Review

The Popular Fuzzy-TOPSIS as the Main Method for Decision Model: An Object-Driven Model for Bibliometric-Based Literature Review

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Abstract: Fuzzy logic serves as a computational modeling method, particularly prominent in the research domain of decision models. To assess the prevalent trends in the utilization of fuzzy logic in the research landscape of decision models and its common combinations with other methods, a conceptual model for article review was developed. This study involved three simple stages: Bibliometric analysis, article review and model construction. The findings indicate an exponential growth in the use of fuzzy logic according to 10,530 documents in ten years, with the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) emerging as the widely favored method combined with fuzzy logic in decision model research (according to 11 documents in the year 2023). Additionally, a comprehensive conceptual model for bibliometric analysis-based reviewing was designed using an object-oriented approach; via UML tools class (with 20 identified classes), sequence and use case (with 3 identified use cases) diagram.

Keywords: TOPSIS, Fuzzy Logic, Decision Model, Decision Making, Object-Oriented Approach

Introduction

Fuzzy logic is a free math modeling method that (Zöbisch *et al*., 2023) operated to manage an uncertainty and ambiguity phenomenon. Dissimilar to classical logic, which operates on true or false values, fuzzy logic employs truth degree values in expressing the value. This method enables the handling of variables and parameter values that cannot be precisely measured or stated; such as temperature, speed, etc.

Fuzzy logic, as a method, is extremely essential in computer modeling due to its ability to address uncertainty and complexity interrelated with the real world and with human perception (Saikia and Chutia, 2023). Fuzzy logic is possibly beneficial for modeling when the data and information vaguely express the insights of the phenomenon. It builds a computer model and the decision suggested is more real. The fuzzy logic-based model well contributes to many applications in the real domain; education, vehicle routing problems, health, project management, etc. For example, in the education field (Zuluaga *et al*., 2023) developed a model to measure the impact of universities on students as a supportable indicator in education. Here, fuzzy logic is used to evaluate data in assessing the efficiency of the study units.

In vehicle routing problems, (Rizqi *et al*., 2023) constructed a demand fuzzy-based model combined with an enhanced Genetic Algorithm (GA) for answering such a problem. In the final model simulation, sensitive analysis functioned to identify the risk of fuzzy demand and traveling distance. Also, Qin and Chen (2023) developed a model of logistics distribution in the same city. Three parameters considered in this model were vehicle capacity, customer demand and customer service time. The method of simulated annealing was combined with fuzzy demand to optimize the delivery routes. Moreover, in the healthiness area, (Kresnawati, 2023) constructed a fuzzy model for categorizing the risk level of stroke patients. The classification result can be operated to accurately identify an appropriate treatment for patients; where the fuzzy logic impression is utilized to produce such classifications mathematically. Three aspects considered in the model were LDL, HDL and total cholesterol. Then, in the specific field of project management (Talib and Rezouqi, 2023) academically created a fuzzy inference model (via combining it with the Analytical Hierarchy Process or AHP method) to estimate the cost impacts on the overall costs of the construction project. Talib and Rezouqi (2023) focused on assessing

the effect scales of cost arithmetically by operating 100 construction projects' real data.

This study undertook a systematic review based on bibliometric analysis to examine the pattern of employing fuzzy logic in a particular research domain of decision models. The findings indicated an exponential annual growth in the utilization of fuzzy logic, with applications across various problem domains to address real-world challenges. This academic paper is constructed in five sequential sections: Introduction, related works, research methodology, results and discussion and conclusion and future works.

Related Work

The hot challenge in this study is a bibliometric-based literature review. There are many researchers have conducted such a study. Amelia *et al*. (2023) utilized a systematic literature review and bibliometric analysis to comprehensively examine the applications of system dynamics simulation in the food supply chain. The study acknowledged the complexity of the food supply chain with various interdependent actors; including suppliers, manufacturers, distributors, retailers and customers. System dynamics, recognized for capturing holistic, nonlinear and multi-loop systems, served as a key simulation methodology. Additionally, Amelia *et al*. (2023) classified the application of system dynamics simulation based on the type of food product, research goals (social, economic, environmental) and stakeholder engagement in the supply chain.

In addition, Lei *et al*. (2023) performed an inclusive bibliometric-based review of study in the learning and teaching of second language (L2) listening from 1948- 2020. A careful investigation of noun phrases in the abstracts is done as a method. It is used to see the trend in L2 listening across specific periods. In this study, by graphically presenting network maps, VOS viewer was also operated to identify highly cited authors, publications and journals. It revealed the most highly cited contributors, publications and journals. The maps also proposed a complete understanding of the interrelations among items. Moreover, Ibrahimi *et al*. (2023) did a bibliometric review to see the research and emerging trends about the connection between the Internet of Things (IoT) and Open Innovation (OI). Ibrahimi *et al*. (2023) employed a scientific method that covers the evaluation of research evolution, identification of powerful authors and countries and investigation of the top journals and conferences where the study was published. Likewise, by utilizing the Vos viewer application, three things keyword, distinct clusters of IoT integration and open innovation were realistically and colorfully plotted.

Finally, Abduh *et al*. (2023) depicted the contemporary connotation of the term" technology" in the context of language education by employing a combination of content analysis through a specific analytical tool and a bibliometric approach. The study identified four fundamental domains that interconnect language and technology in language education: Multiculturalism and technology emerge as a central theme; technology's role in language skill, knowledge and assessment; the nexus between technology and thinking; and technology's influence on language and linguistics. The research suggested that educators should adeptly leverage available technological tools for teaching, learning, language analysis and modeling in language education. However, it acknowledged limitations, primarily the focus on published manuscripts within the realm of language education, which may predominantly include non-empirical primary data.

In light of the existing kinds of literature, the research gap identified in this study underscores the need for a comprehensive framework to facilitate a bibliometric-based review as a model for literature review. This research introduces a conceptual model based on an object-oriented method for conducting a systematic literature review using bibliometric analysis. The proposed model focuses on reviewing topics related to the utilization of fuzzy logic, in conjunction with the TOPSIS method, for the development of decision models aimed at addressing various real issues across multiple domains.

Methodology

A systematic review was done to explore two key research questions: (Q1) What is the trend of fuzzy logic utilization in the decision model research domain? (Q2) Which methodologies are commonly combined with fuzzy logic? This study comprised three primary phases.

Initially, a bibliometric analysis was conducted, followed by a thorough review of selected articles (in phase 2). Subsequently, in the third phase, a conceptual model for the review was formulated. Each stage of the research process is delineated in Fig. 1.
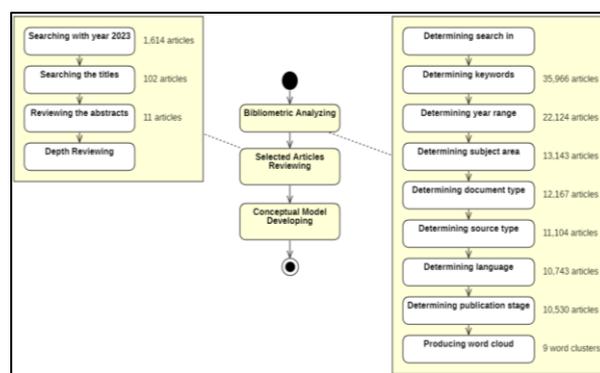

Fig. 1: The detailed research stages

Table 1: Searching criteria

Criteria	Value
C1- Search in	Article, abstract, keywords
C2- Keywords	Fuzzy, model, decision
C3- Year range	2014-2023
C4- Subject area	Computer science, decision science
C5- Document type	Article, conference paper
C6- Source type	Journal, conference proceeding
C7- Language	English
C8- Publication stage	Final

To perform bibliometric analysis, by using VOS viewer, similarly done by Zhao *et al.* (2023), article searching via https://www.scopus.com was conducted on the 25th of Table 1 searching criteria January 2024, using criteria outlined in Table 1. The search criteria included search content, keywords, year range, subject area, document type, source type, language and publication stage. The search yielded 10,530 documents. The distribution of document numbers at each stage of criteria determination can be observed in Fig. 1. Respectively, C2-8 produced 35,966, 22,124, 13,143, 12,167, 11,104, 10.743 and 10,530 documents.

In the second stage, a review was conducted on eleven chosen articles. These articles were selected from those published within the last year (2023), resulting in 1,614 initially identified articles. Following a quick search of the only titles with keywords" fuzzy AND model AND decision", 102 articles were further shortlisted. Then, after a brief review of the abstracts, the final selection comprised eleven articles for in-depth review.

Finally, the conceptual model was designed. In this context, the object-oriented method was operated to describe the model by Utama and Gunawan (2023); with two stages: Analysis and design. There are three types of tools operated; class, sequence and use-case diagrams. The class diagram presents the interconnected entities in the model; the sequence diagram shows the data and information transferred between entities in the constructed model, while the use-case diagram presents the model actors involved both human and other system actors.
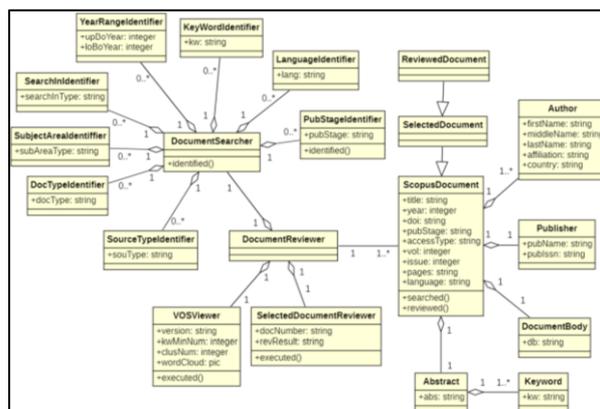
Results and Discussion

Generically, the model to review the article based on bibliometric analysis depends on two main classes: Document reviewer and Scopus document. In this model, the document reviewer is a model constructed to review and the Scopus document is a reviewed object coming from scopus.com. Document reviewer itself consists of three kinds of aggregated classes (parts): Document searcher operated to search the document with eight aggregative criteria identifier classes, VOS viewer used to generate the word cloud and selected document reviewer functioned to do the final review. Then, all aggregated classes with the attributes of Scopus document
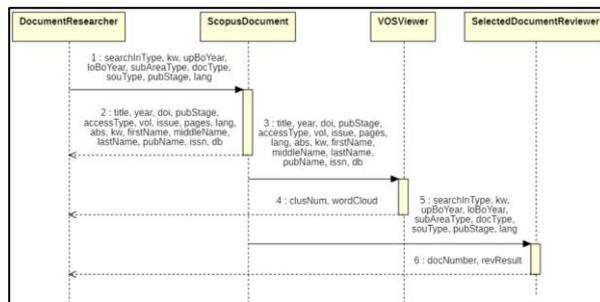
determined are abstract, document body, author and publisher. The Scopus document also has one generated class (i.e., selected document). The class diagram of the model is presented in the Fig. 2.

Notably, the representation of passing parameters or attributes among classes in the constructed model is illustrated through a sequence diagram (Fig. 3). In this scenario, four classes are directly involved. The process initiates with the class document researcher, which, based on predefined criteria, retrieves the document with all its attributes from Scopus. Then, the class Vos Viewer can generate the cluster number (clus num) and a word cloud image (word cloud). Finally, the class-selected document reviewer provides the outcome of the review (rev result).

Moreover, the use-case diagram (Fig. 4) outlines all human and other system actors eligible to utilize the constructed model. While the model is accessible to anyone, it is particularly tailored for use by researchers (specifically those focused on computer and decision modeling), computer modelers and computer science students; and also two kinds of other system actors (i.e., Scopus system and VOS viewer). The model itself consists of three main use cases: Article searching, article reviewing and word cloud generating.

Fig. 2: The class diagram for the constructed reviewing model

Fig. 3: The sequence diagram for the constructed reviewing model

Fig. 4: The use case diagram for the constructed reviewing model

According to the word cloud generated by VOS viewer, there are 9 clusters of words, with" decision making" being the most prominent cluster. This indicates that words closely associated with decision-making have the highest frequency. Refer to Fig. 5 for a visual representation. Additionally, the predominant subject area originates from the field of computer science, comprising 37.10% of the total. Please refer to Fig. 6 for a graphical representation. And, the top three contributing countries are China, India and Iran, as illustrated in Fig. 7. Then, the exponential growth of fuzzy logic used in the research domain of the decision model is illustrated in Fig. 8; where the growth follows exponential math Eq. (1) with $R^2 = 0.98$. All information provides a comprehensive overview of the prominent clusters of words, the primary subject area and the leading contributing countries and also uses the growth of the fuzzy logic method operated in researching the decision model domain:

$$y = 558.37^{e0.1067x} \tag{1}$$

Furthermore, according to 102 researched articles identified in the second stage, the Q2 was addressed. The predominant approach utilized for problem-solving across various domains, combined with fuzzy logic, was the Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS). Eleven of these articles specifically employed TOPSIS and fuzzy logic as primary methods in their decision model research. The studies covered six different areas, including energy management in industry, i.e., power generator plant production processes by Sarwar *et al.* (2023), hospital solar panel projects by Eti *et al.* (2023) and energy consumption in wireless sensor networks/WSNs management by Madhavi *et al.* (2023); manufacturing, i.e., manufacturing relocation by Sequeira *et al.* (2023), product quality management by Siwiec *et al.* (2023), new smart-TV product development by Lee and Kang (2023) and evaluation of manufacturing strategy by Abdullah *et al.* (2023); stock market, i.e., evaluation and ranking of public listed companies based on stock performance by Quek *et al.* (2023); building management, i.e., indoor environment by Madi *et al.* (2023); bank, m-banking selection by Roy and Shaw (2023); and finance, i.e., evaluation of companies'

financial performance by Lam *et al.* (2023). The review summary is mentioned in Table (2).

Fig. 5: Word cloud based on document searching

Fig. 6: Searched documents by subject area

Fig. 7: Documents by the highest 10 contributing countries

Fig. 8: Exponential growth for fuzzy logic method use in the research domain of decision mode

Table 2: Review summary of eleven articles

Author	Case	Issue
Sarwar *et al*. (2023)	Energy management	Power generator plant production processes
Eti *et al*. (2023)	Energy management	Hospital solar panel projects
Madhavi *et al*. (2023)	Energy management	Energy consumption in WSNs management
Sequeira *et al*. (2023)	Manufacturing	Manufacturing relocation
Siwiec *et al*. (2023)	Manufacturing	Product quality management
Lee and Kang (2023)	Manufacturing	Product development
Abdullah *et al*. (2023)	Manufacturing	Evaluation of Manufacturing Strategy
Quek *et al*. (2023)	Stock market	Evaluation and ranking of publicly listed companies
Madi *et al*. (2023)	Building management	Indoor environment
Roy and Shaw (2023)	Bank	M-banking selection
Lam *et al*. (2023)	Finance	Evaluation of companies' financial performance

In the energy management case, context (Sarwar *et al*., 2023) introduced a pioneering linguistic assessment model. The model was designed to manage ambiguous information by operating the Rough Fuzzy Integrated Clouds (RFICs) method. Then, such a method was combined with TOPSIS to see the failure mode of the model. Also, here, the statistical and mathematical methods were academically occupied to identify the ideal solution for prioritizing the failure. The effectiveness of the proposed model was validated by detecting failures in a steam valve system in a power generation plant.

Simulation and sensitivity analyses operated to assess the model's performance under varying control parameters.

Still in the issue of energy management, (Eti *et al*., 2023) announced a novel decision model based on a fuzzy logic method designed to assess the efficiency of solar panels. It was conducted to minimize energy costs for hospitals systematically. The coefficients of the criteria used were determined through the T-spherical fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) method. Additionally, Eti *et al*. (2023) constructed a novel model called TOP-DEMATEL, integrating some steps of TOPSIS with the DEMATEL method. The study findings highlighted the significance of generating one's energy in the long run, identified as the most crucial factor by both T-spherical fuzzy DEMATEL and TOP-DEMATEL methods.

Also, Madhavi *et al*. (2023) combined the fuzzy method with Pythagorean-based VIKOR and TOPSIS-based multi-criteria decision-making model. The model was able to analyze the demanding impacts of Denial of Service (DoS) attacks, specifically in the case of resource reduction. The fuzzy method produced improvements in handling vagueness in the exchanged information during data routing in the whole of the security system. The model demonstrated a 21.29% improvement in throughput, 22.38% enhanced packet delivery fraction and 18.92% reduced energy utilization.

In addition, in the case of manufacturing, (Sequeira *et al*., 2023) created a model based on the combination of three methods: Fuzzy logic, AHP and TOPSIS. The model

aimed to systematically support in making the relocation decisions. Through industry expert input and pairwise comparisons, competitive priorities' decision criteria are assessed. A meta-synthesis of empirical studies generates theoretical relocation scenarios, subsequently ranked using the hybrid model to identify the most viable alternative. The model's resilience was underscored through sensitivity analysis. Results revealed the model's efficacy in simultaneously addressing various relocation options involving governance modes. Notably, the criteria of quality, time and cost exhibited significant impacts, while sustainability has a relatively weaker influence on the choice of relocation.

Furthermore, Siwiec *et al*. (2023) addressed the persistent challenge of simultaneously improving product quality and making informed decisions by developing an integrated model. The research objective was to enhance product quality by analyzing the probabilities, inconsistencies, root causes and suggested enhancement movements. The model incorporated a variety of tools and methods, including the SMARTER method, expert team selection, brainstorming, Ishikawa diagram, 5 M + E rule, FAHP and FTOPSIS methods. The study highlighted the significance of integrating quality management tools and decision-making methods into a unified model, enabling accurate prioritization of activities for product quality management.

Still in the manufacturing issue, (Lee and Kang, 2023) focused on the evaluation and selection of Operating Systems (OS) for a commercially available AI product, specifically an intelligent TV. An MCDM model was devised to facilitate the choice of the most proper OS in developing the TV product. The model comprised three stages: Interpretative Structural Modelling (ISM) for constructing a decision-making network, Fuzzy Analytic Network Process (FANP) for determining factor weights and fuzzy TOPSIS for ranking the operation systems. The proposed model to choose an OS for smart TV development demonstrated its effectiveness, specifically in delivering a comprehensive decision-making method. Thus, the company can implement it practically.

Next, Abdullah *et al.* (2023) combined the fuzzy logic method with AHP and TOPSIS to construct a model for assessing the impact of I4.0 technologies on MSOs. As usual, fuzzy logic is employed to control ambiguity in comparing various technology alternatives. Here, criteria and sub-criteria weights were determined and ranked via conceptions of AHP and TOPSIS respectively. The study findings highlighted cost as the most crucial factor in I4.0 technology implementation. It contributed to the understanding of the intricate relationship between technologies and MSOs, providing important perceptions for companies.

Moreover, in the stock market case, Quek *et al.* (2023) presented a novel fuzzy logic-based Machine Learning (ML) model. The model utilized Picture Fuzzy Sets (PFS) as fuzzified inputs and tried to integrate a Genetic Algorithm (GA) in the training process. The model also combined with other combined methods (i.e., TOPSIS and Evaluation based on Distance from Average Solution/EDAS) in proposing the decision. The daily closing stock prices of five companies from the big cap category in the Kuala Lumpur Stock Exchange (KLSE) over 10 years were operated as a model to run the constructed model; here the Monte Carlo simulation was employed to validate the results.

In the case of building management (Madi *et al.*, 2023) proposed an exclusive model by implementing interval Type-2 fuzzy Membership Functions (IT2 MFs). The data used in the study came from a survey. This concept of fuzzy method is also combined with TOPSIS. This interval-based output suggested, including cautious choices when intervals are wider and overlapping. This data-driven decision represented a unique contribution to the field of the study.

As well, in the case of a bank system (Roy and Shaw, 2023) constructed a fuzzy-based decision model for selecting m-banking applications. In this context, the fuzzy Best-Worst Method (fuzzy-BWM) was employed to calculate the criteria weights, considering expert opinions, while fuzzy-TOPSIS was used to evaluate such m-banking applications. The evaluating criteria themselves were derived from the academic literature and expert judgment. The produced model was demonstrated through a real-life case study. Then, sensitivity analysis was conducted by varying the criteria weights. Results of the study revealed that functionality, performance and lucidity are the most vital features in selecting an m-banking application.

Conclusively, in the last issue of finance (Lam *et al.*, 2023) constructed an MCDM model, based on fuzzy logic and TOPSIS methods, to assess a company's financial performance. This model integrated the entropy method and fuzzy-TOPSIS to evaluate corporations based on liquidness, creditworthiness, adeptness and cost-effectiveness ratios. By reducing vagueness through the incorporation of fuzzy concepts, the proposed model aimed to provide meaningful insights from financial ratios for portfolio investment decisions. Here, the Dow Jones Industrial Average (DJIA) was used as a case study in the model, revealing that return on equity and debt-to-equity ratios significantly influence companies' financial performance. The proposed model identified well-performing companies for portfolio selection and a Mean-Variance (MV) model validated its effectiveness by generating higher mean returns than the benchmark DJIA index at a minimal risk level.

There are two things covered in this study. The first is a bibliometric-based literature review interconnecting to fuzzy logic operation in doing research for making decision model and its popular combined method; that is similarly done by Amelia *et al.* (2023); Lei *et al.* (2023); Ibrahimi *et al.* (2023); Abduh *et al.* (2023). The second is a proposed reviewing model based on the object-oriented approach that has never been talked about by the previous studies; particularly done by Amelia *et al.* (2023); Lei *et al.* (2023); Ibrahimi *et al.* (2023); Abduh *et al.* (2023). Thus, the advantageous model proposed in this research provides a valuable academic resource in bibliometric-based literature reviews. This model serves as a comprehensive guide, aiding researchers in navigating the complexities of their bibliometric analysis and enhancing the quality of their academic review.

Conclusion

The academic model based on object conception for systematically reviewing the articles was designed well. Three diagrams (i.e., class, sequence and use case) were employed to construct such a model. Based on 11 articles reviewed deeply in the year 2023 from more than 35,000 searched articles, two questions were answered. The first is the question of the trend of the fuzzy logic method used in constructing the decision model. The study findings said that the use grows linearly. The second question talks about popular methods that are combined with fuzzy logic in constructing the decision model. The findings presented that the popular method combined with fuzzy logic was TOPSIS.

Furthermore, the use of fuzzy logic in constructing other decision models is still open to study. For example, the decision model implemented in solving the problem in environmental case. Or, the decision model is strongly related to health, transport and education systems. Other tools of the object-oriented approach also can be used in further study in designing the model; such as component, activity, package and state diagrams.

Acknowledgment

their invaluable support and facilitation in fostering collaboration and stimulating insightful discussions throughout this research work.

Ethics

This manuscript substance is the authors' own original work and has not been previously published somewhere else. Authors already read and approved the manuscript and no potential ethical issues are immersed.

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