المجلة الدولية للأداء الاقتصادي
International journal of economic performance
ISSN: 2661-7161 EISSN:2716-9073
Publications are Open Access in this journal

The importance of integrating fuzzy logic analysis and artificial intelligence in decision-making in economic organizations: A Bibliometric Study

Idrissi Mokhtar *	Abrou Djebli	Souar Youcef
idrissi.mokhtar@univ-oran2.dz	aberroudjebli@gmail.com	youcef.souar@univ-saida.dz
University of Oran2 (Algeria)	Meghnia university center (Algeria)	University of saida (Algeria)

Submitted:25/08/2024 Accepted:07/11/2024 Published: 19/12/2024

Abstract:

Fuzzy Logic is a contemporary tool, plays a vital role in decision making within economic institutions. It helps to understand the complexity of the uncertain and rapidly evolving economic landscape. A bibliometric analysis of 70 research papers from the Scopus database highlighted the importance of fuzzy logic in decision-making processes. The findings suggest that research trends integrating fuzzy logic and artificial intelligence for decision making in economic institutions remain limited, which hampers the ability of organizations to process and make effective, optimal decisions, ultimately affecting their performance and economic efficiency.

Key words: fuzzy logic, Economic organization, artificial intelligence, decision making.
JEL Classification Codes: C6, L21, L86, D81.

* Corresponding author

1. Introduction

The world is witnessing a technological and information revolution that has changed many of the traditional concepts associated with the economic decision-making of organizations and institutions in the world, where the environment has changed and complicated and these organizations have become more demanding than ever to build information systems and technology expert in the management of change and appreciation of the crises that may be it is exposed to the institutional environment as it had to rely on scientific methods in the management of big data due to the magnitude and the large number of engagements that have become characteristic of the economic and social reality as well as the relational of many global economic organizations institutions control technology and its innovations, including artificial intelligence tools, which have developed terribly in many fields.

This technological and informational development that characterizes this era is based on the employment of the rules of mathematics in various technical sciences and also social and among the most important mathematical methods that contributed significantly to the construction of many artificial intelligence algorithms is the methods of fuzzy analysis or vague analysis, which was the first contributions to the researcher Lotfi Zadeh (1965) this analysis is based on the fuzzy groups and has been developed by many researchers as it has been used in many fields of research, especially in the economic aspect as an analysis concerned with dealing with uncertainty, ambiguity and uncertainty and among the uses of fuzzy logic in the economic aspect can be mentioned the financial aspect, macroeconomic, microeconomics, marketing, production, strategic aspect, human resources, foreign trade, as well as research and development in the economic aspect

The decision-making by organizations and economic institutions in the complex and changing environment is crucial in determining their fate as it is a factor of their success, adaptation and integration in this changing environment and depends on the right and good decision-making on the availability of data, which has become

characterized by the magnitude and who in this context, mathematical analysis with fuzzy logic is considered one of the distinct ways to solve different problems, in which traditional techniques may not be appropriate due to the presence of uncertainty and ambiguity and therefore resort to it techniques of fuzzy logic for solving problems, especially where information is inaccurate and uncertain and non-linear relationships (Kahraman & Haktanır, 2024) thus trying to make effective and good decisions.

Fuzzy logic is one of the most important methods of logic in building artificial intelligence tools and algorithms through many contributions in many fields of artificial intelligence such as medical diagnosis, image recognition and financial risk analysis

It shows the importance of using fuzzy groups in building smart and expert systems and hence we thought to raise the research problem:

What is the reality of scientific research related to the integration of analysis with fuzzy logic and artificial intelligence in decision-making in economic organizations?

- **General hypothesis:** Assuming that fuzzy logic analysis is among the main tools that correspond to artificial intelligence in making important and effective decisions based on uncertainty and uncertainty, especially in economic institutions in the changing and complex environment of institutions.
- **Objectives and importance of the study**

This paper emphasizes the significance of fuzzy logic analysis in artificial intelligence and decision-making, particularly in economic situations. It highlights the increasing research on the integration of fuzzy logic in artificial intelligence for economic decision-making. The paper highlights the importance of this integration in the digital environment, technological complexity, and data volume faced by organizations and companies. Traditional methods are no longer sufficient to solve problems and make optimal decisions, which are crucial for maintaining and competing in a complex and changing world. The research is a bibliometric study, focusing on fuzzy logic and artificial intelligence in economic decision-making.

- **Methodology applied**

To answer the question of this working paper, we relied on the analytical method by using bibliometric analysis of a group of academic papers downloaded from the Scopus

database, which numbered 70 articles. We applied the steps of bibliometric analysis by using the statistical program R.

2. Literature Review:

Many studies dealt with the importance of methods of fuzzy analysis in many disciplines and fields, whether scientific or technical and as well as social as one of the important analyzes that rely on mathematical analysis in the interpretation of phenomena and decision-making related to the problems presented to institutions and as well as researchers as this type of analysis contributed to the development of artificial intelligence algorithms, which contributed significantly at this time of the technological revolution led to more interest in data science, which is among the important disciplines and which has become control and analysis of a key role in decision-making, especially big data (big data). Dejian, Zeshui, and Wanru, 2018) Study examined international publication patterns and dynamics in fuzzy theory. They analyzed 12936 publications from Chinese researchers over the past 30 years. The study found that scientific publications are highly unbalanced at regional levels in China. The United States was identified as China's most important partner in collaborative research in science and technology, crucial for high research outputs in computer science and engineering. Fuzzy theory research trends have shifted from basic research to applications like decision-making, optimization, modeling and design. Another study (Laengle, et al., 2021) analyzed articles and academic papers published in Fuzzy Sets and Systems from 1978 to 2016, providing a bibliometric overview of research trends. The study found that the theory of fuzzy groups has experienced strong growth due to a diverse range of topics from Europe, North America, East Asia, the United States, and countries such as India, Egypt, Turkey, and Iran. Lotfi A. Zadeh, the most influential author, published several influential papers that shaped the journal, including the inaugural paper in 1978. The study suggests future prospects for more papers linking fuzzy group theory to other fields of engineering, business, and science. Among the studies on applications of fuzzy analysis and artificial intelligence is the study of (Nica, Delcea, & Chirit, 2024) that examines the mathematical applications of fog analysis and artificial intelligence in

financial analysis from 1990 to 2023. It calculates indicators such as annual growth rate, citations, and international cooperation. The study found an estimated 19.54 annual growth rate for fuzzy logic research, with an average of 25.52 citations and 21.16% international cooperation. Fuzzy logic is important in terms of design, model, algorithm, optimization, stability, and terms like "fog control unit". The study highlights the growing impact of fuzzy analysis and artificial intelligence in financial analysis, leading to more research on how to transform global financial and banking analysis practices.

(Radu, Radu, Tabirca, Saplacan, and Lile, 2021) Addressed the exploration of database (WOS) and review of important contributions in the research of fuzzy logic or the theory of fuzzy groups for a long time, where the study explores the research of fuzzy logic and its contributions using database (WOS) methods. It identifies prominent authors, institutions, countries, and journals in the field. The study found a significant increase in research papers published annually in international journals, indicating the development of fuzzy logic research. This research is widely used in various disciplines, particularly in artificial intelligence, informatics, computer science, medicine, and science. The study also found polarization in the Asia region and popular scientific journals, influenced by the number of research papers and character quotes. Another study was published in fuzzy logic (Merino-Arteaga, Alfaro-garcía, and merigó, 2022) this study analyzed academic research on fuzzy systems in the United States and Canada using bibliometric analysis techniques. It found that the United States is the most productive country for fuzzy logic research, with L. A. Zadeh being the most influential author. The study also found that the United States is more advanced in fuzzy system research than Canada. (Zaliluddin, 2023) which was the subject of a study using bibliometric analysis on the topic of multicriteria decision-making with fuzzy logic (MCDM) using a variety of articles relevant to the topic of study, which address the number of studies completed in the topic including authors, titles, citations, updates and other information to illustrate the latest trends future research on fuzzy logic multiple criteria decision making (MCDM).The results of this study concluded that the research on the analysis of fuzzy logic and the most published was by the author L. A. Zadeh, the

founder of vague analysis, over a period of 58 years. (latha, Bhuvaneswari, & Soujanya, 2023) examined 80 scientific research between 2017-2022 using biometric analysis to look at, examine and attempt to construct a conceptual framework for the use of fuzzy logic analysis tools in machine learning in a range of disciplines such as computer science, engineering, mathematics, statistics, medicine, finance and agriculture. Furthermore, the study compares fuzzy query with traditional data models. This survey suggests possible topics for further research into fuzzy data processing and provides a broad overview of fuzzy predictive modeling and data retrieval approaches. The study by (çağlayan, Abbasi, Yilmaz, and Erdebilli, points out, 2024) analyzed 79 articles published between 1995 and 2023 using the database (WOS). It found that the most traded keywords in these articles were "decision distribution, decentralized resolution, and fuzzy analysis." The study also identified active researchers, journals, journal metrics, title document type, and active countries in decision-making based on fuzzy logic. The findings can help researchers find potential partners and stay updated with current research trends, providing new perspectives on fuzzy logic, decision sharing, and decentralized decision making.A bibliometric study (rosário, Dias, and Ferreira, 2023) on 96 research papers from the SCOPUS database revealed that using fuzzy logic in marketing decisions can enhance customer relationships, increase profitability, and improve performance. The study found that incorporating fuzzy logic into marketing strategies can improve competitiveness, performance, and productivity in the ever-changing business environment. The study by (Yu, Xu, and Wang, 2019) analyzed 370 publications from the Journal of Fuzzy Optimisation and Decision Making (FODM) from 2002-2017. The analysis revealed 10 most cited references, with Zadeh (1965) being the most cited reference. The study also identified six most popular keywords over the last five years: 'fuzzy set theory', 'artificial intelligence', 'uncertainty analysis', 'uncertainty differential equations', 'uncertainty distribution', 'uncertainty theory', 'uncertainty distribution', 'fuzzy set theory', 'uncertainty analysis', and 'uncertainty analysis'. These trends suggest that recent research in FODM publications focuses on uncertainty theories, methods, models, and systems and their application to solve optimization and decision-making

problems. (Fernández, Moreno, & Vergara-González, 2022) Pointed out the importance of applying AI mechanisms in project management. This study was conducted using bibliometric analysis to identify recent trends and different applications of fuzzy logic in research areas related to project management. The results of the study concluded that sectors such as construction, software and product development, and systems such as knowledge management or decision support systems have studied and applied the potential of AI more intensively.

3. Bibliometric analysis : Bibliometric analysis is the quantitative study of bibliographic resources and provides an overview of research areas that can be categorized by papers, authors, journals, and the number of citations (Zaliluddin, 2023). Knowing the research trends in any field of science requires tracking research, counting it and identifying its results in order to address research gaps by researchers, and bibliometric analysis is one of the scientific measurement methods that uses mathematical and statistical methods to analyse and evaluate scientific publications and extract indicators that allow researchers to investigate the literature and its emerging trends in any particular research topic, and therefore bibliometric research has the advantage of summarizing large amounts of research and scientific publications in order to know the intellectual structure and emerging research trends in a particular research area (Bota-Avram, 2023).

4. Fuzzy Logic: Fuzzy logic was introduced in 1965 by Lutfi Zadeh, a professor of computer science at the University of California, Berkeley. Fuzzy logic is a multi-value system that allows the use of intermediate values between traditional true/false or yes/no evaluations. Concepts such as "too long" or "too fast" can be treated mathematically, allowing computers to think more like humans. Fuzzy systems are an alternative to traditional notions of set membership and logic, which have their roots in ancient Greek philosophy. One of the traditional laws is the "law of the excluded middle," which states that every proposition must be either true or false. Plato suggested that there is a third zone beyond right and wrong, which is the basis for the idea of fuzzy logic. He was

followed by philosophers such as Hegel, Marx, and Engels, but Lukasiewicz was the first to propose a systematic alternative to Aristotle's two-valued logic (Hellmann, 2001).

4.1.Definition of Fuzzy Logic: Fuzzy logic deals with ambiguity and approximation in its interaction with the real world, describing things in terms of categories with blunt boundaries. While it can be interpreted as a multivalued logical system, it goes beyond that to include a system of reasoning and computation based on fuzziness and approximation (Zadeh, 2015).Fuzzy logic is a type of logic that allows for degrees of truth instead of the traditional right or wrong values. In fuzzy logic theory, values can be both true and false at the same time based on the degree of membership, which determines the extent to which an item belongs to a particular set. This theory is based on the concept of fuzzy sets and membership functions, where the degree of membership expresses the extent to which an element belongs to a certain group, so the degree of membership is considered a fundamental and important feature of fuzzy logic, where the degrees of truth and error vary according to the strength of membership (Nursyachbaini, 2023).

5. Artificial Intelligence: John McCarthy (1990) described artificial intelligence as "the science and engineering of making intelligent machines, especially intelligent computer programs. This description refers to a body of knowledge, research, and science that enables machines to exhibit some form of thought, as well as behavior, perception, and performance. Studies indicate that artificial intelligence (AI) is a term used to describe intelligent systems that strive to acquire cognitive abilities similar to human abilities, such as the ability to reason, comprehend meaning, generalize, learn from past experience, and act—in essence, the philosophy of machine thought, action, and performance (All Noman, Akter, Pranto, & Haque, 2022).

6. Making Decision: Organizations and companies often seek to make choices that ensure their survival in their complex and changing environments, and this choice is sought by making effective and optimal decisions among a range of available alternatives. According to Gigerenzer and Wolfgang (2011), the decision-making process is the selection of alternatives among a myriad of available options, so the possible

outcomes and consequences of adopting any of the alternatives must be considered, and the characteristics of the different options that meet the goals, needs, and objectives of the organization are evaluated. The decision-making process in organizations is complex and is based on many methods that allow to evaluate the results of the decision and its benefits to the company. Companies in all economies strive to achieve, maintain, and sustain superiority and success by achieving and maintaining profits and market share, and therefore the efforts of organizations and companies are focused on making value chains, production processes, and management practices more effective (Apolo-Vivanco, López-Rodríguez, & Sotomayor-Pereira, 2021) . Due to the complexity of the institutional environment with the presence of uncertainty and big data, it has become necessary for researchers to find alternative methods of decision-making in this type of environment surrounding institutions, and among the methods that have become increasingly important is the use of fuzzy analysis methods and methods in making decisions based on uncertainty, which has proven its effectiveness in solving many of the problems and constraints faced by organizations, companies, and institutions in the world. Decision-making processes include a series of stages that decision-makers go through in determining their effective choices, and these stages are as follows (Kahraman & Haktanır, 2024):

Identify the decision: The first step is to recognize that a decision needs to be made. This could be motivated by a problem, an opportunity, or a need for improvement.

Collecting information: Once the decision is identified, relevant information is gathered and synthesized. This step involves finding the facts, data, and insights needed to make an effective decision.

Alternatives Identification: This step generates a set of potential options or solutions to the problem or decision. These alternatives should be comprehensive and reflect different approaches to the problem.

Evaluate alternatives: The information gathered is then used to evaluate and assess the advantages and disadvantages of each alternative. Factors such as feasibility, potential outcomes, costs, benefits, risks, and potential consequences are considered.

Decision Making: Based on the evaluation of the alternatives, a decision is made. This step involves selecting the most appropriate option that meets the decision-maker's goals and objectives.

Taking Action: After the decision is made, the next step is to implement the chosen course of action. This involves planning and executing the steps necessary to put the decision into action.

Review and Learn: The final step is to evaluate the results of the decision and the actions taken. This evaluation helps determine whether the decision was effective, whether the desired results were achieved, and whether any adjustments or modifications need to be made for future decisions.

7.Emperical Study: In order to carry out a bibliometric study of the literature related to the integration of fuzzy logic analysis and artificial intelligence in decision-making in economic organizations, a sample of 70 publications related to the subject of the study was taken, where the research keywords were fuzzy logic, artificial intelligence, and decision-making. The SCOPUS database was used, and the data were entered into the statistical program R and the VOSviewer program in order to extract the main indicators related to the bibliometric study.

7.1 Method and Materials

Bibliometric analysis Bibliometric analysis is a process through which many indicators of research and scientific trends in a particular field or journal publications are obtained. This process is done by examining scientific and academic publications on a particular subject or journal publications so that bibliometric indicators are extracted by relying on mathematical and statistical analyses. Pritchard (1969), in his definition of the word (bibliometric, indicated the application of mathematics and statistical methods to books and other means of communication. In another definition by Potter (1981), bibliometrics is simply the study and measurement of publication patterns for all forms of written communication and their authors (BROADUS, 1987). Bibliometric analysis is carried out according to the following steps (Passas, 2024):

Step one: In this step, the researcher provides a thorough introduction to the topic by outlining the research problem, related questions, study scope, and specifically defined research objectives that will inform subsequent phases of the investigation and the anticipated results.

Step two: The researcher gathers information from reputable databases (Web of Science, Scopus, Science Direct, Springer, etc.) that represents the scientific literature on the topic. The information is then uploaded using various loading formats (RIS, BibTex, plain text, CSV), as well as programs that organize publication data (Endenote, Mindeley Zotero, etc.). All of the journals and magazines, together with the author collection, research summaries, and other data that serve as the foundation for the bibliographic analysis, are included in this file. The next stages include an analysis of it.

Step three: To perform a thorough biometric analysis of the updated and correct data, pre-treatment of data gathered from various databases is used to purify the data.

Step four: Data are input and processed using biometric analysis software, and they are examined using bibliometric indicators to ascertain the analysis technique. This is accomplished by means of data analysis. Co-word analysis, co-citation analysis, and bibliographic coupling.

Step five: Using various software to perform this kind of research (bibliometric study), such as R and Python, VOSViewer, and CiteSpace, the researcher processes data at this point by extracting bibliometric indications. In order to ascertain research orientations in the area of study and to get the findings of the bibliometric analysis.

Step six: In this step, graphical representations of the results of the analysis are created to help explain and present the most important research findings and trends in the study.

Step Seven: The results of the bibliometric study are now interpreted through the interpretation of research indicators, such as key words like "cooperation in research," the number of quotes from magazines and other sources for researchers, the rates of annual development in the subject research, and the identification of all significant indicators in the bibliometric research in order to produce conclusions and

recommendations that aid in determining the weight of trends and research patterns in the subject under consideration as well as the significance and importance of the subject itself, providing direction for future research.

8. Results and discussion: After statistically processing the data collected from the Scopus database on fuzzy logic and artificial intelligence analysis and their importance in economic decision-making and using Statistical Programme R on the sample collected, the results of which were descriptive statistical processing of this sample as shown in the table below:

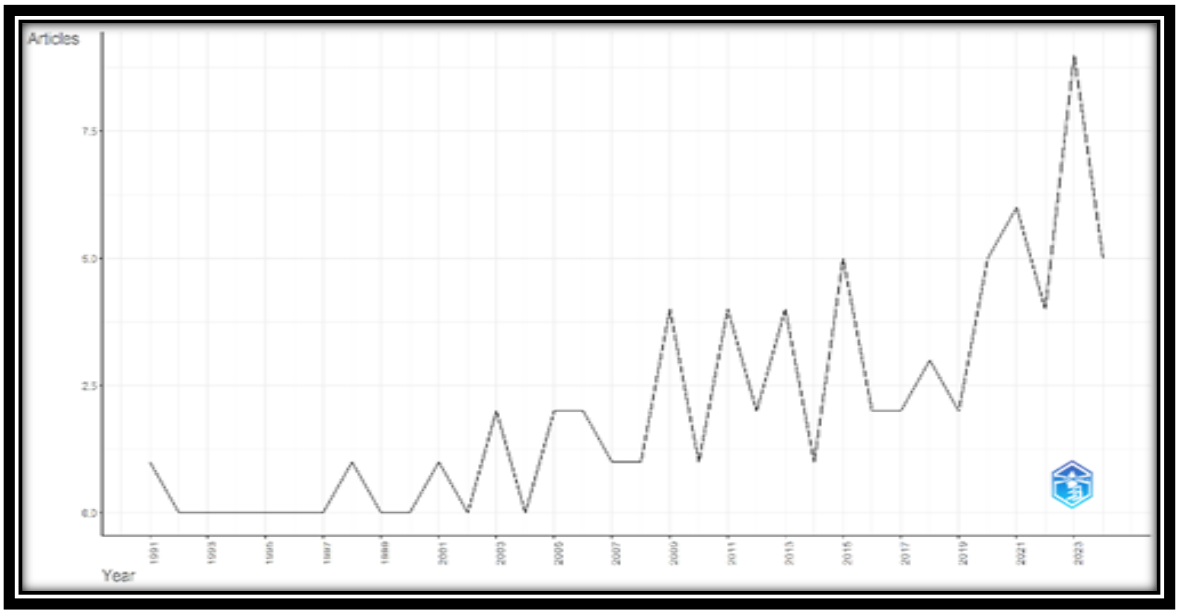
Table (1): Statistic descriptive of data

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1991:2024
Sources (Journals, Books, etc)	50
Documents	70
Annual Growth Rate %	5
Document Average Age	8.47
Average citations per doc	23.5
References	3049
DOCUMENT CONTENTS	
Keywords Plus (ID)	611
Author's Keywords (DE)	257
AUTHORS	
Authors	214
Authors of single-authored docs	8
AUTHORS COLLABORATION	
Single-authored docs	8
Co-Authors per Doc	3.11
International co-authorships %	31.43
DOCUMENT TYPES	
article	43
book	2
book chapter	7
conference paper	14
review	4

Source: Prepared by researchers based on the outputs of R statistical program

8.1. Publication and Citation Trends: One of the important steps in bibliometric analysis is the determination of the annual scientific production in the researched subject. The results of the study show that the annual scientific production in the field of fuzzy logic and artificial intelligence in decision-making underwent several fluctuations during the study period from 1990 to 2024. There were periods of stability in the level of annual scientific production in the years (1992-1997), (1999-2000), (2007-2008), and (2016-2017). However, the annual research in fuzzy logic and artificial intelligence in decision making also experienced several declines in different years, as shown in Figure 01. The period (2022-2023) recorded the highest amount of scientific production in the subject, followed by a decline in annual scientific production during (2023-2024). In general, the volume of research has increased significantly since 2019, indicating an increase in studies related to fuzzy logic and artificial intelligence and their role in economic decision-making. This increase is attributed to the effectiveness of fuzzy analysis methods in solving various economic problems, along with the expanded use of artificial intelligence in recent years. It is expected that there will be many more studies in economics that use fuzzy analysis and its combination with artificial intelligence to address economic problems with performance, effectiveness, and optimization.

Figure (1): Annual Scientific Production



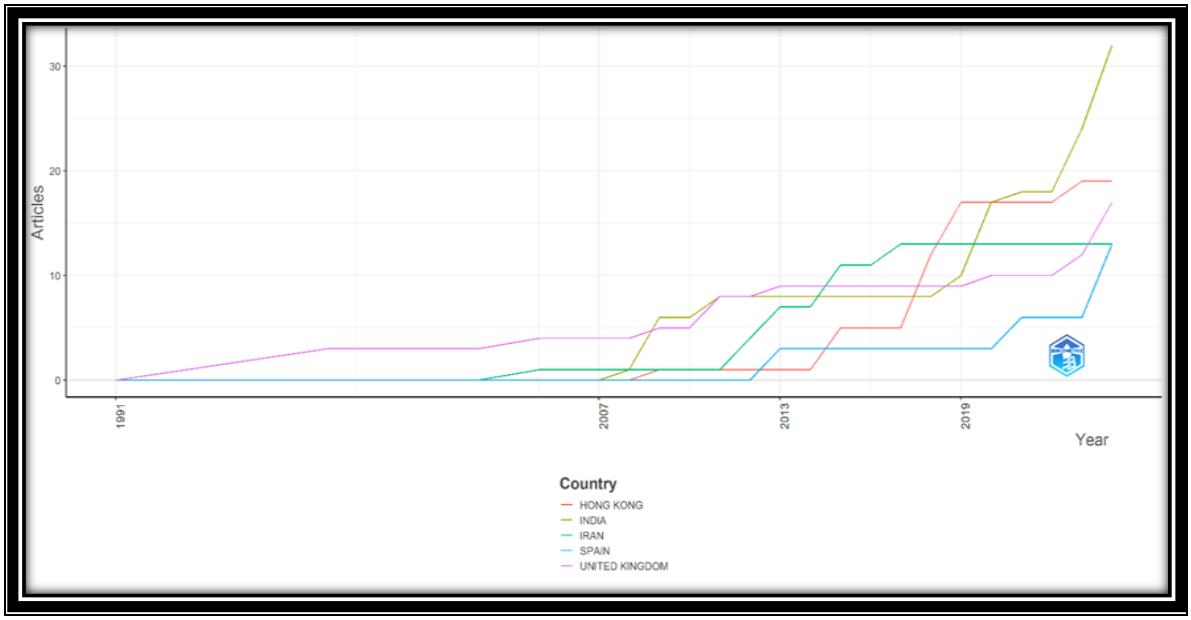
Source: Prepared by researchers based on the outputs of R statistical program

Regarding the most relevant sources related to fuzzy logic analysis and artificial intelligence, we find that the journal KNOWLEDGE-BASED SYSTEMS stands out with a total of 8 publications. In second place is the INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH with an average of 5 publications. Meanwhile, INDUSTRIAL MANAGEMENT AND DATA SYSTEMS and JOURNAL OF CLEANER PRODUCTION share third place with a total of 3 publications each. Other notable sources include JOURNAL OF MANUFACTURING TECHNOLOGY MANAGEMENT, JOURNAL OF THE OPERATIONAL RESEARCH SOCIETY, RESOURCES, CONSERVATION AND RECYCLING, JOURNAL OF CONSTRUCTION ENGINEERING AND MANAGEMENT, and STUDIES IN SYSTEMS, DECISION AND CONTROL, each with 2 publications, followed by the proceedings of the 2ND INTERNATIONAL CONFERENCE ON ARTIFICIAL INTELLIGENCE, MANAGEMENT SCIENCE AND ELECTRONIC COMMERCE, AIMSEC 2011. Thus, researchers interested in fuzzy logic analysis and artificial intelligence and their role in decision-making should focus on these resources to aid their studies and gain insights into the latest research on these topics.

8.2.The Most Productive Countries/Regions and Institutions: Concerning the scientific production of countries on the applications of fuzzy analysis and artificial intelligence in decision making, Figure 02 shows that the United Kingdom (UK) is the leading producer of scientific research since 1998, while most countries have no publications in economics. India is the leading country in scientific production in the field of Fuzzy Analysis and Artificial Intelligence; since 2008, research in India has increased steadily until 2011, when scientific production stabilized at 8 publications per year until 2018. After that, production increased to 32 publications per year. Iran ranks third in terms of scientific publication, with 13 articles by 2024, alongside Spain. Iran's first publication appeared in 2005, and by 2012, the number of publications had increased to 4. In 2013, this number increased to 7, and in 2015, it reached 11, peaking at around 13 in 2017, and maintaining this level until 2024. Spain had no scientific output in the Scopus database in the field of economics until 2013, when three articles were published. By the

end of the study period in 2024, the number of articles published increased to 13. As for Hong Kong, there were no scientific publications from the beginning of the study period (1991) until 2009, when one article was published. The scientific output remained stable until 2015, when it reached 5 publications, and increased to about 19 articles in 2024. The graph illustrates the levels of scientific publication by country for the sample study.

Figure (2): Country Production over Time 1990-2024

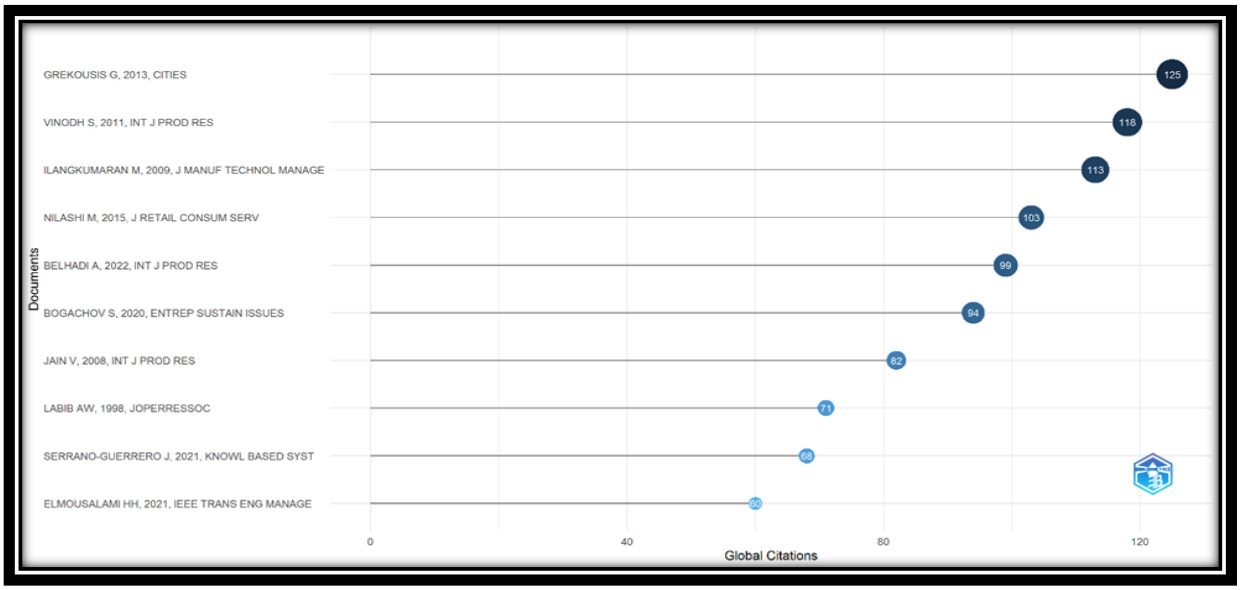


Source: Prepared by researchers based on the outputs of R statistical program

8.3. The Top 10 Most Highly Cited Papers of Reviewed Publications: The citation metric is regarded as a pivotal criterion for assessing the influence of scholarly articles and publications within a specific discipline. Nevertheless, this metric may not provide an accurate representation of the article's or publication's caliber, and the temporal dimension must be considered to evaluate the magnitude of impact (Qin, Xu, Wang, & Skare, 2023). The findings of the investigation indicate that the most frequently cited article, which has garnered 125 citations, is titled "Modeling urban evolution using neural networks, fuzzy logic, and GIS: The case of the Athens metropolitan area," authored by George Grekousis and collaborators, and it pertains to the modeling of urban evolution through the application of neural networks, fuzzy analysis, and geographic information systems. Furthermore, the second position in citation frequency is attributed to the scholarly work of Vinodh and Balaji (2011), titled "Fuzzy logic-based leanness assessment

and its decision support system." The third position, with a total of 113 citations, is occupied by the scholarly article titled "Selection of maintenance policy for the textile industry using a hybrid multi-criteria decision-making approach," authored by Ilangkumaran, M., & Kumanan, S. (2009). The publication "The role of security, design, and content factors on customer trust in mobile commerce," produced by Nilashi et al., has garnered approximately 103 citations. Ranking fifth among publications with fewer than 100 citations is the paper "Building supply-chain resilience: an artificial intelligence-based technique and decision-making framework," authored by Belhadi et al., which has accumulated 99 citations. The article "Artificial intelligence components and fuzzy regulators in entrepreneurship development," written by Sergii Bogachov (2020), has received a total of 94 citations. The seventh most frequently referenced scholarly work was "What is the discourse surrounding the transition from 'lean' to 'agile' integrated supply chains? A fuzzy intelligent agent-based perspective," authored by Jain et al. (2008), which garnered 82 citations. The eighth rank, with a total of 71 citations, was attributed to the study "An intelligent maintenance model (system): an application of the analytical hierarchy process and a fuzzy logic rule-based controller" by Labib et al. (1998). The ninth rank, which received 68 citations, was occupied by the work of Serrano-Guerrero et al. (2021) titled "Fuzzy logic applied to opinion mining: A comprehensive review." Lastly, the article named "Comparison of Artificial Intelligence Techniques for Project Conceptual Cost Prediction: A Case Study and Comparative Analysis" by Haytham H. Elmousalami achieved the tenth position with 60 citations. These findings underscore the significance and diversity in the application of fuzzy logic and artificial intelligence as potent decision-making instruments that can assist organizations in establishing and maintaining their future viability.

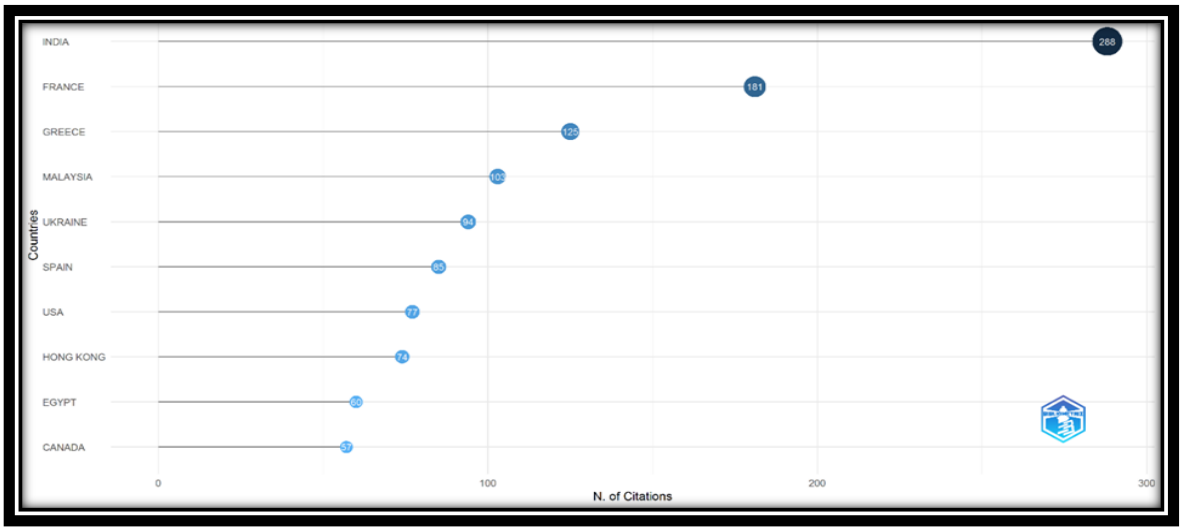
Figure (3): Most Global Cited Documents during 1990-2024



Source: Prepared by researchers based on the outputs of R statistical program

In terms of citations by country, **Figure (3).** below shows that India is the top cited country with approximately 288 citations, followed by France with 181 citations. Greece is in third place with 125 citations, closely followed by Malaysia in fourth place with 103 citations. Ukraine is fifth with 94citations, while Spain is sixth with 85citations. The United States ranks seventh in the hierarchy in terms of the number of citations within the sample analysed, with a total of 77. Hong Kong ranks eighth with 74 citations, while Egypt ranks ninth, with 60 citations, just ahead of Canada, which ranks tenth and last among the top ten most cited research papers, with a total of 57 citations. The figure below shows the number of citations by country.

Figure (4): MostCitedCountries



Source: Prepared by researchers based on the outputs of R statistical program

In terms of cross-country collaboration, **Figure (5).** shows that there is very limited collaboration in fuzzy logic and artificial intelligence research in the economic domain. The cooperation map shows a single line between the United States and Australia, which indicates a high level of cooperation between these two countries. When the line connecting two countries is thin, it indicates a low level of cooperation; when the line is thick, it indicates a high level of cooperation between them (García-Alcaraz, et al., 2023).

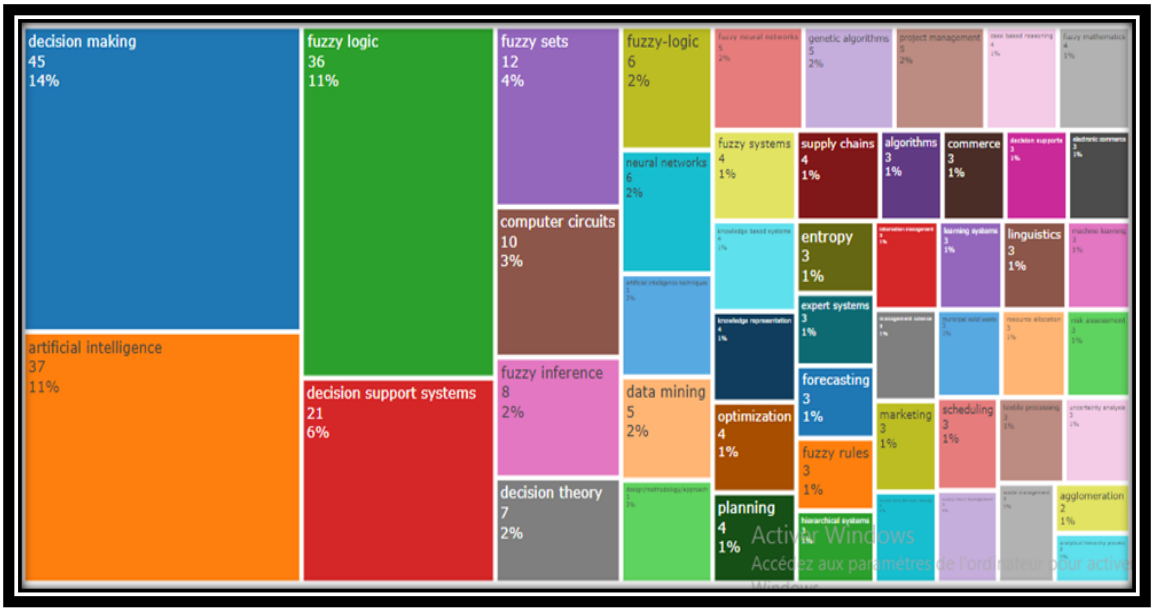
Figure (5): Country Collaboration Map

Source: Prepared by researchers based on the outputs of R statistical program

8.4 Developments and Research Trends:

In terms of developments and research trends in the field of fuzzy analysis and artificial intelligence, the study findings indicate that the key terms identified include decision-making and artificial intelligence. From these, two second-generation terms emerged: fuzzy logic and decision support systems. The third-level terms included fuzzy sets, computer circuits, fuzzy inference, and decision theory. The following figure illustrates the major research trends encompassing artificial intelligence, fuzzy logic, and decision-making.

Figure(6): Most key words Map (TreeMap)

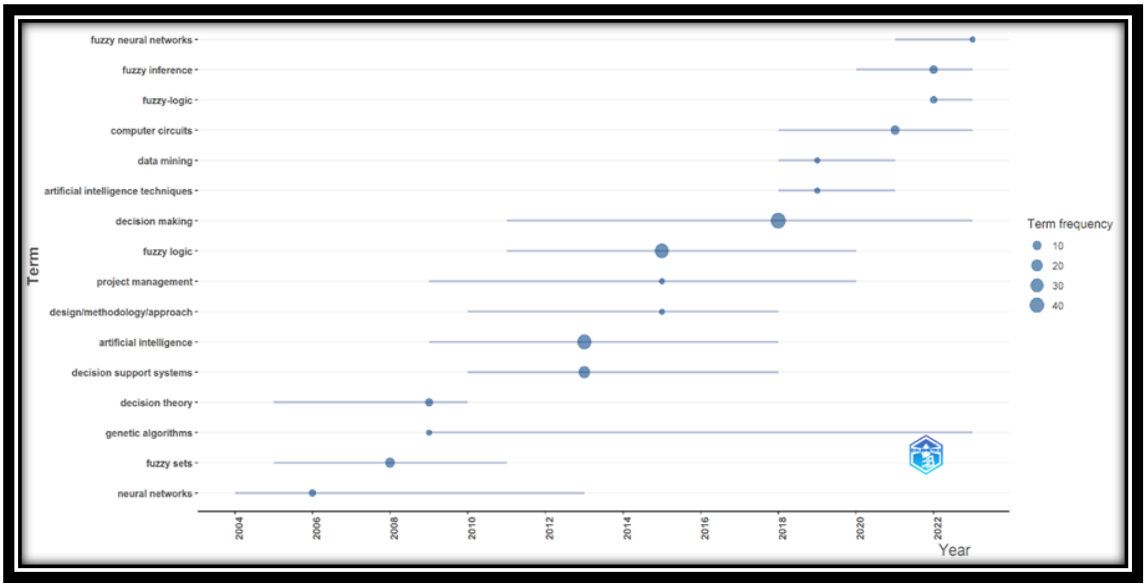


Source: Prepared by researchers based on the outputs of R statistical program

The following Figure (6). (7). Illustrates that the research trends have evolved over the study period through the most frequently used keywords, namely "artificial intelligence" and "decision support systems" in 2013. This was followed by fuzzy analysis in 2015, and in 2018, research trends were focused on decision-making. However, in 2022 and 2023, the research trends shifted to keywords related to fuzzy logic, fuzzy inference, and fuzzy neural networks, but at a lower level compared to previous years. It is noteworthy that keywords related to economic aspects did not appear in the bibliometric analysis, with the exception of supply chain management, waste management, resource allocation, risk assessment, e-commerce, municipal waste management, and project management. This highlights the limited scope of research using fuzzy logic and artificial

intelligence to address issues related to economic institutions and to attempt to make effective decisions that benefit organizations by achieving their financial, marketing, and strategic goals.

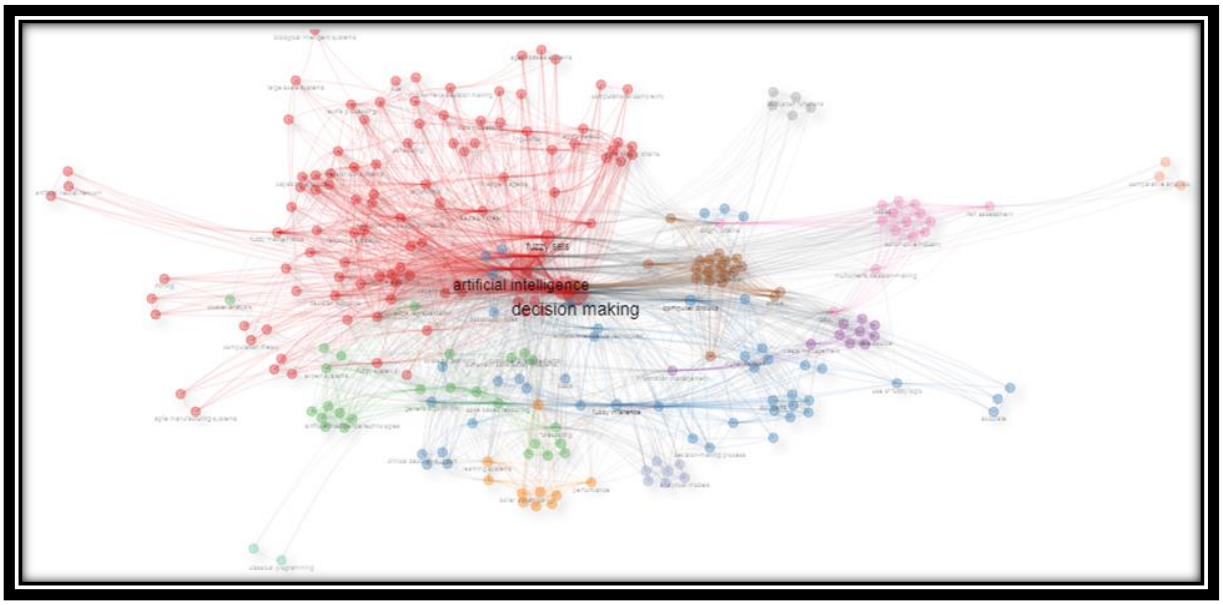
Figure (7): Trend Topics



Source: Prepared by researchers based on the outputs of R statistical program

In terms of keywords, the study results indicate that there are 7 clusters related to fuzzy analysis and artificial intelligence, as shown in **Figure (8)** which shows the groupings. The first group includes topics related to decision-making. The second group is related to computer courses, while the third group is related to case study logic. The fourth group deals with information management, and the fifth includes topics on learning systems. The sixth group includes topics related to machine learning, and the seventh group collects topics related to fuzzy logic.

Figure (8): Trend Topics

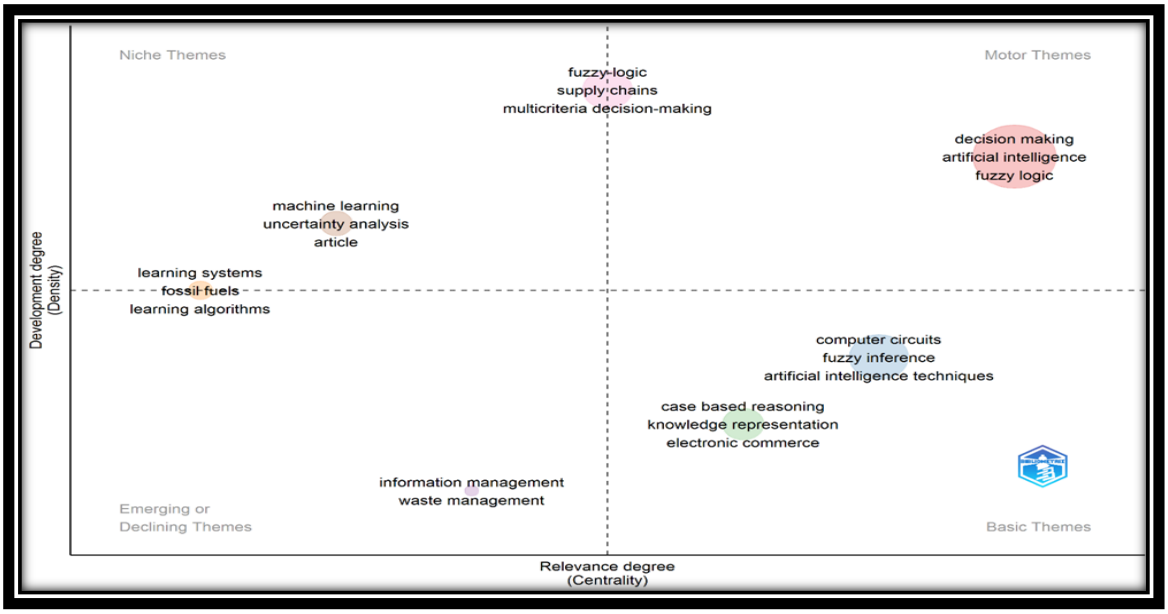


Source: Prepared by researchers based on the outputs of R statistical program

To identify important topics, bibliometric analysis provides a density and centrality map based on co-occurrence analysis of authors' keywords. Centrality measures the degree of interaction between groups, while density measures the degree of cohesion within each group. The map is divided into four quadrants, with the x-axis representing centrality and the y-axis representing density. The bibliometric analysis indicates the presence of seven groups that vary in their levels of density and centrality. It can be seen that the topics in the first quadrant (top right) have high density and centrality, indicating that they are well developed and significant in shaping the field of study. On the other hand, the themes characterized by low centrality and high density are highly developed but isolated. Meanwhile, topics with both low density and centrality are emerging or declining, while topics with high centrality and low density are core topics. Each group consists of a certain number of keywords, and its name is determined by the most frequent keyword. Furthermore, as the frequency of keywords per topic increases, the size of the circle increases accordingly (Qin, Xu, Wang, & Skare, 2021). The results of our study indicate that the group related to "decision making," "artificial intelligence," and "fuzzy logic" is a dominant and advanced cluster within the research sample, consisting of the most frequently occurring keywords due to their importance. The second group, related to "fuzzy logic," "supply chains," and "multi-criteria decision-

making," has low centrality and high density, making it a highly developed but isolated topic. In addition, the group that includes "machine learning" and "uncertainty analysis articles" deserves attention, especially in economic aspects and the life of economic institutions. The third group consists of "information management" and "waste management," representing emerging or declining topics. The fourth group consists of topics such as "Computer Circuits," "Fuzzy Inference," "Artificial Intelligence Techniques," and the group "Case-Based Reasoning," "Knowledge Representation," and "Electronic Commerce." These topics are fundamental, and the following figure illustrates these groups:

Figure (9): Trend Topics



Source: Prepared by researchers based on the outputs of R statistical program

9. Conclusion

The results of the analysis of research trends, both for researchers and countries, indicate a research gap, particularly in the use of fuzzy logic analysis and artificial intelligence applications in decision-making in economic institutions and organizations. This is evident from the limited research trends and various applications of fuzzy logic analysis, which is considered one of the quantitative tools that has significantly and effectively contributed to addressing many issues characterized by uncertainty and doubt. The analysis of keywords showed that "decision making," "artificial intelligence," and "fuzzy logic" form a dynamic group that dominates the sample research studies;

these keywords are the most frequently repeated due to their importance. It can be said that fuzzy logic analysis has a strong correlation with artificial intelligence techniques, which have greatly contributed to solving numerous inquiries from various global institutions.

The results also highlighted the limitations of research trends in fuzzy logic analysis and artificial intelligence applications in decision making, particularly in economic institutions and in the economic field in general. This gap exists both in terms of international trends and among research institutions and even among researchers, as qualitative research within the topic of fuzzy logic and artificial intelligence is limited to a few major countries such as the United States, China, Japan, India, Spain, and Iran, according to the sample studied in the economic field.

The results of the study showed that the applications of fuzzy logic analysis, especially in the economic field, are still limited, except for a small number of countries. Furthermore, the results indicated that the integration of fuzzy logic analysis with artificial intelligence plays a crucial role in the effective decision-making processes necessary for building strong institutions, shaping their policies, achieving their goals, and maintaining their competitiveness and sustainability.

10. Limitations and Future Research:

Fuzzy logic analysis is considered one of the most important quantitative and mathematical methods used to solve problems based on uncertainty and ambiguity, aimed at making effective and optimal decisions that help economic institutions to develop their structure and competitive position.

-The need to focus on methods related to the use of fuzzy logic analysis for the analysis and solution of problems facing economic institutions to reach effective and optimal decisions based on real assumptions.

-The fundamentals of fuzzy logic analysis can be used in the development of artificial intelligence algorithms within the economic context of economic institutions and countries, helping them to keep pace with technological and information advances that have increasingly characterized the use of artificial intelligence programming to build

various strategies, achieve their goals, and address economic, social, and environmental challenges. Promoting research trends in various economic fields based on fuzzy logic analysis and its relationship with artificial intelligence and decision-making is essential for building and developing institutions capable of competing and using technology in an evolving digital environment.

Supporting and promoting research in the field of fuzzy logic analysis as a tool to support decision-making in Arab countries, especially in Algeria, is crucial, as research using fuzzy logic is almost non-existent and very limited, especially in databases and indexed journals, which prevents research institutions and economic institutions from benefiting in their decision-making processes, especially as these processes can be enhanced by artificial intelligence tools.

Referrals and references:

- All Noman, A., Akter, U. H., Pranto, T. H., & Haque, A. B. (2022). Machine Learning and Artificial Intelligence in Circular Economy: A Bibliometric Analysis and Systematic Literature Review. *Annals of Emerging Technologies in Computing (AETiC), 6*(2), 13-40. doi:10.33166/AETiC.2022.02.002
- Apolo-Vivanco, N. J., López-Rodríguez, J., & Sotomayor-Pereira, J. G. (2021). Theoretical Aspects of the Strategic Management Decision-Making of Companies. In K. Nermend , M. Łatuszyńska , & E. Thalassinos, *Decision-Making in Management Methods and Behavioral Tools* (p. 5). Switzerland: Contributions to Management Science. doi:https://doi.org/10.1007/978-3-030-67020-7
- Bota-Avram, C. (2023). *Science Mapping of Digital Transformation in Business A Bibliometric Analysis and Research Outlook.* Romania: SpringerBriefs in Business. doi:https://doi.org/10.1007/978-3-031-26765-9
- Broadus, R. N. (1987). TOWARD A DEFINITION OF "BIBLIOMETRICS". *Scientometrics, 12*(5-6), 373-374. Doi:10.1007/BF02016680
- Fernández, J. M., Moreno, J. J., & Vergara-González, E. (2022). Bibliometric Analysis of the Application of Artificial Intelligence Techniques to the Management of Innovation Projects. *Applied Sciences, 12*(22), 2-15. doi:https://doi.org/10.3390/app122211743

- Laengle, S., Lobos, V., Merigó, J., Herrera-Viedma, E., Cobo, M., & Baets, B. D. (2021). Forty years of Fuzzy Sets and Systems: A bibliometric analysis. *Fuzzy Sets and Systems, 402*, 155-183. doi:https://doi.org/10.1016/j.fss.2020.03.012
- Merino-Arteaga, I., Alfaro-García, V., & Merigó, J. (2022). Fuzzy systems research in the United States of America and Canada: A bibliometric overview. *Information Sciences, 617*, 277-292. doi:https://doi.org/10.1016/j.ins.2022.10.116
- Nica, I., Delcea, C., & Chirit, N. (2024). Mathematical Patterns in Fuzzy Logic and Artificial Intelligence for Financial Analysis: A Bibliometric Study. *Mathematics*(12), 1-35. doi:10.3390/math12050782
- Radu, V., Radu, F., Tabirca, A. I., Saplacan, S. I., & Lile, R. (2021). Bibliometric Analysis of Fuzzy Logic Research in International Scientific Databases. *INTERNATIONAL JOURNAL OF COMPUTERS COMMUNICATIONS & CONTROL, 16*(1), 1-20. doi: https://doi.org/10.15837/ijccc.2021.1.4120
- Yu, D., Xu, Z., and Wang, W. (2019). A bibliometric analysis of Fuzzy Optimization and Decision Making (2002–2017). *Fuzzy Optimization and Decision Making, 18*, 371–397,. doi:https://doi.org/10.1007/s10700-018-9301-8
- Qin, Y., Xu, Z., Wang, X., and Skare, M. (2021). Artificial Intelligence and Economic Development: An Evolutionary Investigation and Systematic Review. *Journal of the Knowledge Economy*, 11. doi:https://doi.org/10.1007/s13132-023-01183-2
- çağlayan, N., Abbasi, S., Yilmaz, ï., & Erdebilli, B. (2024). Bibliometric Analysis on the Distributed Decision, Decentralized Decision, and Fuzzy Logic. *Discrete Dynamics in Nature and Society, 2024*(1). Doi: https://doi.org/10.1155/2024/7305880
- Dejian, Y., Zeshui, X., & Wanru, W. (2018). Bibliometric analysis of fuzzy theory research in China: A 30-year perspective. *Knowledge-Based Systems, 141*, 188-199. doi:https://doi.org/10.1016/j.knosys.2017.11.018
- Dwi Nursyachbaini. (April, 2023). The Application of Fuzzy Logic With the Mamdani Method to. *Jurnal Riset Rumpun Matematika dan Ilmu Pengetahuan Alam (JURRIMIPA)*، *02*(01)، 125.
- Jorge Luis García-Alcaraz، Cuauhtémoc Sánchez-Ramírez، José Roberto Díaz-Reza، Liliana Avelar-Sosa، Rita Puig-i-Vidal ، . (2023). Trends on Decision Support Systems: A Bibliometric Review. Julian Andres Zapata-Cortes، Cuauhtémoc Sánchez-Ramírez، Giner Alor-Hernández، Jorge Luis García-Alcaraz، *Handbook on Decision Making*

(Trends and Challenges in Intelligent Decision Support Systems، p 194). Switzerland: Springer. doi:https://doi.org/10.1007/978-3-031-08246-7

- Kahraman, C., & Haktanır, E. (2024). *Fuzzy Investment Decision Making with Examples.* Istanbul, Türkiye: Springer Nature. doi:https://doi.org/10.1007/978-3-031-54660-0
- L. A. Zadeh. (2015). Fuzzy logic—a personal perspective. *Fuzzy sets and systems*، 08.
- latha, C. M., Bhuvaneswari, S., & Soujanya, K. (2023). State of Art in Fuzzy Logic . *Journal of Survey in Fisheries Sciences*, 3562-3582.
- M Hellmann. (2001). Fuzzy logic introduction. *Université de Rennes*، 01.
- Passas, I. (2024). Bibliometric Analysis: The Main Steps. *Encyclopedia, 4*, 1016. doi:10.3390/encyclopedia4020065
- Qin, Y., Xu, Z., Wang, X., and Skare, M. (2023). Artificial Intelligence and Economic Development: An Evolutionary Investigation and Systematic Review. *Journal of the Knowledge Economy*, 8. doi:10.1007/s13132-023-01183-2
- rosário, A. T., Dias, J. C., and Ferreira, H. (2023). Bibliometric Analysis on the Application of Fuzzy Logic into Marketing Strategy. *Businesses, 3*(3), 402-423. Doi: https://doi.org/10.3390/businesses3030025
- Zaliluddin, D. (2023). Bibliometric Analysis of "Accuracy of Multi Criteria Decision Making (MCDM) of Assistance Recipients with Fuzzy Logic Algorithm". *West Science Interdisciplinary Studies, 7*(1), 354.