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Research Article

Supplier Selection Using Fuzzy Analytical Hierarchy Process: A Bibliometric Analysis

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Abstract
Success in supply chain management often hinges on effective supplier selection. Organizations must establish assessment criteria to provide alignment in ensuring that suppliers are chosen based on their ability to meet key requirements and that they are continuously evaluated to maintain or improve performance standards. Various decision-making processes have been extensively employed for supplier selection, such as Multi-criteria Decision-making (MCDM), a prominent method for choosing the best alternative. Other than that, an extended development in which the criteria used to determine the alternatives was Fuzzy weighted to reduce subjective judgments is also widely utilized. Therefore, this research aims to present an orderly overview as a guide to earlier research on the Fuzzy Analytical Hierarchy Process (AHP) method in supplier selection, develops a categorization structure incorporating important aspects, and identifies areas for further analysis. PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses), which combined quantitative and qualitative methods, is used to perform a comprehensive mapping analysis of supplier selection with Fuzzy AHP (FAHP). The quantitative analysis was conducted with the utilization of two softwares, namely Publish or Perish (PoP) and VOSviewer. The result showed a significant number, 40% of 78 full-reviewed articles on supplier selection with FAHP that consider sustainability factors under sustainable development goals (SDGs) framework. It also demonstrated that 17% of reviewed articles use standalone FAHP while various combined methods are available. Therefore, future research streams should include strategy-oriented supplier selection, as well as green and sustainable practices, which is currently in the early stages of the cycle by parallelly considering a combined method with FAHP adapted to the observed case study so that a more appropriate model for supplier selection can be achieved.

Keywords: Supplier Selection; MCDM; Fuzzy AHP; PRISMA; PoP and VOSviewer.

1. Introduction

The foundation of smooth operational activity in every manufacturing organization is in its supply chain, which facilitates competitive advantage (Kayapinar Kaya & Aycin, 2021). All changes in production setting tend to manifest along the supply chain. The working environment in the twenty-first century was characterized by globalization, rapid technical growth, and changes along the supply chain in response to customer demand. An increasing number of industries tighten the competition making them improve their respective reputation in global trade, aiming to produce high-quality goods and services that are practically connected to suppliers' performance as raw materials providers.

Suppliers constitute the fundamental unit of a supply chain and are regarded as an essential aspect of this network because they play an important role in cost, inventory, and risk management in the chain. These individuals play an essential role in industry success, reacting to market rivalry, as well as enhancing customer satisfaction ss, and product quality. They play a wide range of roles that affect the supply chain's overall performance, going beyond just providing materials. These emphasize that choosing the right suppliers is an integral part to the supply chain. The selection process is crucial for attaining company success and boosting industry competitiveness (Gernowo & Surarso, 2022). Consequently, choosing the ideal suppliers is essential to achieve business objective. The selection process cannot be done without a basis, a strong foundation is needed to determine the choice, for example by compiling criteria to evaluate a number of available suppliers. These criteria must reflect industry strategy, the characteristics of the products or services, and be in line with the supply chain framework.

A variety of decision-making processes have been widely adopted in supplier selection. The Multi-criteria Decision-making (MCDM) is a prominent method which addresses decision-making challenges by evaluating multiple criteria to choose the finest option. MCDM is a mathematical

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method used to make decisions in complex circumstances by analyzing and rating many options and comparing criteria (Gernowo & Surarso, 2022). This method entails weighing several criteria simultaneously when assessing and selecting among different alternatives. Decision-makers tend to benefit from the application of MCDM, when faced with complicated issues including numerous objectives, criteria, and constraints. MCDM frequently incorporates mathematical models, optimization methods, and occasional subjective assessments. MCDM is regularly used in the following disciplines covering engineering, management, economics, environmental science, and public policy. Over the past few decades, MCDM has been integrated with various methods, to enhance its effectiveness and enable it to handle a wider range of scenarios.

A typical example (Yadav & Sharma, 2015) was the Analytical Hierarchy Process (AHP) method proposed by Saaty, (1980), which focused on weighting criteria. MCDM offered a comprehensive framework for making successful judgments in complex decision-making scenarios, such as supplier selection. Meanwhile, using AHP to make decisions involved subjective and qualitative assessments, which introduced uncertainty and ambiguity. A decisive value may not adequately capture this complexity, therefore extending MCDM with Fuzzy logic had been a common practice since 1994 (Mardani et al., 2015). Fuzzy AHP (FAHP), a popular hybrid Fuzzy-MCDM method, provides more accurate and persuasive ranking outcomes (Odusoro & Oke, 2021).

Fuzzy AHP incorporated the concept of Fuzzy logic, enabling the representation of imprecise or uncertain information (Zadeh, 1988). The method effectively managed the inherent vagueness in human judgments using Fuzzy sets and comparison matrices. It also facilitated decision-makers to communicate choices in a flexible and subtle way, leading to more resilient and reliable outcomes. Therefore, Fuzzy AHP enhanced the method by addressing the limitations associated with qualitative assessments, uncertainty, and ambiguity, thereby improving the accuracy and persuasiveness of decision rankings.

Fuzzy AHP method is an adaptation of the conventional AHP, integrating Fuzzy sets into the pairwise comparison matrix. This method was widely used in several publications related to supplier selection. For example, (S. Deshmukh & Sunnapwar, 2019) stated that Fuzzy AHP are common to identify the best green supplier. (Widyatama et al., 2019) applied the method in designing supplier performance evaluation system. Fuzzy AHP is highly effective in evaluating supplier performance by offering Fuzzy weight values for recognized criteria, including reducing the personal judgments of decision-makers (Gernowo & Surarso, 2022). Fuzzy AHP is also used to select suppliers for project contractors with the aim of ensuring that construction completion is smooth, on budget and on time (Tiblola et al., 2024). It is commonly used for weighing criteria and can be effortlessly combined with other supplier selection methods.

This research presented a comprehensive overview to serve as a guide to previous investigations on Fuzzy AHP method in supplier selection. A structured categorization framework, focusing on important aspects, including identifying areas for further investigation, was established. Furthermore, articles published based on several perspectives including the respective primary fields, such as business, science, engineering, or technology were examined.

Supplier selection is a critical decision-making process that has a significant impact on the entire performance of a supply chain. The Fuzzy Analytical Hierarchy Process (FAHP), an extension of the standard Analytical Hierarchy Process (AHP), is essential in this process as it incorporates fuzzy logic to handle the uncertainty in human judgment. Initial research in this area, exemplified by the study conducted by (Kahraman et al., 2003), showcased the efficacy of FAHP in sectors such as textiles, offering a systematic method for addressing subjective variables when selecting suppliers. Research has progressed throughout time by incorporating methodological developments, such as the integration of FAHP with other multi-criteria decision-making approaches like TOPSIS and VIKOR, to improve the reliability of decision-making. Recent bibliometric analysis has emphasized the increasing attention given to FAHP (Fuzzy Analytic Hierarchy Process) for supplier selection. These analyses have shown that research on FAHP is interdisciplinary, with major contributions from domains such as operations management, industrial engineering, and information systems. These studies have analyzed the progression of research, pinpointing significant patterns, influential articles, and major research groups. They have also observed the emergence of hybrid models that integrate FAHP with other methodologies like Data Envelopment Analysis (DEA) and Genetic Algorithm (GA) (HakimiAsl et al., 2016), (Bulut et al., 2012), (Guo & Wu, 2023), (Sun, 2010), (Yang et al., 2009), and (Yang, 2009).

This study is unique because it combines the use of the Fuzzy Analytical Hierarchy Process (FAHP) to improve decision-making in supplier selection with a thorough bibliometric analysis. This integration not only enhances the methodological framework for dealing with the intricacies of supplier selection in uncertain situations, but also offers a meta-analytical viewpoint on the development and research patterns of FAHP in this context, presenting fresh perspectives and identifying possible research areas that need further exploration in this field.

The literature on the descriptors of Fuzzy AHP had been reviewed systematically in this research by using multiple academic databases. Following a structured analysis of the collected articles, a total of first 200 literatures with highest citation published from 2013 to date were investigated. The following research questions, how does the combination of Fuzzy AHP methods in supplier selection impact supply chains?, which countries had conducted research on Fuzzy AHP?, and which authors had published the most relevant articles? were addressed.

The other part of the study was arranged as follows: Section 2 offered a synopsis of the structure and literature review, along with details of the methods adopted. In Section 3, the results and examination of the review were presented,

following the objectives and queries. Finally, Section 4 concluded all discussion accompanied with an explanation of the limitations and recommendations for future research.

2. Research Method

2.1. Review Protocol

This research adopted both quantitative and also qualitative methods to conduct a broad mapping analysis of supplier selection using Fuzzy AHP. Quantitative analysis was conducted using two software tools, namely Publish or Perish (PoP) and VOSviewer. Meanwhile, the qualitative content analysis was carried out to establish research guidelines for forthcoming investigations by analyzing and examining the most recent keyword tendencies and subjects. The systematic mapping procedure is shown in Figure 1, depicting the sequential phases carried out to finally identify major keywords used in the literature on the observed topic.

2.1. PRISMA protocol

This present research followed PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) method for article selection (García-Holgado et al., 2020). Figure 2 showed the search terms protocol, literature sources, research selection criteria, and methods. The search terms including those related to supplier selection AND (Fuzzy OR AHP) combined using Boolean operators AND and OR. The core research question and review method, along with document type was used to filter the data. (e.g., articles), source (e.g., journals), and also language (e.g., English).

The literature review discussed the aspects of choosing the supplier that answer the investigated questions. This review comprised research from thousands of articles published in scholarly journals from 2013 to mid 2024. The articles accessible online, were available on the Scopus database. However in order to ensure the standard of assessment while discovering the cited papers, only articles in international publications were considered.

The search was conducted using two combined terms namely supplier selection and Fuzzy AHP, to ensure a reproducible and unbiased article search process while keeping the context relevant. PoP software was used to capture all articles that met the established qualifications. Articles were gathered from the Scopus database.

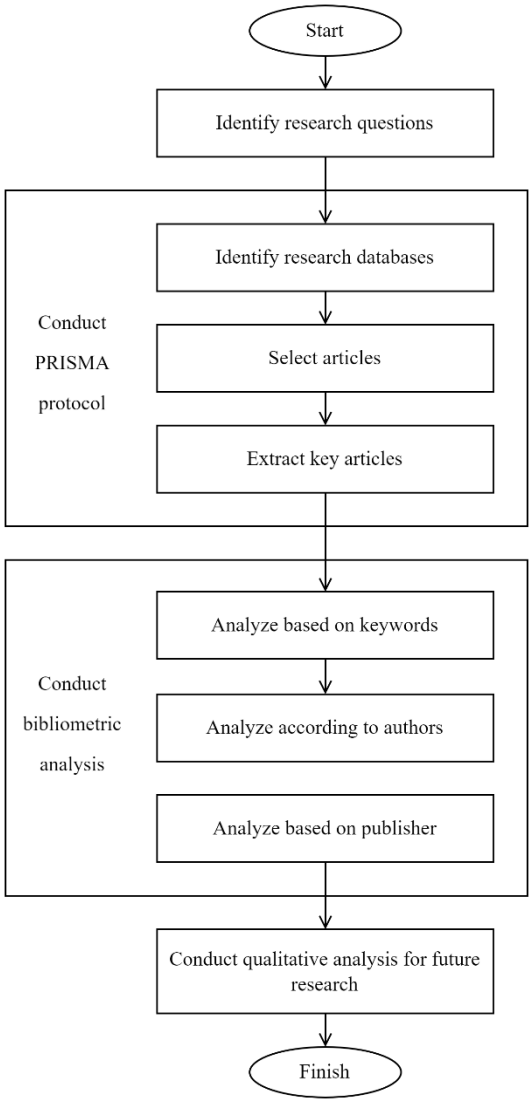

Fig. 1. Systematic mapping stages

The first curation step was by restricting the selection literatures to the publication year from 2013 to 2024, ensuring novelty and relevance. Based on the restrictions capability of PoP, those two determined terms generate approximately 200 literatures from the one with highest citation of 670 times to the several lowest ones of 5 times. VOSviewer software was used to evaluate the articles gathered. Based on bibliographic information, a map was generated using VOSviewer. The keyword co-occurrence criteria in the software were used with varying occurrence rates. This criteria assesses how frequently certain keywords or terms appear collectively in the articles. VOSviewer determined the co-occurrence and terms that showed up simultaneously were regarded as connected or associated. The articles were then analyzed for their titles only, leading to the identification of 10 keywords with minimum occurrences of 5 times. In the final filtration stages, the keywords that were found, as shown in Table 1, sorted based on the connection strength in the last column from the highest to the lowest.

Table 1
Keyword occurrences and total link strength

No.	Keyword	Occurrences	Total Link Strength
1	Green Supplier Selection	21	1.53
2	Sustainable Supplier Selection	14	1.52
3	Supplier Selection	69	1.27
4	Supplier Selection Problem	9	1.16
5	Selection	27	0.94
6	Approach	52	0.86
7	Fuzzy Environment	10	0.83
8	Fuzzy AHP	36	0.81
9	Supplier	23	0.76
10	Application	13	0.31

The sum of all weights of the links or connections allied to a specific keyword in the table is called Total Link Strength. This metric was commonly applied in network analysis, to comprehend the importance or centrality of nodes. VOSviewer calculated the Total Link Strength for each node or keyword by summing the weights of all associated connections. Nodes with higher Total Link Strength ratings were more central or influential in the network, as these are strongly connected to the others.

Table 1 shows that several unique keywords outside case study namely Green Supplier Selection, Sustainable Supplier Selection, Supplier Selection, and Supplier Selection Problem, have the highest strength. The second strongest group with strength score between 0.5 and less then 1 comprises of Fuzzy Environment, Fuzzy AHP, and Supplier. High total link strength keywords can be indicative of significant ideas or themes frequently connected to the others, here is the case of supplier selection considering green aspect.

Despite efforts to manually checked the possibility of duplicated articles with the aid of Ms. Excel, 200 literatures is quite a lot to be further investigated in details, posing challenges for thorough exploration. From these 200 literatures, one of them is book, 8 are book chapters, 26 are conference prosidings/papers, and 165 remainings are articles. Therefore the next step would be the articles filtration according to some defined rules.

We have 191 articles published in journals or proceedings, taking out literatures in form of book and book chapters. Besides, the checking was also conducted to make sure there is no articles of literature review of bibliometric analysis making us having 185. Further, articles with no ISSN were removed for further analysis, leaving us with 184 articles. While assigning a DOI to a research paper is not a requirement in and of itself for publication, it is strongly advised for a number of reasons, including ease of access and location, monitoring and reporting usage statistics, and significance for scholarly publishing and academic integrity therefore we took out articles with no DOI, giving us 178 articles left.

Additionally, the content of the publications were examined, resulting in 177 articles written in English, one in Turkish that was removed from final list. Next step would be checking on relevance of the articles from their abstracts that giving us 167 articles. Lastly, access restriction are taken into account, restricting us to 78 articles for further analysis. Figure 2 shows the detailed framework of the articles search and collection method used in this bibliometric analysis.

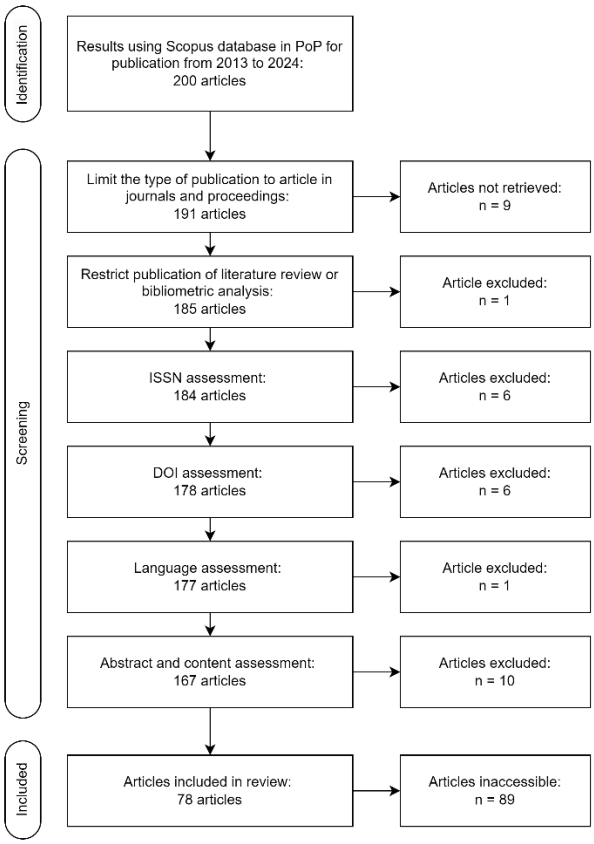

Fig. 2. The framework of article collection and extraction

3. Results and Discussion

3.1. Keywords analysis

The keywords were visualized in Figure 3 and 4. Meanwhile, in Figure 3 the density network depicts the top keywords, where the thickness and color intensity of each keyword area showed the repetition rate. Related topics were signified by the closeness of the collective keywords. Darker blue colors denote less repetition, while bright yellow depicts higher occurrence. The network analysis showed that keywords of Supplier Selection and Approach have the same occurrence rate. The closeness between Supplier Selection and Fuzzy AHP suggesting high relation that they come up often appear together in publication. The grouping of Green Supplier Selection and Sustainable Supplier Selection is also a sign that those words are equivalent in terms of publication presence which means that research that considers green aspects usually also reflects sustainability aspects, which include aspects other than green, namely social and economic. But the density of these two phrases is not bright yellow which indicates low

repetition rate in literatures so that there is an opportunity to fill it in the future.

Figure 4 demonstrates the keyword co-occurrence network, used to discover terms appearing in two or more publications. It was also used to identify keywords co-occurring in two publications in each period, depiciting three clusters with various color schemes. In this network, each node represents a keyword, with the size inversely correlated to the frequency of the co-occurrence. Larger nodes imply more frequent co-occurrence of the keyword. In this case, the following keywords of Supplier Selection, Fuzzy AHP, and Approach appear frequently. In Figure 4, the network exhibits closely related keywords organized into three main clusters represented by different colors namely yellow, green, and purple. The purple cluster focuses on the connection among Supplier Selection, Approach, Selection, Supplier, and Application sorted according to the scale of the relationship showed by the size of the circle. The green cluster establishes the close connection between Fuzzy AHP and Supplier Selection Problem. While the yellow cluster connect Green Supplier Selection and Sustainable Supplier Selection. As shown in bottom right legend, colors also indicate the newness of the publication. Those keywords in yellow are part of newer literatures which is in line with the Sustainable Development Goals (SDGs).

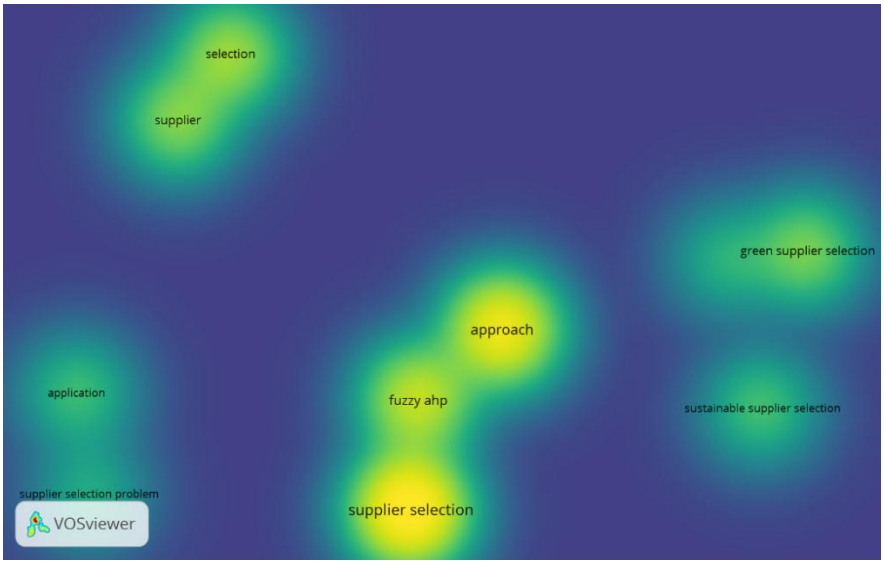

Fig. 3. The density network for the top keyword

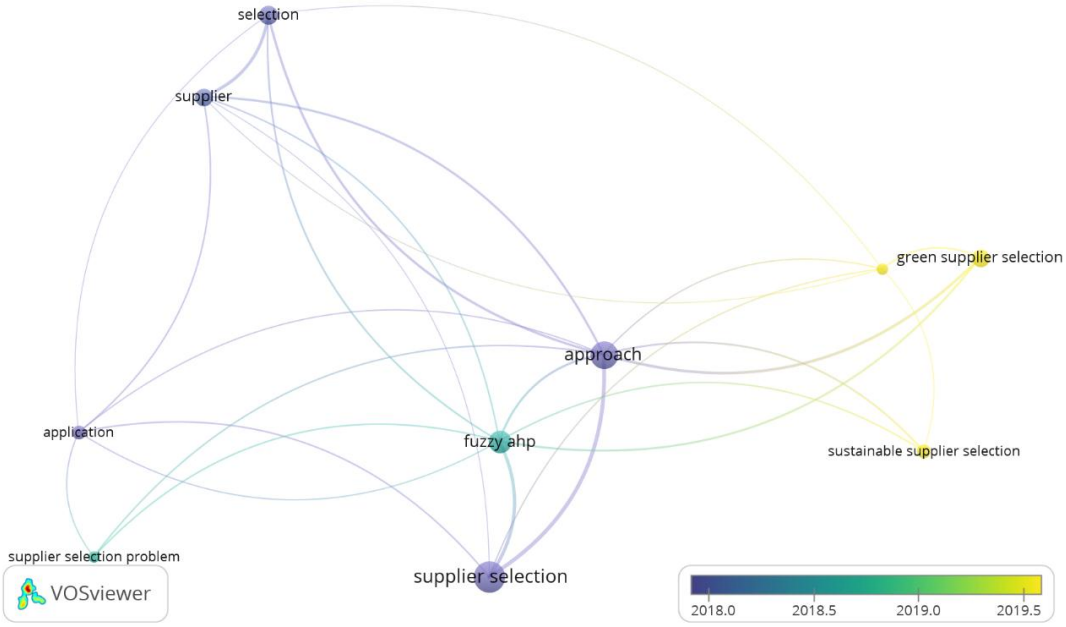

Fig. 4. Keyword co-occurrence network

This visual representation aids in identifying significant research areas for future investigations in supplier selection. The distance between keywords in the visualization was affected by the density, in which the higher the density, the closer the distance between the two vertices. Based on Figure 4, the node representing Fuzzy AHP is close to Supplier Selection, Green and Sustainable aspects. The possible combination of Fuzzy AHP with other supplier selection methods are explained in more details in Table 5 as extended analysis provided in this study. This showed multiple research gaps that needed to be addressed in the future.

3.2. Analysis of research method

The combination of Fuzzy AHP with Fuzzy TOPSIS (FTOPSIS), and Fuzzy AHP with Goal Programming (GP) is the most popular method in supplier selection literature. The difference between Fuzzy AHP and FTOPSIS lies in the focus. Fuzzy AHP algorithm applications relied on pairwise comparisons, while FTOPSIS focused on the measured distance of alternatives from the ideal solution. In the case of combining Fuzzy AHP and GP, Fuzzy AHP was initially applied to obtain the weight of the criteria, followed by GP method to find the optimal order allocation solution for suppliers. There are several other combinations in supplier selection, and 50 others were shown in Table 5.

3.2.1. Problem domain

In recent years, several literature reviews had been conducted on supplier selection and were discussed sequentially. First, Govindan et al. (2015) examined various publications between 1997 and 2011, specifically addressing green purchasing and supplier selection processes. It was reported that AHP was the most commonly used MCDM method for evaluating green suppliers. Furthermore, Fuzzy AHP was widely used in environmental management systems. Another research by Yildiz and Yayla (2015) examined 91 analyses on general supplier selection published from 2001 to 2014. The analyses showed that quality and cost are the most important elements in the case of supplier selection. Additionally, this research did not specifically focus on the selection of suppliers, considering sustainability or green aspects (Govindan et al., 2015).

In the following year, Wetzstein et al. (2016) examined some articles on supplier selection from the year of 1990 and 2015, in the subsequent year. Potential research areas related to green and sustainability issues were identified. The research clearly showed the prevalent use of mathematical methods. It was advocated that future research needed to include strategy-oriented supplier selection, as well as green and sustainable practices, which are still in the primary phases of growth. Another research by Karsak and Dursun (2016) analyzed 149 publications from 2001 to 2013, concentrating on non-deterministic investigative methods, such as stochastic/Fuzzy, in the occurrence of inaccurate data. The investigation focused on the relevance of supplier selection methods capable of considering imprecise and qualitative data, aiming to have a better consideration of the evaluation and selection procedure, while providing a hands-on reference for research and practitioners on the use of non-deterministic approaches and analysis.

In 2017, only one review paper focused on the problem of supplier selection. Simić et al. (2017) managed a full analysis of supplier selection and evaluated publications over the past 50 years, based on Fuzzy set principle, models, and hybridization. Furthermore, 54 publications from peer-reviewed journals were analyzed, evaluating Fuzzy supplier selection strategies by combining individual and integrated methods. Alkahtani and Kaid (2018) researched a selection of journal papers published between 1995 and 2018, centering on prevalent supplier selection trends, study gaps, and the selection criteria. This research provided valuable insights into the evolving supplier selection field. Ocampo et al. (2018) examined 240 peer-reviewed journals published between 2006 and 2016, exploring the use of various methods for supplier selection and review, involving single and mix methods. The research also stated the relevance of uncertainty, risk analysis, and sustainability variables in the unique supplier selection criteria. Meanwhile, between 2009 and 2020, Ograh et al. (2021) identified 41 research from 12 peer-reviewed journals, with 31 papers focusing on integrating green practices into supplier selection. The research provided insight on the strategies used to promote green incorporation while considering the different stages of supplier selection process.

Considering another literature review by Resende et al. (2021), 14 publications were analyzed to explore quantitative models assisting supplier selection in the Industry 4.0 era. Majority of the research in the review focused on models designed by integrating MCDM and artificial intelligence (AI) methods. Specifically, criteria closely associated Industry 4.0 such as knowledge sharing, capacity technology, cooperation, and digital involvement, were commonly identified. Therefore, the technological investigation concentrated on the significance of integrating MCDM and AI methods to develop decision-making support tools, particularly dashboards, in this modern era. The investigation also showed that 64% of research linked two or more methods in decision models, with Fuzzy logic often considered as a significant component. Specifically, the blend of Fuzzy logic with MCDM-AI method was the most regularly used, accounting for 50% of all applications.

Another review by (Ghorabaee et al., 2017) examined publications on multi-attribute decision-making (MADM) for the evaluation and selection of supplier from the year of 2001 to 2016. The study's findings indicate that the most widely used strategies are the AHP and TOPSIS techniques. Additionally, Taiwan and China rank first and second, respectively, in terms of citations and publications. The International Journal of Production Research, Expert Systems with Applications, and The International Journal of Advanced Manufacturing Technology were the top three journals in terms of publications.

Table 2
Problem domain and related references

Problem Domain	References
Literature review (13)	(Govindan et al., 2015) (Yildiz & Yayla, 2015) (Wetzstein et al., 2016) (Karsak & Dursun, 2016) (Simić et al., 2017) (Ghorabaee et al., 2017) (Alkahtani & Kaid, 2018) (Ocampo et al., 2018) (Ograh et al., 2021) (Resende et al., 2021) (Masudin et al., 2022) (Saputro et al., 2022) (Karakoç et al., 2024)

Masudin et al. (2022) conducted an extensive review of 220 research journals on the issue of green procurement in supplier selection. The review comprised numerous journals published between 1994 and 2022. Similarly, Saputro et al. (2022) examined 326 journals issued between 2000 and 2001, exploring the leading scope of supplier selection, containing sourcing strategy, dimension of decision and ecosystem, selection criteria, and result method. The analysis showed that 36.36% of all literature evaluations on supplier selection prioritized the green/sustainable process, while 63.63% discussed the same topic using various criteria and a combination of other methods. This showed that a few number of articles on supplier selection focused on environmental factors.

The latest literature review on sustainable supplier selection (SSS) was presented by (Karakoç et al., 2024) covering publication from limited years from to 2018 to 2022 with focus on social, economic, and environmental aspects. They highlight that the most widely applied approaches in SSS investigations are TOPSIS, AHP, VIKOR, BWM, DEA, DEMATEL, and MULTIMOORA, as well as their variations. Modern mathematical methods, however, such as Fuzzy sets and their hybrid forms, have not been applied to SSS studies. Consequently, the use of these methods in SSS research is encouraged by this study.

3.2.2. Deterministic and optimization models

This section discussed the deterministic optimization methods for supplier selection, using Fuzzy inference AHP method. Deterministic global optimization is a subfield of numerical optimization that focuses on finding a global solution with theoretical assurances of accuracy in a predefined tolerance. Articles with several citations were discussed, and a comprehensive detail of other publications included in Table 5.

Ayhan (2013) examined how Fuzzy AHP method could be utilized to solve supplier selection challenges in gear motor industries. This research used AHP empowered with Fuzzy method. However, due to the nature of the problem being a single source type, complex model constructions were unnecessary, given that in such scenarios, one supplier may meet all the requirements of the buyer.

Rezaei et al. (2014) designed a novel two-phased funnel method for supplier selection, focusing on the suitability for airline retail industry. Sivrikaya et al. (2015) implemented a multi-criteria Fuzzy Analytic Hierarchical Process with Linear Programming (FAHP-LGP) model to evaluate the performance of apparel firms and distribute the purchase amount to the best-performing enterprises. Fuzzy AHP was used initially, to establish the weights of the criteria, followed by Goal Programming method to recognise the best solution for order allocation to providers. Galankashi, Helmi et al. (2016) exploited an integrated Balanced Scorecard-Fuzzy Analytic Hierarchical Process (BSC-FAHP) model to choose suppliers in the automotive industry. This innovative method modernized supplier selection process in the automobile sector, by combining various performance measurements to aid decision-makers.

Ajalli et al. (2017) adopted a hybrid method, combining Fuzzy AHP and COPRAS methods to balance and rank the criteria and options for supplier selection. The model identified the best suppliers and major criteria by considering elements significantly influencing supplier quality. This research combined Fuzzy AHP and COPRAS methods, using both for criterion weighting, and supplier rankings, resulting in negative and positive criteria. Diouf and Kwak (2018) recommended a novel structure for supplier selection and advance in the publishing and printing sectors. This framework incorporating Fuzzy set theory, AHP, DEA, and management evaluation, addressed subjectivity and ambiguity in expert assessments using Fuzzy AHP. It evaluated suppliers based on various factors and used DEA to assesses the relative efficiency. The managerial analysis provided valuable insights for decision-makers across diverse settings.

Kayapinar Kaya and Aycin (2021) presented an actual case study to describe the practical application of the suggested framework. This model integrated the IT2F-AHP and COPRAS-G methods. Gernowo and Surarso (2022) introduced a web-based decision support system, employing Fuzzy AHP MOORA method to analyze system switch supplier selection. By conducting literature analysis, six supplier selection criteria were identified and subsequently selected by the decision-makers of industryy. The weight of each criterion was determied by the firm decision-makers, utilizing AHP pairwise comparisons. The deterministic optimization models for supplier selection, classified corresponding to numerous elements (criteria) involving quality, service, price, delivery, flexibility, reliability, supplier profile, and relationship, and many others, are shown in Table 3.

Table 3
Model criteria and associated references

Multiple Criteria	References
Quality	(Junior et al., 2014) (Deng et al., 2014) (Kahraman et al., 2014) (Hamdan & Cheaitou, 2017) (Beikkhakhian et al., 2015) (Gupta et al., 2019) (Rezaei et al., 2014) (Kar, 2015) (Ayhan & Kilic, 2015) (Singh et al., 2018) (Büyüközkan & Göçer, 2018) (Kar, 2014) (Chatterjee & Stević, 2019)

	(Lu et al., 2019) (Vasiljevic et al., 2018) (Zavadskas et al., 2020) (Stević et al., 2019) (Alegoz & Yapicioglu, 2019) (Dotoli et al., 2020) (L. H. Li et al., 2017) (Tirkolaee et al., 2021) (T. C. Wang & Tsai, 2018) (Polat et al., 2017) (Z. Li et al., 2013) (Shakourloo et al., 2016) (Gegovska et al., 2020) (Puška et al., 2018) (Bruno et al., 2016) (Rodríguez et al., 2013) (Zhou & Chen, 2020) (Astanti et al., 2020) (Pourjavad & Shahin, 2020) (Diouf & Kwak, 2018b) (Rasmussen et al., 2023b) (Saputro et al., 2023b) (Salimi & Edalatpanah, 2020) (Ulutas, 2019) (C.-N. Wang et al., 2022) (Safari et al., 2013) (Tsai & Phumchusri, 2021) (Ramos et al., 2020) (Ersoy & Dogan, 2020) (Fu et al., 2021) (Y. Xu et al., 2015) (Nirmala & Uthra, 2019) (Mokhtari et al., 2013) (C. N. Wang et al., 2022) (Erdebilli et al., 2023b) (A. J. Deshmukh & Vasudevan, 2018) (Islam & Arakawa, 2022) (Alinezhad & Seif, 2020b)
Service Performance/ Benevolence/Service Level	(Deng et al., 2014) (Büyüközkan & Göçer, 2018) (L. H. Li et al., 2017) (T. C. Wang & Tsai, 2018) (Z. Li et al., 2013) (Gegovska et al., 2020) (Bruno et al., 2016) (Zhou & Chen, 2020) (Saputro et al., 2023b) (C.-N. Wang et al., 2022) (Nirmala & Uthra, 2019) (Hien & Thanh, 2022) (Fagundes, Hellingrath, et al., 2021b) (Erdebilli et al., 2023b) (A. J. Deshmukh & Vasudevan, 2018)
Price/Cost/Economy/ Financial	(Junior et al., 2014) (Awasthi et al., 2018) (Deng et al., 2014) (Kahraman et al., 2014) (Hamdan & Cheaitou, 2017) (Beikkhakhian et al., 2015) (Gupta et al., 2019) (Rezaei et al., 2014) (Kar, 2015) (Z. Xu et al., 2019) (Pamucar & Ecer, 2020) (Ayhan & Kilic, 2015) (Singh et al., 2018) (Mohammed et al., 2018) (Galankashi et al., 2016) (Liu et al., 2019) (PrasannaVenkatesan & Goh, 2016) (Wang Chen et al., 2016) (Kar, 2014) (Chatterjee & Stević, 2019) (Lu et al., 2019) (Vasiljevic et al., 2018)

	(Zavadskas et al., 2020) (Stević et al., 2019) (Alegoz & Yapicioglu, 2019) (Dotoli et al., 2020) (Tirkolaee et al., 2021) (Dang et al., 2022) (Görener et al., 2017) (Gold & Awasthi, 2015b) (Jain et al., 2020) (Polat et al., 2017) (Z. Li et al., 2013) (Shakourloo et al., 2016) (Nguyen et al., 2022) (Gegovska et al., 2020) (Puška et al., 2018) (Bruno et al., 2016) (Roy et al., 2020) (Rodríguez et al., 2013) (Bektur, 2020) (Zhou & Chen, 2020) (H. Li et al., 2021b) (Astanti et al., 2020) (Pourjavad & Shahin, 2020) (Diouf & Kwak, 2018b) (Rasmussen et al., 2023b) (Saputro et al., 2023b) (Salimi & Edalatpanah, 2020) (C.-N. Wang et al., 2022) (Safari et al., 2013) (Tsai & Phumchusri, 2021) (Ersoy & Dogan, 2020) (Kahraman et al., 2016) (Fu et al., 2021) (Nirmala & Uthra, 2019) (Bronja & Bronja, 2015) (Mokhtari et al., 2013) (Hien & Thanh, 2022) (Fagundes, Hellingrath, et al., 2021b) (C. N. Wang et al., 2022) (Erdebilli et al., 2023b) (A. J. Deshmukh & Vasudevan, 2018) (Islam & Arakawa, 2022) (Diem My et al., 2022) (Alinezhad & Seif, 2020b)
Delivery/Agility	(Junior et al., 2014) (Kahraman et al., 2014) (Hamdan & Cheaitou, 2017) (Beikkhakhian et al., 2015) (Gupta et al., 2019) (Rezaei et al., 2014) (Kar, 2015) (Ayhan & Kilic, 2015) (Kar, 2014) (Chatterjee & Stević, 2019) (Lee et al., 2015) (Lu et al., 2019) (Zavadskas et al., 2020) (Tirkolaee et al., 2021) (Görener et al., 2017) (Polat et al., 2017) (Shakourloo et al., 2016) (Gegovska et al., 2020) (Puška et al., 2018) (Rodríguez et al., 2013) (Astanti et al., 2020) (Pourjavad & Shahin, 2020) (Diouf & Kwak, 2018b) (Hoseini et al., 2022) (Saputro et al., 2023b) (Salimi & Edalatpanah, 2020) (Ulutas, 2019) (C.-N. Wang et al., 2022) (Ersoy & Dogan, 2020) (Fu et al., 2021) (Bronja & Bronja, 2015)

	(Mokhtari et al., 2013) (Fagundes, Hellingrath, et al., 2021b) (C. N. Wang et al., 2022) (Erdebilli et al., 2023b) (Islam & Arakawa, 2022) (Alinezhad & Seif, 2020b) (A. J. Deshmukh & Vasudevan, 2018)
Reliability/Data Accuracy	(Beikkhakhian et al., 2015) (Zavadskas et al., 2020) (Puška et al., 2018) (Tsai & Phumchusri, 2021) (Ersoy & Dogan, 2020) (Kahraman et al., 2016) (Bronja & Bronja, 2015) (C. N. Wang et al., 2022)
Flexibility	(Rezaei et al., 2014) (Büyüközkan & Göçer, 2018) (Chatterjee & Stević, 2019) (Lee et al., 2015) (Zavadskas et al., 2020) (Tirkolaee et al., 2021) (Görener et al., 2017) (Pourjavad & Shahin, 2020) (Diouf & Kwak, 2018b) (Hoseini et al., 2022) (Saputro et al., 2023b) (Ulutas, 2019) (C.-N. Wang et al., 2022) (Ersoy & Dogan, 2020) (Bronja & Bronja, 2015) (C. N. Wang et al., 2022)
Supplier Profile/ Credibility/Integrity	(Junior et al., 2014) (Deng et al., 2014) (Rezaei et al., 2014) (Büyüközkan & Göçer, 2018) (Galankashi et al., 2016) (Chatterjee & Stević, 2019) (Lee et al., 2015) (Alegoz & Yapicioglu, 2019) (T. C. Wang & Tsai, 2018) (Z. Li et al., 2013) (Shakourloo et al., 2016) (Puška et al., 2018) (Bruno et al., 2016) (Rodríguez et al., 2013) (Shaverdi et al., 2013) (H. Li et al., 2021b) (Hoseini et al., 2022) (Ulutas, 2019) (C.-N. Wang et al., 2022) (Ersoy & Dogan, 2020) (Kahraman et al., 2016) (Fu et al., 2021) (Y. Xu et al., 2015) (Nirmala & Uthra, 2019) (Mokhtari et al., 2013) (Fagundes, Hellingrath, et al., 2021b) (C. N. Wang et al., 2022)
Supplier Relationship	(Junior et al., 2014) (Rezaei et al., 2014) (Rasmussen et al., 2023b) (Hoseini et al., 2022) (Saputro et al., 2023b) (Ramos et al., 2020) (Kahraman et al., 2016) (Y. Xu et al., 2015) (Bronja & Bronja, 2015)
Information/Electronic (Technology) Access/ Support/ Communication System	(Beikkhakhian et al., 2015) (Kar, 2015) (Büyüközkan & Göçer, 2018) (Kar, 2014) (Chatterjee & Stević, 2019) (Vasiljevic et al., 2018) (Stević et al., 2019) (Alegoz & Yapicioglu, 2019)
	(Görener et al., 2017) (Gold & Awasthi, 2015b) (Polat et al., 2017) (Ulutas, 2019) (Kahraman et al., 2016)
Capacity/Competence/ Capability including related to technology	(Kahraman et al., 2014) (Hamdan & Cheaitou, 2017) (Rezaei et al., 2014) (Kar, 2015) (Büyüközkan & Göçer, 2018) (Kar, 2014) (Lee et al., 2015) (Alegoz & Yapicioglu, 2019) (L. H. Li et al., 2017) (Tirkolaee et al., 2021) (Polat et al., 2017) (Shakourloo et al., 2016) (H. Li et al., 2021b) (Astanti et al., 2020) (Diouf & Kwak, 2018b) (Hoseini et al., 2022) (Saputro et al., 2023b) (Ulutas, 2019) (C. N. Wang et al., 2022) (Ersoy & Dogan, 2020) (Kahraman et al., 2016) (Y. Xu et al., 2015) (C. N. Wang et al., 2022)
Logistics Support/ Transportation	(Beikkhakhian et al., 2015) (Vasiljevic et al., 2018) (Stević et al., 2019) (Tirkolaee et al., 2021) (Roy et al., 2020) (Astanti et al., 2020) (C. N. Wang et al., 2022) (Ersoy & Dogan, 2020) (C. N. Wang et al., 2022)
Traceability	(Singh et al., 2018)
Geographical Location	(Chatterjee & Stević, 2019) (Lee et al., 2015) (Zavadskas et al., 2020) (Ersoy & Dogan, 2020) (Bronja & Bronja, 2015) (Mokhtari et al., 2013)
Social/Society	(Pamucar & Ecer, 2020) (Mohammed et al., 2018) (Zimmer et al., 2017) (Y. Liu et al., 2019) (Alegoz & Yapicioglu, 2019) (Dang et al., 2022) (Gold & Awasthi, 2015b) (N. Jain et al., 2020) (Nguyen et al., 2022) (Nguyen et al., 2022) (Roy et al., 2020) (Bektur, 2020) (Hien & Thanh, 2022) (Diem My et al., 2022)
Customer Relationship Management (including after sales service, warranties, claim, guarantee, and others)	(Ayhan & Kilic, 2015) (Galankashi, Helmi, et al., 2016) (PrasannaVenkatesan & Goh, 2016) (Lee et al., 2015) (Zavadskas et al., 2020) (Alegoz & Yapicioglu, 2019) (L. H. Li et al., 2017) (Puška et al., 2018) (Diouf & Kwak, 2018b) (C. N. Wang et al., 2022) (Ersoy & Dogan, 2020) (Ersoy & Dogan, 2020)
Certification/Documents for legal operations	(Puška et al., 2018) (Ramos et al., 2020) (Ersoy & Dogan, 2020)
Lead Time/Cycle Time	(Alegoz & Yapicioglu, 2019) (Polat et al., 2017)

	(Rasmussen et al., 2023b) (C. N. Wang et al., 2022) (Nirmala & Uthra, 2019)
Risk Management	(Zimmer et al., 2017) (PrasannaVenkatesan & Goh, 2016) (Alegoz & Yapicioglu, 2019) (Gold & Awasthi, 2015b) (Wang & Tsai, 2018) (Z. Li et al., 2013a) (Hoseini et al., 2022) (Saputro et al., 2023b) (A. J. Deshmukh & Vasudevan, 2018)
Learning and Growth Perspective/Continuous Improvement/ Innovation/Creativity	(Galankashi, Helmi, et al., 2016) (Ersoy & Dogan, 2020) (Bronja & Bronja, 2015) (Alinezhad & Seif, 2020b) (A. J. Deshmukh & Vasudevan, 2018)
Digitalization	(Büyüközkan & Göçer, 2018)
Covid-19 Pandemic Response Strategies	(Dang et al., 2022)
Safety	(Ramos et al., 2020) (C. N. Wang et al., 2022)
Brand image	(Fu et al., 2021)

Several publications in Table 3 are explicitly stated considering researchs on green supplier, they are (Gupta et al., 2019), (Pamucar & Ecer, 2020), (Wang Chen et al., 2016), (Lu et al., 2019), (Gegovska et al., 2020), (Zhou & Chen, 2020), and (Pourjavad & Shahin, 2020). While less others are mentioned about sustainable supplier, namely (Z. Xu et al., 2019), (Shaverdi et al., 2013), and (H. Li et al., 2021a). Therefore we can say that most other literatures were not yet counting the green and/or sustainable aspects, giving us wide chances for future exploration. The specific green/sustainable factors contemplated in literatures, are shown in Table 4.

Table 4
Green factors for supplier selection with FAHP

Green Criteria	References
Green Image	(Hamdan & Cheaitou, 2017) (Gupta et al., 2019)
Green Innovation	(Musaad O et al., 2020)
Green Product/Materials/ Eco-design	(Gegovska et al., 2020) (Pourjavad & Shahin, 2020) (Hoseini et al., 2022) (C. N. Wang et al., 2022)
Green Technology	(C. N. Wang et al., 2022)
Green Packaging	(Pourjavad & Shahin, 2020)
Green Transportation	(Pourjavad & Shahin, 2020)
Green Warehousing	(Pourjavad & Shahin, 2020)
Green Procurement	(Pourjavad & Shahin, 2020)
Green Policy	(C. N. Wang et al., 2022)
Pollution Control/ Emissions	(Gupta et al., 2019) (Gegovska et al., 2020) (C. N. Wang et al., 2022) (Ersoy & Dogan, 2020) (C. N. Wang et al., 2022)
Solid Waste	(Pourjavad & Shahin, 2020)
Chemical Waste	(Pourjavad & Shahin, 2020)
Wastewater	(C. N. Wang et al., 2022)
Water Recovery	(Pourjavad & Shahin, 2020)
Resource Consumption/Energy Usage	(Gupta et al., 2019) (Pourjavad & Shahin, 2020) (C. N. Wang et al., 2022)
Noise	(Pourjavad & Shahin, 2020)
Green Competencies/ Capacities/Staff Environment Training	(Gupta et al., 2019) (Tirkolaee et al., 2021) (Musaad O et al., 2020)
ISO 14001 and Other Similar Certification	(Gupta et al., 2019)
Reverse Logistics/ Recycling	(Pourjavad & Shahin, 2020) (C. N. Wang et al., 2022)
Environmental/Design for Environment/ Environment Protection/ Management	(Awasthi et al., 2018) (Hamdan & Cheaitou, 2017) (Gupta et al., 2019) (Xu et al., 2019) (Pamucar & Ecer, 2020) (Mohammed et al., 2018) (Y. Liu et al., 2019) (Wang Chen et al., 2016) (Lu et al., 2019) (Alegoz & Yapicioglu, 2019) (Tirkolaee et al., 2021) (Dang et al., 2022) (Gold & Awasthi, 2015b) (N. Jain et al., 2020) (Nguyen et al., 2022) (Gegovska et al., 2020) (Roy et al., 2020) (Bektur, 2020) (Zhou & Chen, 2020) (Ersoy & Dogan, 2020) (Hien & Thanh, 2022) (C. N. Wang et al., 2022) (A. J. Deshmukh & Vasudevan, 2018) (Diem My et al., 2022)
Carbon Footprint/ Reduction Initiatives	(Singh et al., 2018) (Alegoz & Yapicioglu, 2019)
Sustainability	(Shaverdi et al., 2013) (Alinezhad & Seif, 2020b)
Ecological safety	(Bronja & Bronja, 2015)

3.2.3. Operation research methods

Table 5 shows the categorized literature based on operations research (optimization) methods. Furthermore, Fuzzy AHP alone was the most commonly used method, followed by the hybrid of Fuzzy AHP and Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) under 12 articles. The most recent research which adopted Fuzzy AHP was conducted in 2020, while the investigation incorporating TOPSIS was carried out in 2023. Generally, the table showed a preference for hybrid methods incorporating Fuzzy AHP, among authors.

Table 5
Classification of the papers according to the operations research methods

Methods	References
Fuzzy AHP	(Rezaei et al., 2014) (Pamucar & Ecer, 2020) (Lu et al., 2019) (Vasiljevic et al., 2018) (Zavadskas et al., 2020) (Gold & Awasthi, 2015b) (Z. Li et al., 2013a) (Bruno et al., 2016) (Shaverdi et al., 2013) (Astanti et al., 2020) (Tsai & Phumchusri, 2021) (Ramos et al., 2020) (A. J. Deshmukh & Vasudevan, 2018)
Fuzzy Extended AHP	(Fagundes, Hellingrath, et al., 2021b)
Incomplete IVIF AHP	(Y. Xu et al., 2015)
Fuzzy AHP, MILP	(Ayhan & Kilic, 2015)
Fuzzy AHP, MOILP	(Shakourloo et al., 2016)
Fuzzy AHP, Fuzzy GP	(Kar, 2014)
Fuzzy AHP, NN	(Kar, 2015)
Fuzzy AHP, IOM	(Zimmer et al., 2017)
Fuzzy AHP, BSC	(Galankashi, Helmi, et al., 2016)

Fuzzy AHP, DEA	(Wang & Tsai, 2018) (Diouf & Kwak, 2018b)
Fuzzy AHP, QFD	(Alinezhad & Seif, 2020b)
Fuzzy AHP, Fuzzy DEA	(Ersoy & Dogan, 2020) (Dotoli et al., 2020)
Fuzzy AHP, GTMA	(Safari et al., 2013)
Fuzzy AHP, Fuzzy EDAS	(Stević et al., 2019)
Fuzzy AHP, Fuzzy OCRA	(Ulutas, 2019)
Fuzzy AHP, PROMETHEE	(Roy et al., 2020) (Bektur, 2020)
Fuzzy AHP, Fuzzy PROMETHEE, MOPSO	(PrasannaVenkatesan & Goh, 2016)
Fuzzy AHP, Fuzzy TOPSIS	(Junior et al., 2014) (Y. Liu et al., 2019) (Wang Chen et al., 2016) (Chatterjee & Stević, 2019) (Lee et al., 2015) (N. Jain et al., 2020) (Polat et al., 2017) (Puška et al., 2018) (Rodríguez et al., 2013) (Saputro et al., 2023b) (C. N. Wang et al., 2022) (Bronja & Bronja, 2015)
IFS, Fuzzy AHP, Fuzzy TOPSIS	(Islam & Arakawa, 2022)
Fuzzy AHP, TODIM	(Hien & Thanh, 2022)
Fuzzy AHP, Fuzzy TOPSIS, SECA	(Rasmussen et al., 2023b)
Fuzzy AHP, Fuzzy TOPSIS, Fuzzy ELECTRE	(Gegovska et al., 2020)
Fuzzy AHP, DEMATEL, TOPSIS	(Singh et al., 2018)
Fuzzy AHP, Fuzzy DEMATEL, Fuzzy TOPSIS	(Pourjavad & Shahin, 2020)
Fuzzy AHP, Fuzzy TOPSIS, Fuzzy MOPM	(Mohammed et al., 2018)
ISM, Fuzzy AHP, and Fuzzy TOPSIS	(Beikkhakhian et al., 2015)
SVM, TFN-RS-AHP, TOPSIS-CD	(L. H. Li et al., 2017)
Fuzzy AHP, VIKOR	(Awasthi et al., 2018)
Fuzzy Delphi, Fuzzy AHP, Fuzzy VIKOR	(Mokhtari et al., 2013)
(Fuzzy extension) D-AHP	(Deng et al., 2014)
Fuzzy AHP, D-Numbers	(Salimi & Edalatpanah, 2020)
(AHPSortII) Fuzzy AHP based on interval type-2 fuzzy sets (IT2FSs)	(Kahraman et al., 2014) (Xu et al., 2019)
Fuzzy TOPSIS, AHP, ILP	(Hamdan & Cheaitou, 2017)
Fuzzy TOPSIS, Type-2 Fuzzy AHP, GP	(Alegoz & Yapicioglu, 2019)
IT2F AHP	(Hoseini et al., 2022)
IT2F AHP, TOPSIS	(Görener et al., 2017)
Fuzzy AHP, MABAC, WASPAS, TOPSIS	(Gupta et al., 2019)
Fuzzy AHP, TOPSIS, GP	(Tirkolaee et al., 2021)
Fuzzy AHP, TOPSIS-Grey	(Musaad O et al., 2020)
Interval Valued Intuitionistic Fuzzy (IVIF) Sets, AHP, ARAS	
IVIF AHP, TOPSIS	(Kahraman et al., 2016)
IVIF AHP, NWIIA	(Nirmala & Uthra, 2019)
IV Pythagorean Fuzzy AHP, COPRAS	(Erdebilli et al., 2023b)
DEA, Spherical Fuzzy (SF) AHP, SF-WASPAS	(Nguyen et al., 2022)
Spherical Fuzzy AHP, G-COPRAS	(Dang et al., 2022)
SF-AHP, CODAS	(Diem My et al., 2022)
SF-AHP, CoCoSo	(C. N. Wang et al., 2022)
Pythagorean Fuzzy AHP, VIKOR, MRM	(Zhou & Chen, 2020)
Shapley value-IVIFS AHP-TOPSIS	(H. Li et al., 2021b)
Fuzzy AHP, Fuzzy ARAS, MSGP	(Fu et al., 2021)

From Table 5, Fuzzy Analytical Hierarchy Process (AHP) could be combined with many other methods. Some of them are MABAC (Multi-Attributive Border Approximation Area Comparison), WASPAS (Weighted Aggregated Sum-Product Assessment), IFS (Intuitionistic Fuzzy Set), MOPM (Multiobjective Programming Model), BSC (Balanced Scorecard), ARAS (Additive Ratio Assessment), IOM (Input Output Modelling), MOPSO (Multi-objective Particle Swarm optimization), G-COPRAS (Grey Complex Proportional Assessment), PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation), EDAS (Evaluation based on Distance from Average Solution), MRM (Median Ranking Method), VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje), GP (Goal Programming), SVM (Support Vector Machine), TOPSIS-CD (TOPSIS with Connection Distance), SECA (Simultaneous Evaluation of Criteria and Alternatives), OCRA (Operational Competitiveness Rating), GTMA (Graph Theory and Matrix Approach), FARAS (Fuzzy Additive Ratio Assessment), MSGP (Multisegment Goal Programming), NWIIA (Nearest Weighted Intuitionistic Interval Approximation), TODIM (Interactive and Multicriteria Decision-Making in Portuguese Model), CoCoSo (Combined Compromise Solution), and MILP (Mixed-Integer Linear Programming).

3.3. Cases analysis

Table 6 provides an overview of the prevalent applications discussed in different research, offering insights into the characterization process. Several research had incorporated case studies while remaining others were not clearly state on this. Some papers provided limited information about the goods and services considered on their researchs.

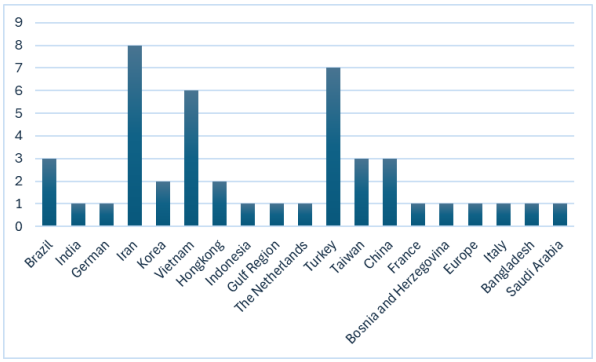

Fig. 6. Classification of the papers based on year

Regarding supplier selection using Fuzzy AHP, general manufacturing company is acknowledged as the most common application area with 11 articles covering several country bases, followed by automotive/automobile production chain (9 articles), apparel industry/twill fabric/textile/fashion (7 articles), and iron and steel manufacturing firm (6 articles). The geographical focus of the case studies were considered, revealing that Iran, Turkey, and Vietnam are considered as prominent regions featured in all application models with 8, 7, and 6 articles respectively, as can be seen in Figure 6.

Table 6
Applications of the model

Application	Country of the Case Study	References
Automotive/automobile production chain (9)	Brazil	(Junior et al., 2014)
	India	(Gupta et al., 2019)
	German	(Zimmer et al., 2017)
	Iran	(Galankashi, Helmi, et al., 2016)
	Korea	(Lee et al., 2015)
	Vietnam	(Dang et al., 2022)
	-	(Vasiljevic et al., 2018) (Bronja & Bronja, 2015) (Islam & Arakawa, 2022)
Electronic goods manufacturing company (2)	-	(Awasthi et al., 2018) (Tsai & Phumchusri, 2021)
Manufacturing company (11)	Hongkong	(Deng et al., 2014)
	Iran	Safari et al., 2013)
	-	(PrasannaVenkatesan & Goh, 2016) (Chatterjee & Stević, 2019) (Shakourloo et al., 2016) (Saputro et al., 2023b) (Salimi & Edalatpanah, 2020) (Safari et al., 2013) (Nirmala & Uthra, 2019)
	Iran (polyethylene products and couplings)	(Beikkhakhian et al., 2015)
	Indonesia (leather glove)	(Astanti et al., 2020)
Facilities management company (1)	Gulf Cooperation Council region	(Hamdan & Cheaitou, 2017)
Airline retail/aviation industry (3)	The Netherlands (The Royal Dutch Airlines (KLM))	(Rezaei et al., 2014)
	Turkey	(Görener et al., 2017)
	Taiwan	(Fu et al., 2021)
Iron and steel manufacturing firm (6)	India	(Kar, 2014) (Kar, 2015) (N. Jain et al., 2020)
	Vietnam	(Nguyen et al., 2022) (C. N. Wang et al., 2022)
	-	(Zavadskas et al., 2020)
Packaged/agri food company (4)	India	(Kar, 2015)
	Iran	(Tirkolaee et al., 2021)
	China	(Zhou & Chen, 2020)
	Brazil	(Ramos et al., 2020)
Gear motor company (2)	Turkey	(Ayhan & Kilic, 2015)
	India	(A. J. Deshmukh & Vasudevan, 2018)
Meat abattoir and processor company (3)	-	(Singh et al., 2018) (Mohammed et al., 2018)

	France	(Y. Liu et al., 2019)
Freight companies (1)	Turkey	(Büyüközkan & Göçer, 2018)
Luminance Enhancement Film (LEF) industry (Optical prism (TOP) manufacturing) (1)	Taiwan	(Wang Chen et al., 2016)
Straw biomass (energy) industry (1)	China	(Lu et al., 2019)
Plastic bags and foils manufacturing (1)	Bosnia and Herzegovina	(Stević et al., 2019)
Public procurement tenders (2)	European Institution	(Dotoli et al., 2020)
	-	(Rodríguez et al., 2013)
Cloud service (1)	-	(L. H. Li et al., 2017)
Focal companies (1)	-	(Gold & Awasthi, 2015b)
Solar panel (1)	Taiwan	(Wang & Tsai, 2018)
Contractors/international railway construction project (4)	Turkey	(Polat et al., 2017)
	Italy	(Bruno et al., 2016)
	Iran	(Hoseini et al., 2022)
	China	(H. Li et al., 2021b)
Apparel industry/twill fabric/textile (7)	Hongkong	(Z. Li et al., 2013a)
	Bangladesh	(Roy et al., 2020)
	Turkey	(Ulutas, 2019) (Ersoy & Dogan, 2020)
	Iran	(Mokhtari et al., 2013)
	-	(Gegovska et al., 2020) (Kahraman et al., 2016)
SMEs (1)	Saudi Arabia	(Musaad O et al., 2020)
Paper manufacturing company (1)	-	(Puška et al., 2018)
Medical (devices) manufacturing (2)	Turkey	(Bektur, 2020)
	-	(Alinezhad & Seif, 2020b)
Vaccine manufacturers (1)	Vietnam	(Hien & Thanh, 2022)
Publishing company (2)	Iran	(Shaverdi et al., 2013)
	Korea	(Diouf & Kwak, 2018b)
Painting industries (1)	Iran	(Pourjavad & Shahin, 2020)
Aerospace & defense/military industry (2)	Turkey	(Erdebilli et al., 2023b)
	-	(Rasmussen et al., 2023b)
Oil and natural gas company (1)	Brazil	(Fagundes, Hellingrath, et al., 2021b)
Chemical sector (1)	Vietnam	(C. N. Wang et al., 2022)
Fertilizer industry (1)	Vietnam	(Diem My et al., 2022)

3.4. Journal analysis

From 78 selected articles reviewed thororughly, we can see that they are published under 49 different journal/proceedings sites, as shown in Table 7. Meanwhile, Expert Systems with Applications, Journal of Cleaner Production, Applied Soft Computing Journal have published at least 5 articles on this topic of Fuzzy AHP for supplier selection. While other 9 publications of Mathematical Problems in Engineering, Computers and Industrial Engineering, International Journal of Sustainable Engineering, Mathematics, Processes, IFAC-PapersOnLine, Operational Research in Engineering Sciences: Theory and Applications, and Sustainable Production and Consumption have issued more than one article each, for thr Fuzzy AHP-related study. The remaining journals or proceedings contributed exactly one article respectively, counted to total of 38 items as shown in detail in Table 7.

Table 7
The publication list

Journal Name	**Number of Articles**
Alexandria Engineering Journal	1
Applied Mathematical Modelling	1
Applied Soft Computing Journal	4
Axioms	1
Cleaner Engineering and Technology	1
Cogent Engineering	1
Computational Intelligence and Neuroscience	1
Computers and Industrial Engineering	3
Computers and Operations Research	1
Computers, Materials and Continua	1
Decision Making: Applications in Management and Engineering	1
Decision Science Letters	1
Economic Computation and Economic Cybernetics Studies and Research	1
Energies	1
Engineering Journal	1
Expert Systems with Applications	8
Facta Universitatis, Series: Mechanical Engineering	1
IEEE Access	1
IFAC-PapersOnLine	2
Information Sciences	1
Intelligent Automation and Soft Computing	1
International Journal of Computational Intelligence Systems	1
International Journal of Production Economics	1
International Journal of Supply and Operations Management	1
International Journal of Sustainable Engineering	3
IOP Conference Series: Materials Science and Engineering	1
Journal of Civil Engineering and Management	1
Journal of Cleaner Production	5
Journal of Computational Science	1
Journal of Fuzzy Extension and Applications	1
Journal of Industrial Engineering and Management	1
Journal of Optimization in Industrial Engineering	1
Knowledge-Based Systems	1
Logistics	1
Materials Today: Proceedings	1

Mathematical Problems in Engineering	4
Mathematics	3
Operational Research in Engineering Sciences: Theory and Applications	2
Procedia Computer Science	1
Processes	3
Production	1
Research Journal of Applied Sciences, Engineering and Technology	1
Soft Computing	1
Sustainability (Switzerland)	1
Sustainable Production and Consumption	2
Technological and Economic Development of Economy	1
Tehnicki Vjesnik	1
Transport	1
Transportation Research Part E: Logistics and Transportation Review	1

3.5. Year-based publication

Articles related to supplier selection and Fuzzy AHP were classified annually as shown in Figure 7. However, only 78 articles published from 2013 to the present were included. The total of papers issued in international journals on this topic remained relatively low for several years in 2013, 2014, 2016, 2017, 2021, and 2024, averaging 5 to 7 articles per year. The contribution had been quite prominent in other years and a significant increase was recorded in 2018, 2019, and 2022. The peak was recorded in 2020, when 15 articles were published and then a big decrease was experienced to 2021.

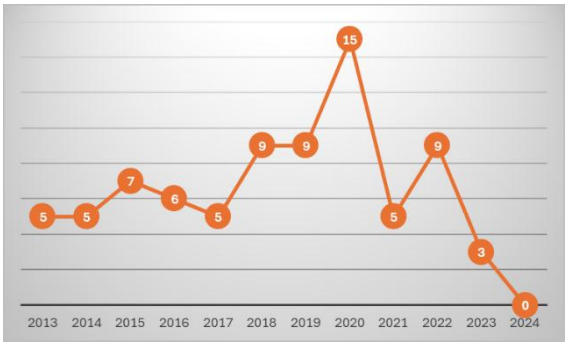

Fig. 7. Classification of the papers based on year

The inconsistent distribution over the years, along with the diverse range of topics, suggested several research gaps in supplier selection field which needed to be addressed using Fuzzy AHP or other methods. These results also showed that research had been rarely conducted recently. Considering the unique and specific characteristics of case studies from various countries, provided valuable insights and contributions to this area of research.

4. Managerial Implications

The results show that the Company can apply multi criteria decision making (MCDM) approaches such as Fuzzy-AHP, TOPSIS, VIKOR, DEMATEl, etc, to the process of selection of suppliers because this approach and its range of methodologies have proven to provide a systematic and fairly accurate framework. Besides, this method has also been widely adopted in various industries from automotive to textile that supports evidence if its application is acceptable to these industries.

There are only a few things that need to be considered for this cutting-edge to deliver optimal results such as integrating elements of supply chain criteria, technology, sustainability, risk control, geographical and service performance in the framework making process rather than just looking at operational aspects and prices. In addition, some research results showed the importance of combining some MCDM (Hybrid method) methods such as Fuzzy AHP-DEA to provide much better results and reduce the subjectivity aspects of respondents to obtain results that are much more in line with the business realities for each case study. This hybrid approach is also still slightly adopted compared to the non-hybrid approach, it opens opportunities for the Company to get a better set of strtegy from most of its competitors and win competition in the market. Overall, based on these results, MCDM approaches like Fuzzy-AHP will be able to help the Company make intelligent, responsive decisions that are in line with the Company's long-term goals. Companies are judged to be able to maintain competitive advantage in competition in a dynamic and growing global market.

5. Conclusion

In conclusion, this research conducted a bibliometric analysis of Fuzzy AHP utilization in the discipline of supplier selection and investigated the writing sources that applied this specific hybrid MCDM method. The visualization showed that Fuzzy AHP, with Fuzzy TOPSIS, and other related MCDM methods have been dominant in the observed research areas, with co-occurrence networks identifying these terms frequently across various studies. These methods have distinct focuses: Fuzzy AHP uses pairwise comparisons, whereas Fuzzy TOPSIS prioritizes the distance from the ideal solution. Additionally, the study reviewed past literature, showing that earlier research concentrated on quality-cost factors, while more recent studies increasingly address sustainability, green, and the management of uncertain data through non-deterministic approaches. Regarding the locations of the case study, Iran, Turkey, and Vietnam are reportedly leading for empirical study, appearing in broad application models.

The experiments conducted showed that 40% of all full reviewed articles on supplier selection with Fuzzy AHP have mentioned at least one criterion related to green/sustainable aspect, while others concentrated on general criteria such as quality, price, and delivery. This phenomenon can be explained as there is a need for future research following the accomplishment of SDGs set by the United Nations due to currently only limited number of articles available addressing environmental considerations in supplier selection with Fuzzy AHP. Moreover, there were numerous opportunities for additional case studies, particularly in areas that had never explored, such as suppliers for service businesses or various types of uncommon manufacturing sectors including paper production industries whose raw material supply is

required to meet environmental sustainability aspect providing traceability to relevant stakeholders.

The use of Publish or Perish and VOSviewer softwares were significantly facilitated the progress of this research, including the construction and visualization of citation networks. Both qualitative and quantitative methods were recommended for forthcoming analysis. The study suggests addressing research gaps in the integration of modern Industry 4.0 with green/sustainable supplier selection, as this area is still in its nascent stages. Furthermore, future studies may consider expanding the scope of keyword analysis to include a wider range of terms that could capture emerging trends in supplier selection. Lastly, exploring case studies from various countries offered unique insights into supplier selection analysis, enriching the field in ways that previous investigations might not have captured.

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