifically excluding relevant documents. Additionally, since the records exported from the WoS core collection included the "full record," we attempted to capture these keywords in all articles. Our analysis shows that there are obvious gaps in this area of research.

6. Implications of the Study

This study's analysis provides valuable insights into the keywords and highly cited publications concerning distributed decisions, decentralized decisions, and fuzzy logic. These findings can be practically applied in multiple ways: research collaboration, strategic decision making, emerging trends identification, and knowledge transfer. The information and findings from this study are anticipated to be utilized for promoting research collaboration, supporting strategic decision-making processes, identifying emerging trends, and facilitating knowledge transfer. While researchers can use this information to identify potential collaborations and track current trends, managers in academic institutions or R&D organizations can allocate resources effectively, identify priority research areas, and establish partnerships aligned with prevailing trends. Furthermore, through social network analysis, new trends emerging in these research domains can be identified. These insights can contribute to a deeper understanding of current research areas and the dissemination of knowledge, particularly through educational programs or workshops organized for researchers or professionals.

Figure 7: The analysis of the co-citation of authors.

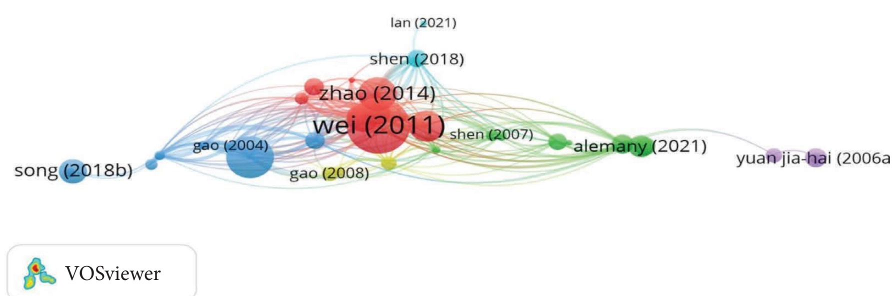

Figure 8: The analysis of bibliographic coupling of documents.

Table 3: The list of bibliographic coupling of documents.

Document	Citation	Total link strength
Zhao (2017)	19	116
Zhao (2014)	37	110
Wei (2012)	26	89
Gao (2005b)	57	85
Gao (2004)	4	85
Song (2014)	1	84

Table 4: Summary of papers.

Reference	Document type	Publication year	WoS categories	Research areas
[22]	Review	1995	ACS; II	ACS; II
[23]	Proceedings paper	1998	ACS	ACS
[24]	Proceedings paper	2000	CS, cybernetics; EEE	CS; E
[25]	Proceedings paper	2002	CSIS; EEE; II; telecommunications	CSIS; II; telecommunications
[26]	Article	2003	CS, cybernetics; CSTM	CS
[27]	Proceedings paper	2003	CSAI; CSIS; CSTM	CS
[28]	Proceedings paper	2004	CSAI; CSIS; CSTM	CS
[20]	Proceedings paper	2004	CSAI	CS
[29]	Article; proceedings paper	2004	CSAI	CS
[30]	Proceedings paper	2005	CSAI	CS
[31]	Article	2005	Mathematics, applied	Mathematics
[32]	Proceedings paper	2005	CSAI; CSIA; CSTM	CS
[33]	Proceedings paper	2006	CS; EEE; telecommunications	CS; E; telecommunications
[34]	Article	2006	Economics; EF; ES	BE; EF; ES
[35]	Proceedings paper	2006	EF; EEE	EF; E
[36]	Proceedings paper	2006	EEE	E
[37]	Proceedings paper	2007	CSAI; CSTM	CS
[38]	Article	2007	CSAI	CS

Table 4: Continued.

Reference	Document type	Publication year	WoS categories	Research areas
[39]	Article	2007	CSAI; CSIS; ORMS	CS; ORMS
[40]	Article; proceedings paper	2007	M; ORMS	BE; ORMS
[41]	Proceedings paper	2008	ACS; CSAI; CSTM	ACS; CS
[42]	Article	2008	CSAI; EEE; ORMS	CS; E; ORMS
[43]	Article	2008	CSAI; CSIA; CSIS; ORMS	CS; ORMS
[44]	Article	2008	IE	E
[45]	Article	2009	CSIA; IE	CS; E
[46]	Article	2009	CSAI	CS
[47]	Proceedings paper	2010	M	BE
[48]	Proceedings paper	2010	ACS; EEE	ACS; E
[49]	Article	2011	CSAI; EEE; ORMS	CS; E; ORMS
[50]	Article	2012	CSAI	CS
[18]	Article	2012	ORMS	ORMS
[51]	Article	2012	Agriculture, multidisciplinary; CSIA	Agriculture; CS
[52]	Article	2012	CSAI	CS
[53]	Proceedings paper	2013	CSAI	CS
[54]	Proceedings paper	2013	CSAI; EEE; telecommunications	CS; E; telecommunications
[55]	Article	2014	EM; MIA; mechanics	E; mathematics; mechanics
[19]	Proceedings paper	2014	EEE	E
[56]	Article	2014	EM; MIA	E; mathematics
[21]	Article	2014	MIA	MST
[57]	Article; book chapter	2014	CSAI; CSIA; ORMS	CS; ORMS
[58]	Proceedings paper	2015	CSAI; CSTM; EEE	CS; E
[59]	Article	2016	IE	E
[60]	Article	2016	CSTM; ergonomics	CS; E
[61]	Article	2017	CSAI; CSIA	CS
[62]	Article	2017	ORMS	ORMS
[63]	Article	2017	CSAI, E, manufacturing	CS; E
[64]	Proceedings paper	2017	ACS; EEE	ACS; E
[65]	Article	2017	EM; MIA applications	E; mathematics
[17]	Article	2017	CSIA; CSAI; telecommunications	CS; telecommunications
[53]	Article	2018	Mathematics, applied	Mathematics
[66]	Article	2018	CSAI; EEE	CS; E
[67]	Article	2018	CSAI	CS
[68]	Article	2018	ACS; CSAI; CSAI	ACS; CS
[69]	Article	2018	EI; M	E; BE
[70]	Article	2018	CE; water resources	Water resources
[71]	Article	2018	CBT; CE	CBT; E
[72]	Article	2018	EEE	E
[73]	Article	2020	CSIS; EEE; telecommunications	CS; E; telecommunications
[74]	Proceedings paper	2020	CSAI; CSTM	CS
[75]	Article	2020	CSAI; CSTM	CS
[76]	Article	2020	CSAI	CS
[77]	Article	2020	GSST; EF EEE	Science & technology; EF; E
[78]	Article	2020	CSTM; MA	CS; mathematics
[79]	Article	2020	EM	E
[80]	Article	2020	Business; M	BE
[81]	Article	2021	CSAI	CS
[82]	Article	2021	Mathematics, applied	Mathematics
[83]	Article	2021	ACS; CSIA; IE	ACS; CS; E
[84]	Article	2021	CSAI	CS
[85]	Article	2021	ACS; CS, cybernetics	ACS; CS
[86]	Article	2021	M	BE
[87]	Article	2021	CSIA; IE	CS; E
[88]	Article	2022	IE; EM	E
[89]	Article	2022	M	BE
[5]	Article	2022	EEE; transportation science & technology	E; transportation
[90]	Article	2022	Mathematics	Mathematics
[91]	Article	2023	EM; MIA	E; mathematics
[92]	Article	2023	CSAI; CSIA	CS
[4]	Article; early access	2022	GSST; environmental sciences	Science & technology; ES

Table 5: The most used category definition used in the summary paper list.

Categories	Definition
CS	Computer science
II	Instruments & instrumentation
EE	Energy & fuels
IAM	Mathematics, interdisciplinary applications
ES	Environmental sciences
CE	Civil engineering
BE	Business & economics
MST	Mathematics; science & technology
CBT	Construction & building technology
GSST	Green & sustainable science & technology
EE	Engineering

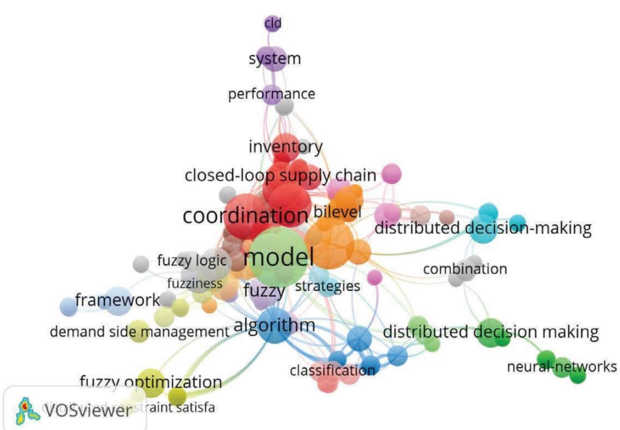

Figure 9: Analysis of the most related keywords.

7. Conclusions and Future Research

With bibliometric analysis, some findings can be obtained by examining different bibliometric features of studies published in an academic field. These findings can be used to make comparisons on various subjects, to determine the rate of use of scientific communication tools, to determine the most influential authors in the relevant literature, to find the most used keywords, to provide information about the countries with the most publications, and to evaluate a journal.

It has been observed that there are 79 studies obtained as a result of the screening performed by the specified criteria. It is seen that the years with the most publications between 1995 and 2023 were from 2017 to 2022. Among the countries that contributed the most to the literature for the criteria determined, China, Iran, USA, Australia, and Spain are in the first five places, respectively.

In the analysis made to show the link between the common citation analysis and the authors, it is seen that Jie Wei and Jing Zhao have the most vital link in the network. It is revealed by the analysis that the most studied categories about distributed decision and fuzzy concepts are electrical electronic engineering, OR management science, and management. Accordingly, it is seen that the most cited topics depending on these categories are supply chain, fuzzy sets, unconstrained optimization, feature selection, and distributed generation. Moreover, by analyzing the co-occurrence of the most used keywords and other keywords to which they are linked in all studies, it was seen that the most used keywords in the literature were distributed decision, decentralized decision, fuzzy model, coordination, distributed decision making, algorithm, fuzzy optimization, system, optimization, and decision making.

The use of related keywords and the words associated with these keywords together in many studies reveals the trend in the field. According to the literature, the most frequently used keywords are distributed decision, decentralized decision, and fuzzy model. The rising popularity of decentralized decision-making techniques that use fuzzy logic to optimize complex systems is reflected in these terms. It is also clear how important coordination is because it allows distributed agents to work effectively together. Algorithms are considered another essential component of distributed decision-making systems, which effectively process massive amounts of data. The use of fuzzy optimization techniques to resolve complex issues involving uncertainty and imprecision is on the rise. These keywords generally highlight the importance of distributed decision-making systems that can handle large amounts of data while enhancing intricate systems to produce desired results.

The results demonstrate that the articles on distributed decision, decentralized, and fuzzy logic in the world have increased over the years. The analysis result shows that these keywords are used for a wide range of work. It can be said that the increase in citations to these articles and the high number of multidisciplinary studies are a result that shows the increasing importance of the subject.

For future studies, various analysis methods like systematic literature review can be used. Thus, it can be determined which issues about distributed decision, decentralized decision, and fuzzy logic are mainly studied. Comparisons between databases can be made using different databases. With the studies carried out, gaps are revealed in the literature and many different results can be determined for researchers, thus contributing to the field. Our analysis shows that there are obvious gaps in this area of research. More studies can be conducted in the future to provide a variety of analyses. For further development, with further increase in studies in the field, research based on the WoS database can be supported by the inclusion of other scientific databases (Scopus, Elsevier, Google Scholar, etc.). Our analysis highlights that more efforts are warranted to increase the production of quality papers and enhance the connections between the various research groups.

Data Availability

The data and materials are not publicly available but can be provided upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All authors are contributors at all stages.

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