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Article

Analysis between Ontology and Multicriteria methods: An Integrated Bibliometric Study

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Abstract: This systematic mapping addressed a significant research gap by integrating ontology and multi-criteria methods to facilitate decision-making. The study utilized the Scopus and Web of Science (WoS) databases to review research conducted between 2013 and the present, focusing on seminal articles supported by robust citations and recent relevance. The analysis involved using specialized software and platforms, such as VOSviewer, RStudio, and Bibliometrics, to stratify and interpret bibliometric data. This approach enabled the identification of emerging research trends, key journals driving this field of knowledge, notable authors dedicated to this area, and global interactions among various research groups. A script written in the R language facilitated the identification of forty-one duplicated documents across the analyzed databases.

Keywords: Ontology; Multicriteria methods; Bibliometrix; Scientometrics.

1. Introduction

Effective decision-making is a fundamental pillar in any field of knowledge, whether in the corporate environment or the academic and scientific sphere. At the heart of this process, the database's quality and the information's relevance play a critical role in the construction of knowledge. Traditionally, the foundations of ontology have been a powerful tool for knowledge representation, allowing the capture of concepts and relationships in a structured and semantic way. At the same time, the multicriteria methods approach provides a robust framework for structuring and evaluating diverse decision situations involving multiple criteria and multi-decision makers. Integrating these two lines of knowledge efficiently can provide valuable insights to support decision-making. As an interdisciplinary field focusing

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on modeling concepts and relationships within specific domains, Ontology has been widely adopted in various fields of knowledge. Its ability to create explicit knowledge structures and enable interoperability between systems and data sources makes it a valuable approach to organizing complex systems. [1] However, the successful application of ontology in decision-making requires a solid understanding of how this knowledge representation can be translated into measurable criteria and indicators. On the other hand, multicriteria methods offer a systematic approach to evaluating alternatives from different criteria or perspectives. This approach is especially relevant when decisions are complex and involve conflicting considerations. The combination of ontology and multicriteria methods offers significant potential for improving knowledge representation in complex decision problems by providing a means of structuring ontological information into weighted evaluation criteria. This paper aims to explore the existing literature in the Scopus and Web of Science databases to direct other studies with this line of research. Therefore, this paper examined the recent contributions of these two areas and their interdisciplinary applications, seeking to identify gaps in knowledge and promising areas for future research.

This Systematic Mapping Study (SMS) aims to investigate the literature on multimethodological approaches between ontology and multicriteria decision support methods (MCDA). Specifically, it is proposed that related studies be ordered, given the relevance of the sources.

The structure of this paper follows:

In topic 2, there is an overview of SMS, emphasizing protocol, research questions, search strings, obtaining the database (scopus and Web of Sciense) and modeling the database. Next, in topic 3, primary studies are highlighted, presenting answers to the research questions. In Section 4, there is an analytical approach to the modeled database. Conclusion and work in progress are described in the final stage.

The Research limited its scope to articles published between 2013 and 2023 in the Scopus and Web of Science databases, with the following string: `(TITLE-ABS-KEY ("ontology") AND TITLE-ABS-KEY ("multicriteria") OR TITLE-ABS-KEY ("mcda") OR TITLE-ABS-KEY ("mcdm")) AND PUBYEAR > 2012.`

The libraries applied on the *RStudio* platform: The research limited its scope to articles published between 2013 and 2023 in the Scopus and Web of Science databases, with the following string:

```
(TITLE-ABS-KEY ("ontology") AND TITLE-ABS-KEY ("multicriteria") OR TITLE-ABS-KEY ("mcda")OR TITLE-ABS-KEY ("mcdm")) AND PUBYEAR > 2012.
```

The libraries applied on the RStudio platform [2]: `convert2df("file.extension",dbsource = "scopus or wos",format = "csv or plaintext")`, to model the database file (Scopus and WoS) and, to unify these databases and remove duplicate files, the library was used `(mergeDbSources(file scopus, file wos, remove.duplicated = TRUE).`

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To analyze the stratified base, the command was applied `(biblioAnalysis(file))`, followed by the library `(summary (object = analise, k = 20)` delimiting the 20 most relevant papers.

And, finally, the generation of graphics using the command `(plot (analise, k=20)`. Moreover, finally, the generation of graphics using the command `(plot(analise, k=20)`. This same base was submitted to the Bibliometrix platforms [3] and VOSviewer [4] to obtain metrics that this Research considered relevant (Figure 1).

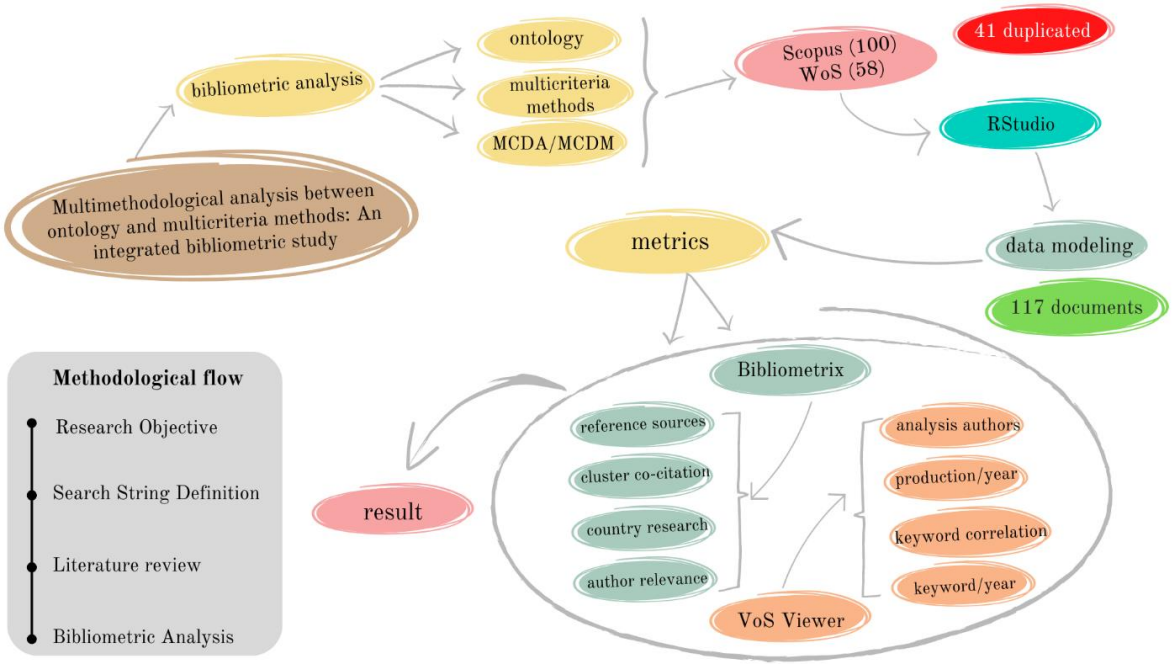

Figure 1. Methodological flow

Bibliometrics: tools and devices of relevant literature

[5] [6] Considering that systematic reviews are considered secondary studies, which have their source of data in primary studies, they prove to be valuable to the academic community for synthesizing and addressing trends in the literature. A bibliometric study is a quantitative approach that analyzes scientific production through statistical and mathematical methods and is applied to identify patterns, trends, and research gaps [7]. Two major databases are the sources where these papers are indexed: Scopus and Web of Science, even understood that [8] Treating this data (different bases) is a limiting factor due to the setup in each base. The bibliometric community must continue its efforts to develop methods and indicators that include scientific production that is not covered in WoS or Scopus [9].

This methodology employs statistical and computational techniques to examine a wide range of bibliographic sources, identifying patterns, trends, gaps, and relationships between works [10].

[11] It is through robust bibliometric tools that established and emerging research groups are identified for topological analysis, identification of themes and lines of research, interrelationships, and collaboration patterns.

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The script was applied, in the *R language*, on the RStudio platform, used in modeling the database:

```
setup
install.packages("bibliometrix")
library ("bibliometrix")
modeling 1
s <- convert2df ("file location/file scopus.csv", dbsource = "scopus", format = "csv")
w < - convert2df ("file location/file wos.txt", dbsource = "wos", format = "plaintext")
modeling 2
u < - mergeDbSources(s, w, remove.duplicated = TRUE)
write.table(u, "location of file to be created/filename.csv",sep = ";",row.names = FALSE)
res < -biblioAnalysis(u)
ds < - summary(object =res, k=20)
```

Ontology as a structure of knowledge

[12] They address the importance of ontology in data integration and highlight the opportunities offered by this approach. Furthermore, it explores the challenges faced when creating and using ontologies to improve semantic data integration, understanding that these overcome the information load of simple data. Obtaining information and understanding the degree of relationship and interaction between these elements is vital to understanding the mechanism of action. The insertion of semantic data in data science helps to maximize the quality of information.

Multicriteria Methods in the basis of decision making

In this understanding, other methods could be effective upon understanding the proposed modeling and the expected output objective, [15] considering the aspect of the respective problem, α, β, γ or δ (choice, classification, ordering, or description). [13], [14] The different approaches to MCDA, whether from the American or French schools, are characterized by the depth and diversification of the variables. Therefore, it is necessary to understand the scenario to understand the proposed problem's interrelations.

Results

Following this configuration, 100 documents were obtained from the Scopus database and 58 from the Web of Science database. Data modeling was carried out on the RStudio platform, making it possible to apply the joining library of these databases, where 41 duplicate documents were identified (same article published in both databases). Therefore, in this research, only 117 documents were considered (Table 1). Thus, this dataset identified

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the primary authors and academic institutions that produced highly relevant literature in this field of knowledge. It was also possible to analyze the temporal evolution of this production, allowing trends and directions to be identified. It was also possible to identify the world's leading journals and the citations received by the papers, allowing the impact of the respective production to be assessed.

Table 1. Main Information About Data

Timespan	2013 : 2024
Sources (Journals, Books, etc)	83
Documents	117
Annual Growth Rate %	-20.8
Document Average Age	4.61
Average citations per doc	9.017
Average citations per year per doc	1.545
References	4306

The documents follow the following classification (Table 2), where, highlighting the most relevant, 53 documents were found, corresponding to approximately 45% of this database and conference papers equivalent to 30.76%, followed by conference review with 17%.

Table 2. Document Types

article	53	45,29%
conference paper	36	30,76%
conference review	20	17,09%
proceedings paper	4	3,41%
book chapter	2	1,70%
book	1	0,85%
review	1	0,85%

Considering that this topic presents a negative growth rate (-20.8%) but that the years 2022 and 2023, interest in this line of research returns to the prospects for sustainable growth. Thus, it is necessary to intensify academic approaches to rescue this approach (Table 3).

Table 3. Annual Scientific Production

Year	Articles
2013	13
2014	12
2015	4
2016	6
2017	16
2018	6
2019	13

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2020	9
2021	3
2022	17
2023	17
2024	1

Based on this basis, the reference authors were identified, those with the greatest relevance and, consequently, the greatest citation. In this evaluation criterion, the citation rate per year was considered, where it was observed that the author *Le Sun*, in his paper *Cloud-FuSeR: Fuzzy ontology and MCDM based cloud service selection*, published in *Future Generation Computer Systems*, has an average of 13 citations per year (Table 4). This respective author presents a representative Normalized Citation Impact (NTC) citation index, 4.969. This index is calculated by dividing the number of citations received by an article by the average number of citations received by similar articles in its research area. This index is a normalized measure of the citation impact of an article in relation to the average number of citations in its research area. The calculation of the NTC citation index can be carried out using tools such as Web of Science and Scopus, which have databases with information about scientific articles and their respective citations.

Table 4: Top manuscripts per citations

	DOI	TC	TCperYear	NTC	AUTHOR
1	10.1016/j.future.2015.11.025	106	13.25	4.969	SUN L, 2016
2	10.1016/j.knosys.2018.06.010	96	16.00	2.894	NAWAZ F, 2018
3	10.1016/j.compenvurbsys.2012.07.007	66	6.00	9.640	SCHEUER S, 2013
4	10.1007/s11227-017-2039-1	62	8.86	5.636	KUMAR RR, 2017
5	10.1016/j.omega.2020.102254	47	11.75	3.777	MOHAMMADI M, 2020
6	10.1016/j.advengsoft.2019.02.001	43	8.60	4.947	REN G, 2019
7	10.1016/j.eswa.2014.12.012	40	4.44	2.286	BOUHANA A, 2015
8		38	5.43	3.455	LAURINI R, 2017
9	10.1016/j.compenvurbsys.2018.05.012	34	5.67	1.025	JELOKHANI-N, 2018
10	10.1016/j.envsoft.2017.11.011	32	5.33	0.965	JELOKHANI-N, 2018
11	10.1109/TSMCC.2013.2265234	31	3.10	3.263	ZHANG W, 2014
12	10.3390/su11154208	31	6.20	3.566	KONYS A, 2019

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13	10.1016/j.compind.2020.103391	30	10.00	3.000	CISNEROS-C, 2021
14	10.1109/ICWS.2014.53	29	2.90	3.053	LE S, 2014
15	10.15439/2015F295	29	3.22	1.657	WĄTRÓBSKI J, 2015
16	10.1016/j.advengsoft.2017.08.010	27	4.50	0.814	ZHANG J, 2018
17	10.1016/j.future.2019.12.024	24	6.00	1.929	HUSSAIN A, 2020
18	10.1109/JSYST.2015.2427338	21	3.00	1.909	ZHANG M, 2017
19	10.1016/j.websem.2020.100592	19	4.75	1.527	MOHAMMADI M, 2020
20	10.1016/j.proeng.2014.03.104	18	1.80	1.895	IORDACHE R, 2014

It was found that the aforementioned author [16] of the most relevant paper on this topic, Cloud-FuSeR: Fuzzy ontology and MCDM-based cloud service selection, addressed the importance of privacy in the digital era and presented a privacy model [17] (Figure 2). This paper discusses a system that uses a fuzzy ontology for selecting cloud services. It is based on MCDM to select services in cloud environments, considering various factors such as performance, cost, reliability, security, and others. Fuzzy ontology deals with the uncertainty and vagueness often present when dealing with different cloud services. It allows the representation of concepts and relationships more flexibly, reflecting data's imprecise and ambiguous nature in service selection.

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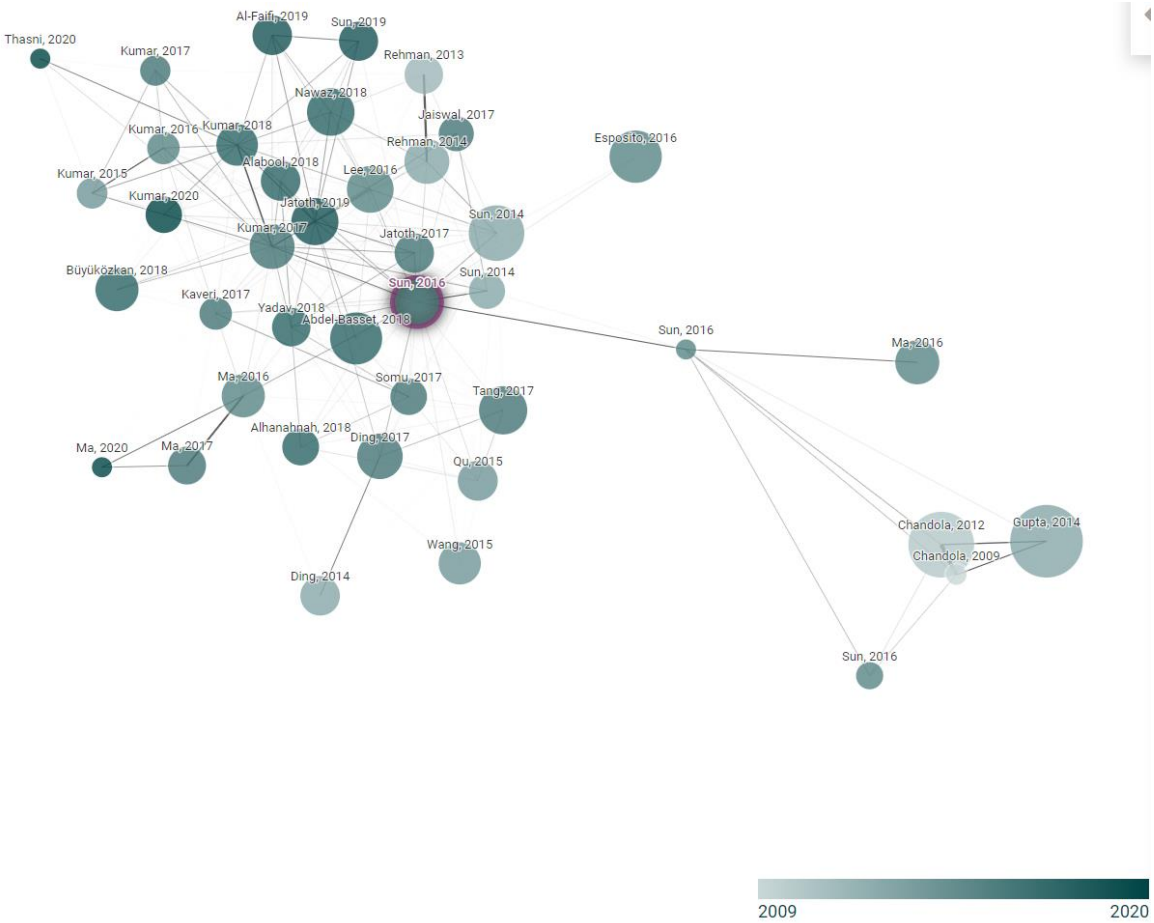

Figure 2. Network of authors and reference papers

A strong relationship was identified between the two most cited authors, Sun and Kumar. In 2016, he wrote the paper *Exploring Data Mining Techniques in Medical Data Streams* [18], the study of data stream mining in various application domains. A recent highlight is the impact of population aging on national and international healthcare systems. Anomaly detection is a typical example of a data stream application involving the identification of abnormal behaviors in constantly flowing data. The focus of the paper is to discuss existing techniques for anomaly detection in medical data streams. Additionally, a process utilizing the Autoregressive Integrated Moving Average (ARIMA) model to analyze electrocardiogram (ECG) data streams is presented. Citing the paper *A Multicriteria Decision-Making Method for Cloud Service Selection and Ranking* [19].

The paper discusses recent advances in cloud computing and its significance in providing on-demand subscription-based services. With the proliferation of various companies offering a wide range of cloud services, choosing the ideal service has become a significant challenge for customers. Faced with the difficulty of deciding among a wide diversity of options, the article proposes using TOPSIS to assist customers in selecting the most suitable cloud service for their needs. The research reveals that this method is practical and efficient in solving the cloud service selection problem, comparing favorably with previous approaches such as AHP and the fuzzy AHP method, demonstrating greater flexibility and accuracy.

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The same year, he wrote the paper Data stream mining in medical sensor-cloud. One of the limitations is the difficulty in correctly defining and identifying the context in which the data is being shared. Furthermore, the model may be vulnerable to attacks from hackers who attempt to steal sensitive information from the shared data. Another limitation is that the model may require a large amount of context data to be effective, which may be challenging to obtain in some instances. However, the model may not be suitable for dealing with situations where multiple users share data in the same context.

This research considered the relevance and reach of publications when analyzing the respective metrics (SCP and MCP). These consider citations in the country of origin, Single Country Publications, which measures international citations, and Multiple Country Publications. In bibliometric studies, these indexes are important for evaluating the impact and relevance of the paper (Table 5).

With this, it was identified that the paper *Cloud-FuSeR: Fuzzy ontology and MCDM based cloud service selection*, mentioned above, presented a different index from the group, followed by the paper Ensemble ranking: *Aggregation of rankings produced by different multicriteria decision-making methods* [20]. This has a strong relationship with the relevance of the journals responsible for the publications Omega and Future.

Table 5: Corresponding Author's Countries

	Country	Articles	MCP_Ratio
1	FRANCE	6	0.333
2	SOUTH AFRICA	6	0.000
3	UNITED KINGDOM	6	0.167
4	BRAZIL	5	0.200
5	CHINA	5	0.400
6	SPAIN	5	0.200
7	CANADA	4	0.000
8	IRAN	4	0.000
9	POLAND	4	0.000
10	GERMANY	3	0.000
11	INDIA	3	0.000
12	AUSTRALIA	2	0.000
13	MEXICO	2	0.000
14	NETHERLANDS	2	0.000
15	TUNISIA	2	0.000
16	USA	2	0.000
17	ALGERIA	1	0.000

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18 ETHIOPIA	1	1.000
19 GREECE	1	1.000
20 ITALY	1	0.000

Lecture Notes in Computer Science, covers several areas of computer science, under the responsibility of Springer, such as algorithms, artificial intelligence (IA), computer systems, and information security, among others. *Advances in Intelligent Systems and Computing* covers a wide range of topics related to intelligent systems and computing. Some of the main topics covered by this journal include: IA, Machine Learning, Natural Language Processing (NLP), Neural networks, Optimization and Decision support systems (Table 6).

Table 6: Most Relevant Sources

1	LECTURE NOTES IN COMPUTER SCIENCE
2	ADVANCES IN INTELLIGENT SYSTEMS AND COMPUTING
3	19TH AMERICAS CONFERENCE ON INFORMATION SYSTEMS AMCIS 2013
4	COMMUNICATIONS IN COMPUTER AND INFORMATION SCIENCE
5	PROCEDIA COMPUTER SCIENCE
6	LECTURE NOTES IN NETWORKS AND SYSTEMS
7	ADVANCES IN ENGINEERING SOFTWARE
8	COMPUTERS ENVIRONMENT AND URBAN SYSTEMS
9	ENVIRONMENTAL MODELLING & SOFTWARE
10	FRONTIERS IN ARTIFICIAL INTELLIGENCE
11	INFORMATION TECHNOLOGY AND CONTROL
12	INTERNATIONAL JOURNAL OF ELECTRICAL AND COMPUTER ENGINEERING
13	LECTURE NOTES IN BUSINESS INFORMATION PROCESSING
14	PROCEDIA ENGINEERING
15	SMART INNOVATION SYSTEMS AND TECHNOLOGIES
16	IEEE SYMPOSIUM SERIES ON COMPUTATIONAL INTELLIGENCE SSCI 2016
17	2ND INTERNATIONAL CONFERENCE COMPUTER AND INFORMATION SCIENCES
18	5TH INTERNATIONAL CONFERENCE ON ARTIFICIAL INTELLIGENCE BIG DAT
19	ADVANCES IN TRANSDISCIPLINARY ENGINEERING
20	AICT 2013: APPLIED INFORMATION AND COMMUNICATION TECHNOLOGIES

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Keywords (DE) are keywords that describe the main content of an article. At the same time, Keywords-Plus (ID) are additional keywords suggested by indexers that can be used to complement the main keywords and improve the indexing of the paper. It can be seen that in both cases, Ontology predominates as the central term (Table 7).

Table 7. Most Relevant Keywords

	Keywords(DE)		Keywords-Plus(ID)	
1	ONTOLOGY	34	ONTOLOGY	49
2	COMPLEXITY METRICS	6	DECISION MAKING	48
3	ELECTRE	6	DECISION SUPPORT SYSTEMS	14
4	MCDM	6	MULTICRITERIA DECISION-MAKING	12
5	MULTI-CRITERIA DECISION MAKING	6	SEMANTICS	12
6	ONTOLOGY RANKING	6	MULTI CRITERIA DECISION MAKING	11
7	AHP	5	ONTOLOGY'S	11
8	CLOUD SERVICE SELECTION	5	DECISION THEORY	9
9	DECISION SUPPORT SYSTEMS	5	RISK ASSESSMENT	9
10	SEMANTIC WEB	5	WEB SERVICES	9
11	BIOPORTAL	4	MULTI CRITERIA DECISION-MAKING	8
12	CLOUD COMPUTING	4	MULTICRITERION DECISION MAKINGS	8
13	MCDA	4	MACHINE LEARNING	7
14	MULTI-CRITERIA DECISION-MAKING	4	MULTI-CRITERIA DECISION ANALYSIS	7
15	MULTICRITERIA DECISION MAKING	4	MULTICRITERIA ANALYSIS	7
16	ONTOLOGIES	4	KNOWLEDGE BASED SYSTEMS	6
17	SEMANTIC INTEROPERABILITY	4	MULTICRITERIA DECISION SUPPORT	6
18	DECISION SUPPORT SYSTEM	3	ARTICLE	5
19	FUZZY TOPSIS	3	ARTIFICIAL INTELLIGENCE	5
20	GENETIC ALGORITHM	3	COMPLEXITY METRICS	5

It is observed that the authors with high scientific production, Kumar and Nawaz, together with Sun form a large research group in this area of knowledge (Figure 3).

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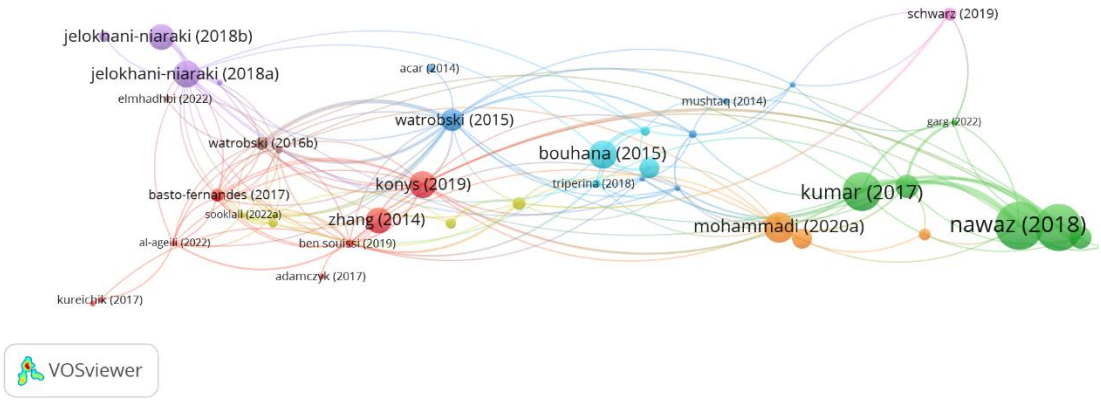
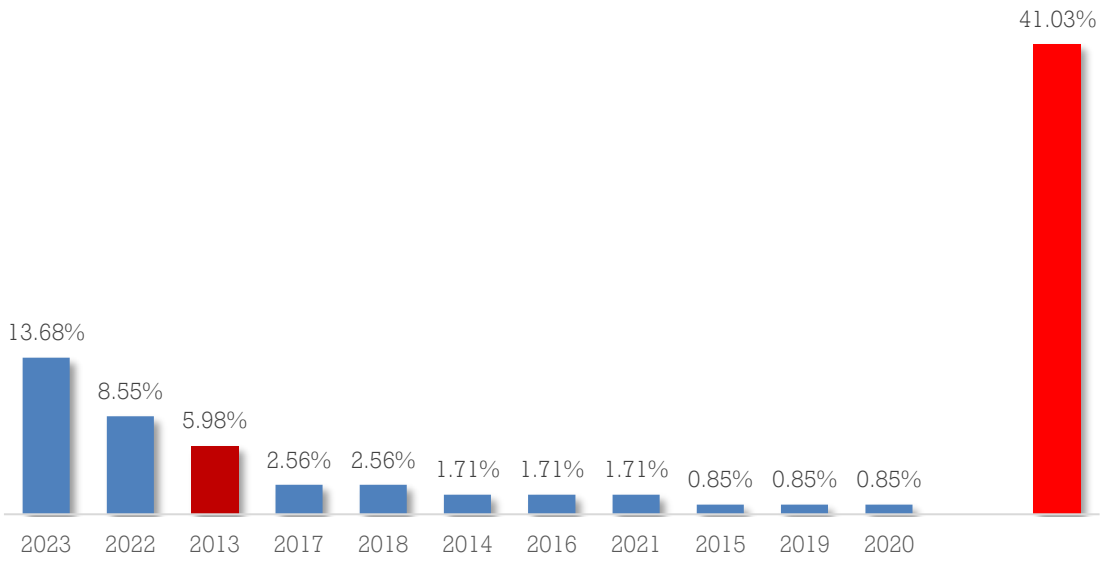


Figure 3. Cluster of relevant authors

It is observed that in this line of research, the average time to gain relevance and notoriety takes approximately four years. It was identified that, in this period researched, 41% of the papers did not present any citations. The year 2013 stands out in this analysis, with 6% of papers without any citation, a considerable rate for this database (Graph 1). For the paper to fully expand, it is necessary for the author to create ways to publicize his research, until it gains notoriety and support.

Graph 1. Pareto Chart - Index of papers without citation



There are opportunities to work in the line of research involving ontology and multicriteria methods to determine which method is appropriate depending on the problem. Given the growing number of methods validated by academia, whether from the American or French schools. The topic of Ontology and Multicriteria or Decision theory is

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approached as an instrument to support decision-making (Figure 4). Knowing the appropriate method to structure such a decision could be a valid instrument in the literature.

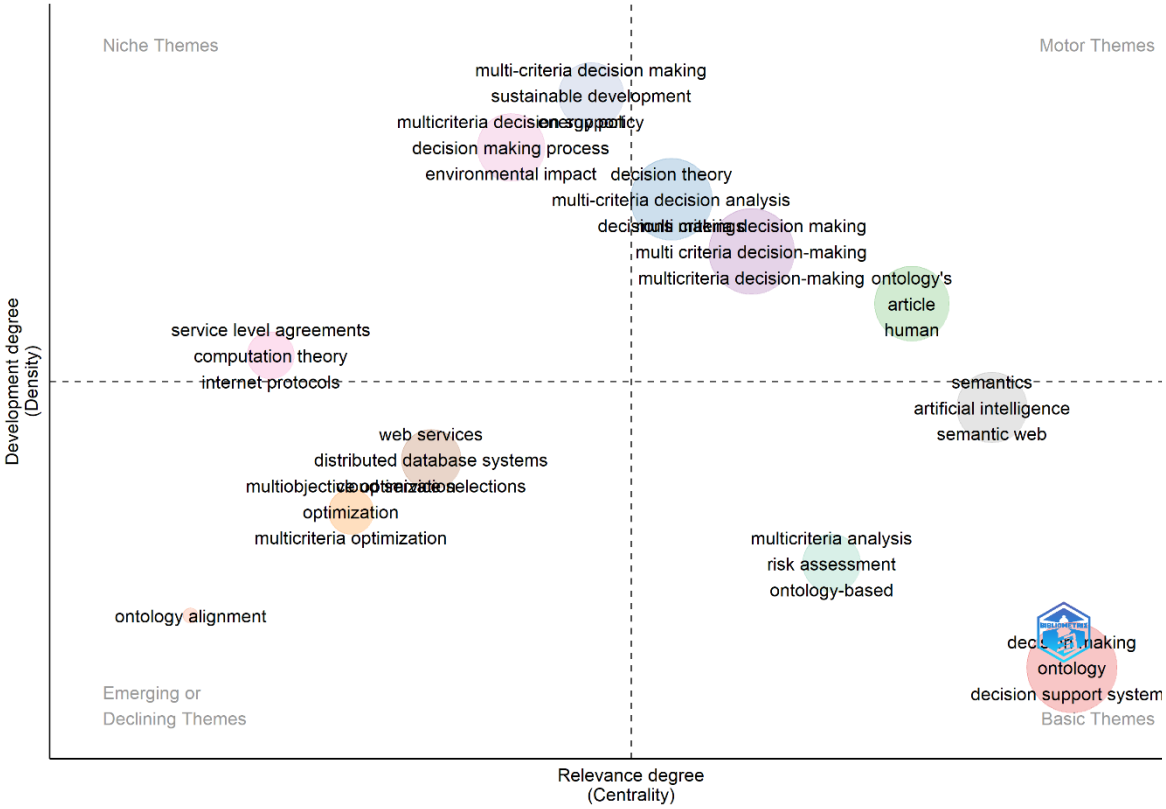

Figure 4: Analysis of density and centrality of research themes

It was found in this research that the emphasis given in the available literature is directed at approaching ontology as an element of decision-making. Thus, it was realized that there is an opportunity to run studies to propose an ontology to suggest the most appropriate multi-criteria method, depending on the ongoing problem (Figure 5).

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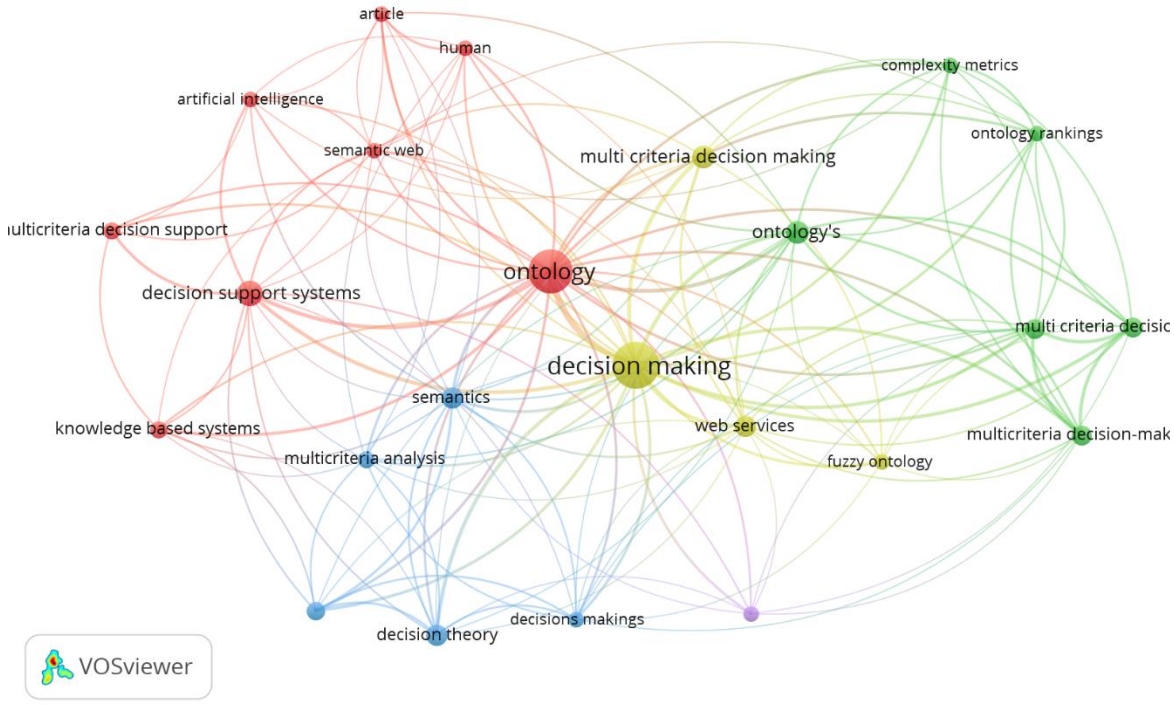

Figure 5: Cluster of literature study áreas

This conclusive summary highlights the existing literature gap, where the emphasis is on the decision-making process rather than on understanding the characteristics of structuring multi-criteria methods. The research identified a line of action that aims to study ontology about the characteristics of multi-criteria methods. The goal is to develop an algorithm that, in the face of a structured problem, can propose the most suitable method for the specific context. This innovative approach seeks to fill a significant gap in research by providing a more structured approach focused on selecting multi-criteria methods based on ontological considerations.

It was noticed that the study of ontology focuses on the nature of existence, seeking to understand the fundamental structure of reality, of beings, and the relationships between them. Therefore, ontology examines questions about what exists and how it exists (interrelationship). On the other hand, the multi-criteria structure generates the basis for decision support in complex environments by providing mathematical and axiomatic elements to result in evaluation, ordering, or comparison. Thus, this multi-methodological proposal has space for research and can be replicated in any area of knowledge.

Conclusion

The present research contributed significantly to researchers in ontology and multi-criteria methods by exploring the intersection of these two fields in a bibliometric approach. The usefulness of this research lies in its ability to provide a deeper understanding of this

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complex relationship, allowing for a more comprehensive and informed analysis in diverse contexts. Furthermore, as a result of this research, it is suggested that future studies expand the temporal window of analysis, enabling a more comprehensive investigation of changes over time and their impact on decisions and ontological concepts. Such studies could enrich theoretical understanding and provide practical insights for applying these methods in dynamic and constantly evolving scenarios.

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