UNIVERSIDAD LAICA ELOY ALFARO DE MANABÍ

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ARTICULO CIENTIFICO

PREVIO A LA OBTENCIÓN

DEL TÍTULO DE

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“SUSTAINABLE-RESILIENT SUPPLIER SELECTION: A REVIEW OF QUANTITATIVE MODELS”

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FACULTAD DE INGENIERIA INDUSTRIA Y ARQUTECTURA

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“SUSTAINABLE-RESILIENT SUPPLIER SELECTION: A REVIEW OF QUANTITATIVE MODELS”

Sometida a consideración del Honorable Consejo Directivo de la Facultad de Ingeniería, Industria y Arquitectura de la Universidad Laica “Eloy Alfaro” de Manabí, como requisito para obtener el título de:

INGENIERO INDUSTRIAL

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DECANO DE LA FACULTAD **Ing.**	DIRECTOR **Ing.**
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Certificación del Tutor

En calidad de docente tutor(a) de la Facultad de Ingeniería, Industria y Arquitectura de la Universidad Laica "Eloy Alfaro" de Manabí, CERTIFICO:

Haber dirigido, revisado y aprobado preliminarmente el Trabajo de Integración Curricular bajo la autoría de los estudiantes **Cedeño Mendoza Laura Denisse y Mazzini Piguave David Joel**, legalmente matriculado en la carrera de Ingeniería Industrial, período académico 2024-2, cumpliendo el total de 384 horas, cuyo tema de titulación es "*Sustainable-Resilient Supplier Selection: A Review Of Quantitative Models*"

La presente investigación ha sido desarrollada en apego al cumplimiento de los requisitos académicos exigidos por el Reglamento de Régimen Académico y en concordancia con los lineamientos internos de la opción de titulación en mención, reuniendo y cumpliendo con los méritos académicos, científicos y formales, y la originalidad de este, requisitos suficientes para ser sometida a la evaluación del tribunal de titulación que designe la autoridad competente.

Particular que certifico para los fines consiguientes, salvo disposición de Ley en contrario.

Ing. Antonio Zavala Alcívar Mg.Sc.
TUTOR DE TITULACIÓN

Declaración de Autoría de Tesis

Nosotros, Cedeño Mendoza Laura Denisse y Mazzini Piguave David Joel, estudiantes de la Universidad Laica Eloy Alfaro de Manabí, Facultad de Ingeniería Industria y Arquitectura, Carrera de Ingeniería Industrial, libre y voluntariamente declaro que la responsabilidad del contenido del presente trabajo titulado ""*Sustainable-Resilient Supplier Selection: A Review Of Quantitative Models*". Es una elaboración personal realizada únicamente con la dirección del tutor, Ing. Antonio Xavier Zavala-Alcívar Mg.Sc. y la propiedad intelectual de la misma pertenece a la Universidad Laica Eloy Alfaro de Manabí.

Manta, 18 de diciembre de 2024

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Dedicatoria de Denisse Cedeño

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Índice

Índice de Tablas

Índice de Figuras

Sustainable-Resilient Supplier Selection: A Review of Quantitative Models

Abstrac: This study systematically analyzes the most widely applied quantitative methodologies for supplier selection within a sustainable and resilient supply chain. Approaches that combine risk assessment, environmental commitment and social responsibility are explored, highlighting methods such as AHP, TOPSIS and hybrid techniques that integrate artificial intelligence. The findings reveal how a holistic supplier assessment can strengthen the supply chain, enabling companies to not only survive disruptions, but also lead change towards a more sustainable future. This research provides a comprehensive framework for making strategic decisions that transform supplier management into a tool for resilience and sustainability.

Keywords: supply chain management; resilience; sustainability; performance management; conceptual framework; literatura review

1 Introduction

In an increasingly interconnected and globalized world, supply chains face unprecedented complexity and vulnerability. Proper supplier selection is a critical factor in ensuring operational continuity and business success. Recent disruptions, such as the COVID-19 pandemic, natural disasters, socioeconomic crises and geopolitical conflicts, have highlighted the need for resilient and sustainable suppliers, able to adapt quickly to disruptions and align with economic, social and environmental sustainability goals (Ghamari et al., 2022; Pamucar et al., 2023). Failure to anticipate and manage these risks can result in supply chain failures, significant economic losses, prolonged operational delays and irreparable damage to corporate reputation (Suryadi & Rau, 2023).

Globalization and technological advances have intensified the interdependence between the different links in the supply chain, thus increasing exposure to risk. Dependence on suppliers distributed in different regions of the world increases the possibility of interruptions due to natural disasters, political crises or logistical failures (Khan et al., 2023). Also, the rise of environmental, social and governance criteria, known by their acronym (ESG) requires companies to select suppliers that are not only resilient, but also operate in a responsible and sustainable manner (Althaqafi, 2023). Failure to take a holistic approach to this selection can compromise the organization's ability to respond to market demands and maintain its long-term competitiveness (Sonar et al., 2022).

Resilience in suppliers implies the ability to anticipate, withstand and recover quickly from disruptive events (Varchandi et al., 2024). On the other hand, sustainability in the supply chain encompasses not only economic efficiency, but also the fulfillment of social responsibilities and the reduction of environmental impact. The combination of these two approaches enables companies not only to survive in adverse environments, but also to thrive responsibly and competitively (Mirzaee & Ashtab, 2024). In addition, an appropriate selection of sustainable suppliers can strengthen corporate reputation, improve customer relations and ensure compliance with increasingly stringent environmental regulations.

This article aims to analyze the methodologies used for the selection of resilient and sustainable suppliers in the supply chain. Through a systematic review of the literature and the analysis of applied models, it examines the ways in which companies evaluate their suppliers holistically, considering not only their ability to cope with disruptions, but also their commitment to sustainability and their positive impact on the social and environmental surroundings.

This article is structured as follows: the Introduction presents the context and relevance of selecting sustainable and resilient suppliers, highlighting the current challenges in supply chains. The background section addresses the fundamental concepts related to resilience and sustainability in supplier selection, as well as the traditional methodologies used. The methodology details the Systematic Literature Review (SLR) process applied to identify and analyze the most relevant quantitative models in the field. In results and discussion, the findings obtained are analyzed, highlighting the most implemented mathematical and quantitative models and their impact on the selection of sustainable and resilient suppliers. Finally, the conclusions section summarizes the key points of the study and discusses how these models contribute to more efficient, resilient and sustainable supplier selection in the context of supply chains.

2 Background

This section addresses supplier selection from a general level covering sustainability and resilience.

2.1 Supplier selection

Supplier selection in the supply chain has evolved towards resilient and sustainable approaches through the use of advanced technologies. Methods such as big data analysis with multi-agent systems optimize selection in complex industrial environments (Zekhnini et al., 2024). In the food industry, hybrid techniques such as

Delphi-FAHP-FMOP balance economic, resilient and sustainable criteria (Ye et al., 2024). Artificial intelligence and blockchain strengthen robustness and reduce risks in order allocation (Lotfi et al., 2024; Mirzaee & Ashtab, 2024). Models integrating BWM, TOPSIS and fuzzy methods improve decisions under uncertainty (Sun et al., 2024; Varchandi et al., 2024). In addition, hierarchical structures are applied to evaluate cloud service providers (Amoujavadi & Nemati, 2024) and additive manufacturing improves chain resilience (Singh et al., 2024). These approaches reflect a trend toward adaptive and resilient practices in specific industries such as pharmaceuticals and food (Ben Abdallah et al., 2024; Kayani et al., 2023).

2.2 Supplier selection resilience

Resilience in supplier selection focuses on ensuring that the supply chain can adapt and recover quickly in the face of disruptions and risks. Advanced approaches such as big data systems and intelligent agents are applied to facilitate decisions in complex and dynamic contexts (Zekhnini et al., 2024). Implementation of blockchain improves robustness and traceability, reducing vulnerabilities in order allocation (Lotfi et al., 2024). Hybrid methods such as Delphi-FAHP-FMOP and decision techniques such as BWM and TOPSIS help manage uncertainty and optimize resilient decisions (Ye et al., 2024); (Sun et al., 2024). In specific sectors such as cloud services and the pharmaceutical industry, agility, security and risk mitigation criteria are evaluated to strengthen supply chain resilience (Amoujavadi & Nemati, 2024; Kayani et al., 2023).

2.3 Sustainability in Supplier Selection

Sustainability in supplier selection prioritizes environmental, social and economic criteria to ensure responsible practices in the supply chain. Tools such as big data and artificial intelligence are integrated to evaluate suppliers based on their sustainable impact (Zekhnini et al., 2024); (Mirzaee & Ashtab, 2024).

Multi-criteria methods such as Delphi-FAHP-FMOP and fuzzy approaches allow balancing sustainability and economic efficiency (Ye et al., 2024); (Varchandi et al., 2024). Technologies such as blockchain facilitate transparency and traceability, promoting more sustainable supply chains (Lotfi et al., 2024). In addition, sectors such as the food industry and cloud services adopt specific sustainability criteria to reduce their environmental footprint and improve their social responsibility (Ben Abdallah et al., 2024); (Amoujavadi & Nemati, 2024).

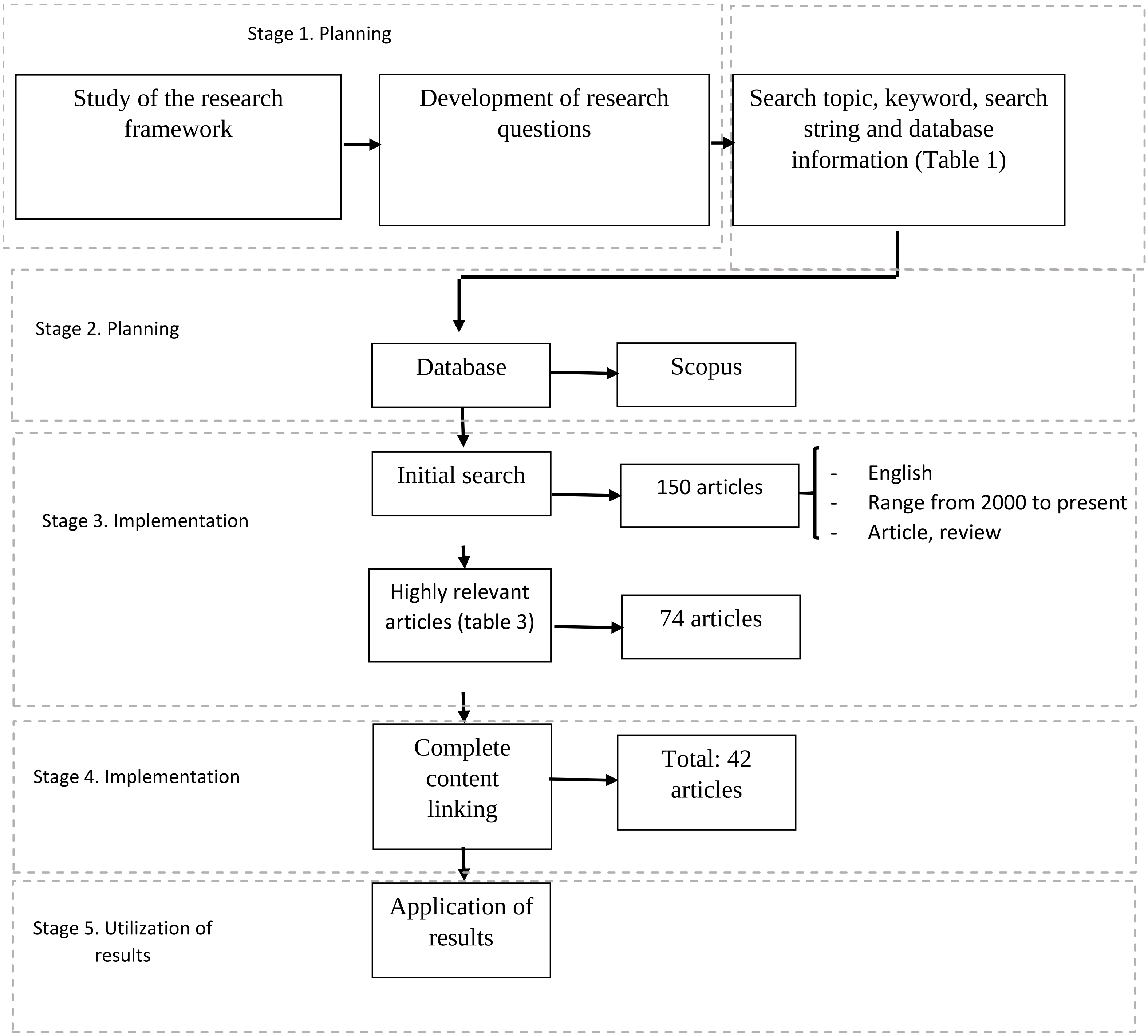
In this context, the incorporation of advanced tools and innovative practices further strengthens the ability of companies to efficiently manage supplier choice.

3 Methodology

The Systematic Literature Review (SLR) consists of five fundamental stages. In the first stage, the research questions are defined and formulated. The second stage involves planning the literature search in specific databases. During the third stage, the most relevant studies are selected and evaluated. The fourth stage focuses on the analysis and linkage of the selected contents. Finally, in the fifth stage, the results are applied to answer the questions posed and achieve the research objectives, which are shown in figure 1.

Figure 1

Systematic procedure


Stage 1. Planning
Study of the research framework
Development of research questions
Search topic, keyword, search string and database information (Table 1)
Stage 2. Planning
Database
Scopus
Stage 3. Implementation
Initial search
150 articles
- English
- Range from 2000 to present
- Article, review
Highly relevant articles (table 3)
74 articles
Stage 4. Implementation
Complete content linking
Total: 42 articles
Stage 5. Utilization of results
Application of results

3.1 Stage 1: Formulation of the Research Question

In order to identify existing conceptual frameworks that facilitate the analysis and evaluation of quantitative models applied to sustainable and resilient supplier selection, it is essential to understand how these methodologies can optimize decision making in complex and dynamic contexts. The correct implementation of these models can strengthen the supply chain in the face of potential disruptions and improve its adaptive capacity. In this sense, the following research questions arise:

Which mathematical models are considered in the selection of suppliers that incorporate resilience and sustainability criteria, How can quantitative models improve the selection process of sustainable and resilient suppliers, Which quantitative model(s) are the most implemented to select and sustainable and resilient suppliers, thus improving management in the supply chain and sustainability of companies, Which quantitative model(s) are the most implemented to select and sustainable and resilient suppliers, thus improving management in the supply chain and sustainability of companies?

3.2 Stage 2: Identification of Bibliographic Sources

Four topics are considered in the search: “Supplier selection”, “Resilience”, “Sustainability” and “Supply chain”. The search criteria are described in Table 1. The search was conducted in the Scopus database using specific search terms and strings. Keywords such as “Supplier Selection”, “Resili”, “Sustainabil ‘** and ’Supply Chain” were used. The search covers the period from 2000 to the present.

Table 1

Search criteria

Search Topics	keywords	Search strings	Database
Supplier selection Resilience Sustainability Supply chain	“Supplier Selection” “Resili*” “Sustainabil*” “Supply chain”	(“supplier”) AND (“selection” or “preference” OR “choice”) AND (“resili*” OR “risk” OR “disruptive”) AND (“sustainab*”) AND (“supply chain”	Scopus

3.3 Stage 3: Identification and Analysis of Relevant Literature

The initial search was carried out taking into account the title, abstract and keywords of the articles, which made it possible to identify 150 articles in the Scopus database. After applying the inclusion criteria described in Table 2, the most relevant papers were selected. The search focused on articles and literature reviews, published from 2000 to the present and in English. As a result, the total number of articles was reduced to 74.

Table 2

Inclusion criteria

Inclusion criteria	Description
Type of publication	Published exclusively in scientific journals. Books, book chapters and conferences were excluded.
Type of article	Research articles and literature reviews.
Search horizon	From 2000 to the present.
Language of publication	English
Research context	Articles dealing with sustainable and resilient supplier selection, with emphasis on quantitative models.

Some of the results obtained might not be relevant to the research objective, despite meeting the terms of the search string and the inclusion criteria. For this reason, a manual selection of the literature was carried out. This selection was made by analyzing in detail the title, abstract and results of each study, ensuring that they were focused on the selection of suppliers within the supply chain.

3.4 Stage 4: Analysis and Synthesis

The identification of the articles was carried out following three specific guidelines, described in Table 3, which made it possible to purify and reduce the set of documents to a total of 42 relevant articles.

Table 3

Final Guidelines for Item Screening and Selection

Guideline	Description
Preliminary screening	Specific parameters were applied to identify relevant articles, excluding those that were not relevant and eliminating duplicates, resulting in a total of 42 articles.
Title and abstract evaluation	Titles, abstracts and results were reviewed, ensuring that they included information on “supplier selection in the supply chain”.
Full reading	A detailed analysis of each article was carried out. This process allowed validating and confirming the relevance of the selected documents, consolidating a total of 42 articles..

3.5 Stage 5: Dissemination of Knowledge and Use of Results

The connections identified between the articles reviewed and the research questions are presented. The purpose is to use the findings in a broad manner to foster new knowledge and promote its application in different areas related to the topic studied.

4 Results and Discussion

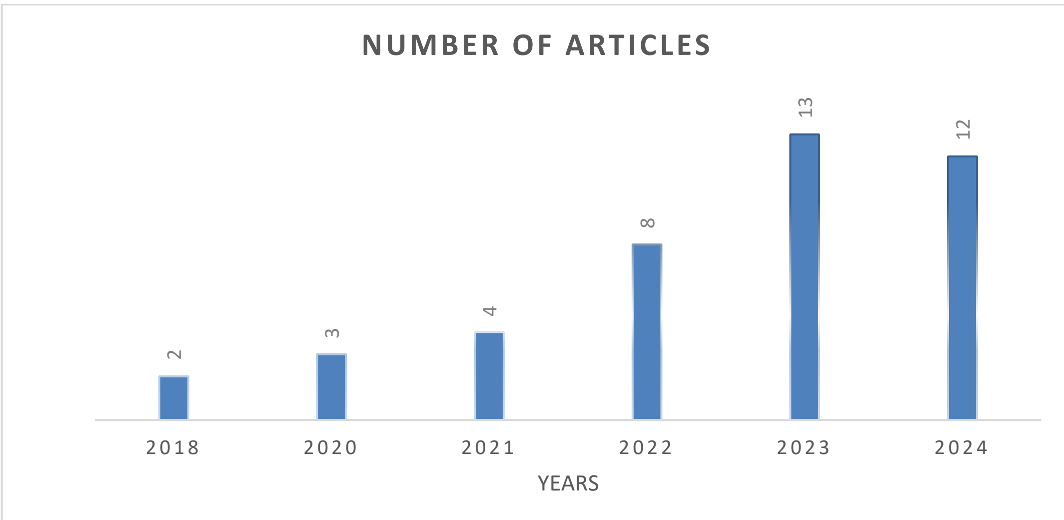
4.1 Descriptive Analysis

The global crisis caused by the COVID-19 pandemic spurred research focused on resilience due to the urgent need to mitigate disruptions and adapt to new market dynamics. This phenomenon was consolidated in 2023 and 2024, years that represent the highest peaks in the number of publications, suggesting a greater adoption of quantitative models to evaluate sustainability and resilience criteria in decision making. Figure 2 shows a sustained growth in publications related to the selection of sustainable and resilient suppliers in supply chains, which reflects a growing interest on the part of the scientific and professional community, especially from 2020 onwards.

This increase in scientific output highlights the ongoing need to develop strategies that enable supply chains to become more efficient, sustainable and adaptable in the face of contemporary challenges, such as global crises, logistical disruptions and changes in market demands. The implementation of these approaches not only seeks to mitigate risks, but also to strengthen operational processes and improve the resilience of companies, which is crucial for maintaining competitiveness in an increasingly dynamic and demanding environment.

Figure 2

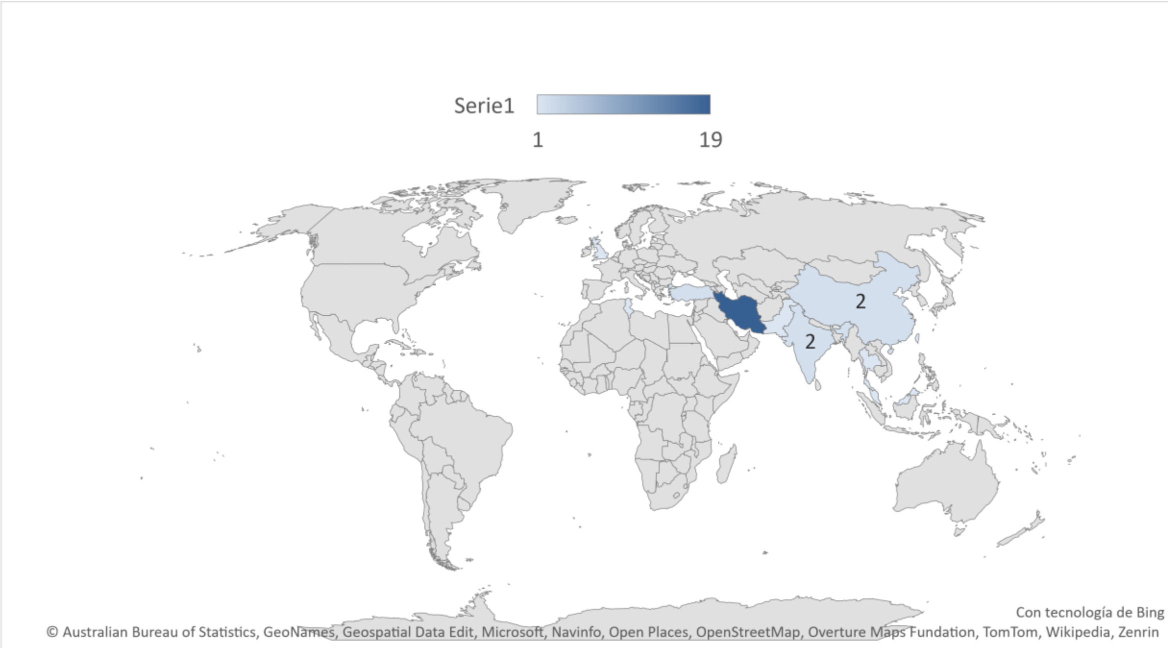
Articles published by year.



An analysis of the geographical distribution of the published articles shows a marked concentration in certain countries. Figure 2 shows that Iran is the country with the highest number of publications, with 19 articles, reflecting a high level of research activity on issues related to the selection of sustainable and resilient suppliers. This predominance may be motivated by local factors such as industrial policies or particular economic contexts.

Figure 3

Articles published by country



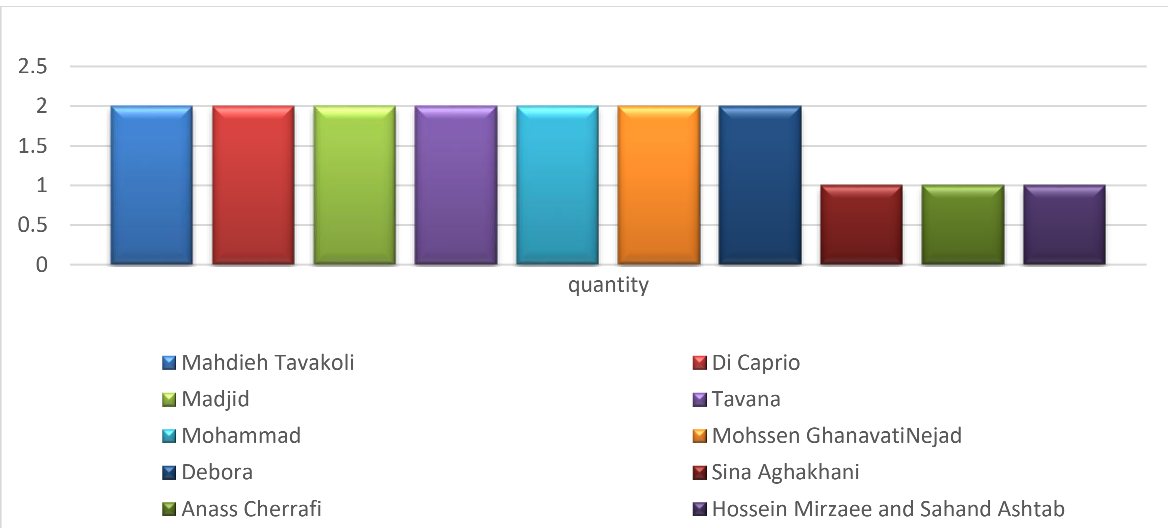
On the other hand, countries such as China and India show a more moderate contribution with 2 publications each, possibly related to their rapid industrial growth and the need to adapt their supply chains to resilience and sustainability criteria to face logistical challenges in globalized markets. Interest in resilience research in supply chain management has gained greater emphasis due to natural disasters and anthropogenic events that have severely affected several economies. These events have prompted countries with emerging and strategically positioned economies to develop strategies to strengthen their supply chains and mitigate specific vulnerabilities in their local contexts.

Progress in this field has been built thanks to a series of fundamental contributions that have marked its development. These contributions come from various researchers whose ideas and methodologies have driven new strategies and approaches applied to dynamic and challenging contexts. Recognizing the most mentioned authors allows us to identify the key references and understand how their work has influenced the evolution of knowledge. Graph 3 reveals the outstanding participation of researchers such as Mahdieh Tavakoli, Di Caprio, Madjid, Mohammad, Mohssen Ghanavati-Nejad, Tavana, and Hossein Mirzaee and Sahand Ashtab, who have 2 mentions each in the articles analyzed.

This frequency indicates the relevance of their contributions in the field of sustainable and resilient supplier selection, especially in the development of quantitative models. In addition, authors such as Sina Aghakhani, Anass Cherrafi and Debora contribute to enrich the area with complementary approaches. These works address methodologies such as multi-criteria analysis, optimization algorithms and decision models, which enable companies to optimize their supplier selection processes in the face of sustainability and resilience challenges. The variety of authors and approaches is evidence of international collaboration and a solid theoretical and practical foundation, making it easier for organizations to adapt to a dynamic environment, strengthen their responsiveness and mitigate risks associated with disruptions and changes in the global marketplace.

Figure 4

Main authors mentioned.

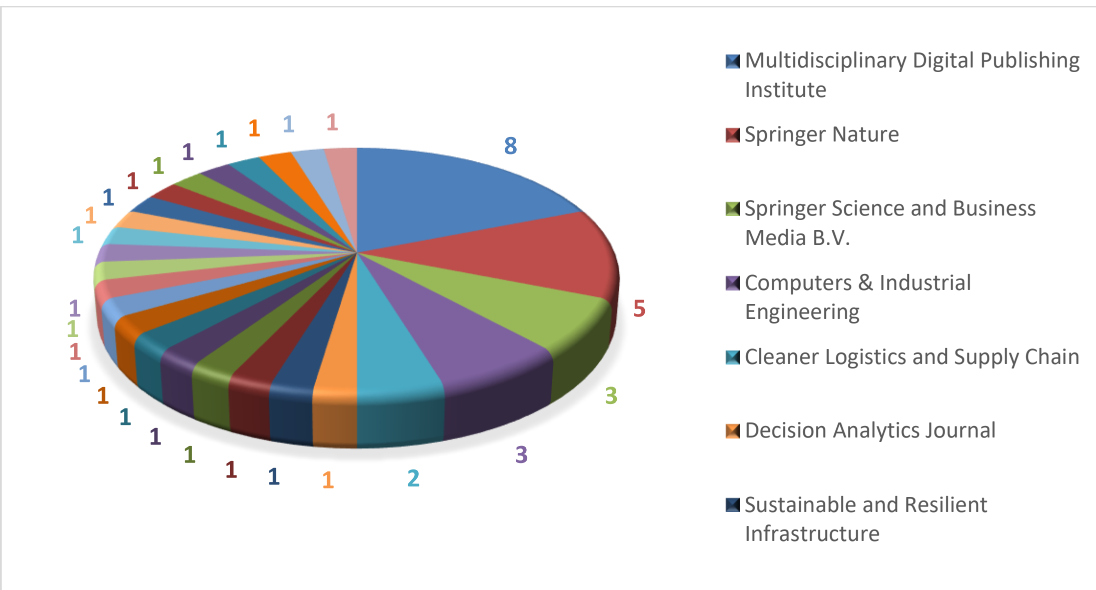


Publications in scientific journals reflect a clear trend towards certain editorial media that are preferred by authors to disseminate research related to resilience, sustainability, circular economy and industry 4.0 applied to the supply chain. Identifying the most published journals provides insight into the most relevant and consolidated channels in these fields of study, thus facilitating the search and reference of updated scientific literature.

Figure 5 shows that the journal “Multidisciplinary Digital Publishing Institute” leads with 8 publications, standing out as the medium most used by researchers due to its broad thematic coverage and acceptance of multidisciplinary articles. It is followed by “Springer Nature”, with 5 publications, reaffirming its relevance in sustainability and technology studies. In third place are “Springer Science and Business Media B.V. and Computers & Industrial Engineering”, both with 3 publications, evidencing a technical focus on industry and engineering. Finally, “Cleaner Logistics and Supply Chain”, with 2 publications, stands out for its emphasis on sustainable and circular logistics practices. These results suggest that researchers prioritize multidisciplinary journals specialized in sustainability, engineering and supply chain issues to disseminate their studies.

Figure 5

Most published journals.



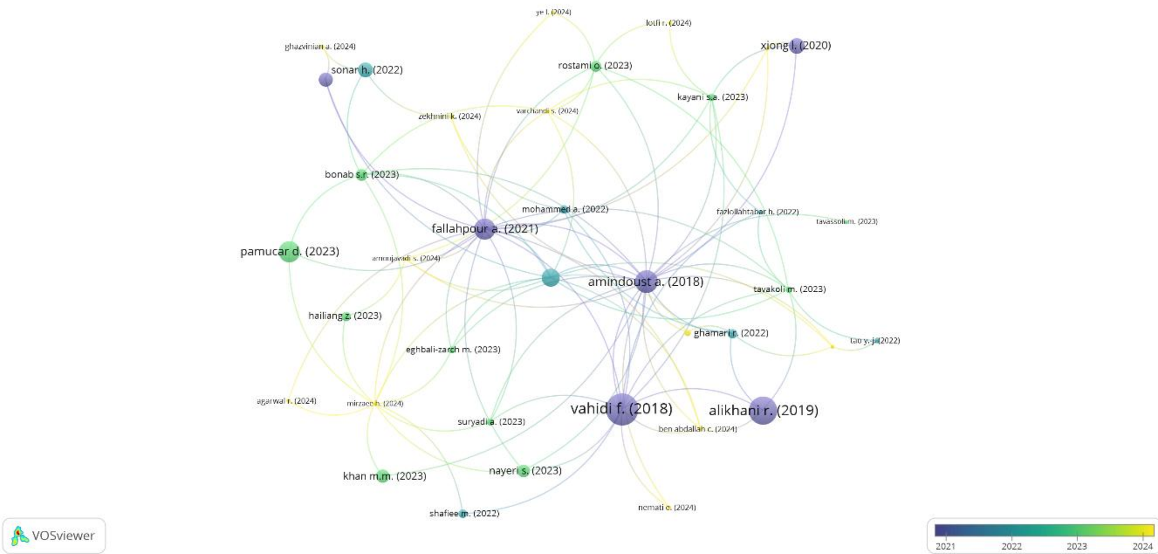
4.2 Relational analysis

The analysis of the bibliometric network generated in VOSviewer (Figure 6), shows that papers such as those by (Amindoust, 2018), (Vahidi et al., 2018) and (Alikhani et al., 2019) represent the publications with the highest number of citations, highlighting their central influence in the field. The density of connections between these studies reveals a high scientific interdependence and collaboration.

A temporal evolution of publications is observed, from 2021 to 2024, indicating a continuous growth in research. Researchers such as (Fallahpour et al., 2021), (Sonar et al., 2022) and (Pamucar et al., 2023) have been instrumental in the most recent approaches, integrating advanced quantitative methods to address sustainable and resilient supplier selection.

Figure 6

Bibliometric analysis of bibliographic documents, illustration made with VOSviewer software.



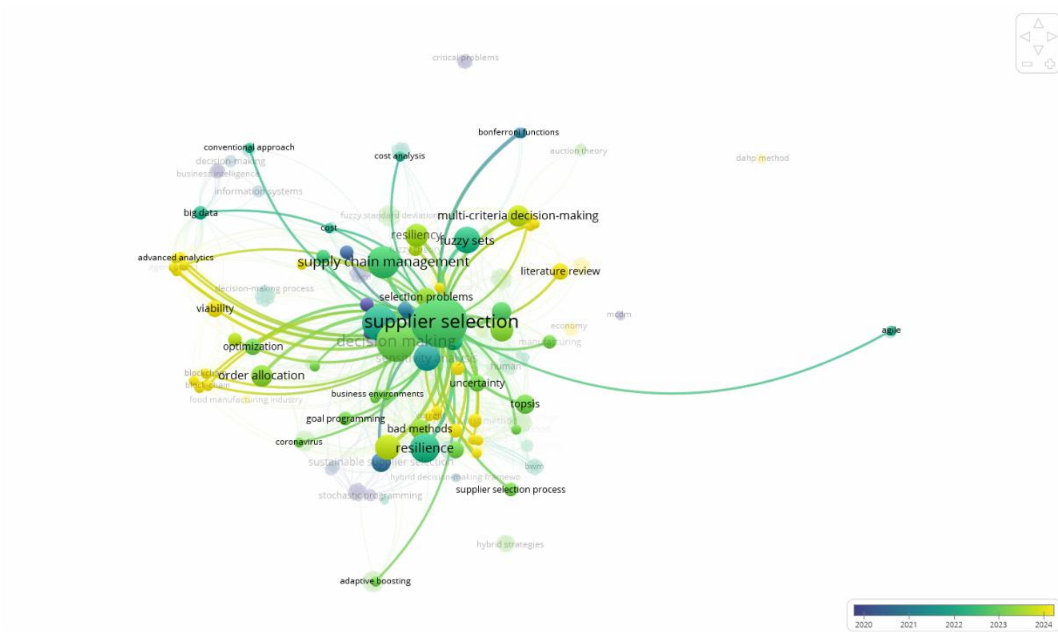
The exploration of bibliometric relationships through VOSviewer (Figure 7), reveals that supplier selection occupies a central position in the research field, connecting with key areas such as supply chain management, decision making, resilience and multi-criteria decision making methods (MCDM). The relevance of these concepts is evidenced by their size and number of links, reflecting their importance in the current literature.

There is a trend towards more advanced and adaptive approaches to supplier management, highlighting quantitative methods such as fuzzy sets, TOPSIS and optimization, which allow uncertainty and complexity to be managed by evaluating multiple criteria. In addition, attention to factors such as resilience and uncertainty suggests an interest in strengthening the ability of supply chains to adapt and recover from disruptions.

Concepts such as “order allocation”, “viability” and “advanced analytics” are also prominent, reflecting the focus on optimizing resource allocation processes and applying advanced analytical techniques to improve decision making. The presence of terms such as “agile” indicates an emerging exploration of agile methodologies applied to this context.

Figure 7

Keywords co-occurrence analysis, Illustration made with VOSviewer software.



4.2.1 Quantitative Methods in Supplier Selection

The selection of resilient and sustainable suppliers in the supply chain requires rigorous methodological approaches. Several studies have applied quantitative methods to optimize the decision-making process, ensuring an objective and efficient evaluation. Table 4 presents an analysis of these methods used in recent research, highlighting their ability to address aspects such as uncertainty, multi-criteria analysis and process automation through advanced systems.

Table 4

Analysis of methods

Authors	Quantitative methods
(Zekhnini et al., 2024)	In industry, MAS (Multi-Agent Systems), Big Data Analytics, FIS (Fuzzy Inference System) and MCDM (Multi-Criteria Decision Making Methods) methods are integrated to optimize supplier selection. MAS coordinates autonomous tasks, Big Data Analytics processes large volumes of data in real time, FIS manages uncertainty through fuzzy logic, and MCDM evaluates multiple criteria simultaneously. This combination improves the accuracy and efficiency of industrial supply chain decision making.
(Ye et al., 2024)	The Delphi method facilitates consensus among experts to identify and prioritize relevant criteria through structured feedback rounds. The FAHP allows assigning weights to these criteria using fuzzy logic to handle uncertainty and subjectivity. Finally, FMOP optimizes order allocation and supplier selection by considering multiple objectives and imprecise data. Together, these methods offer a robust approach to achieve economical, resilient and sustainable results in the food manufacturing industry.
(Lotfi et al., 2024)	RSO optimizes decisions under uncertainty, WVAR manages financial risks with weighting, MINLP solves problems with mixed and nonlinear variables, and MILP optimizes with integer variables and linear constraints. These methods ensure robust and efficient supplier selection with risk management.
(Varchandi et al., 2024)	RSO handles uncertainty by ensuring robust solutions, while WVAR manages financial risk with weights. MINLP optimizes problems with mixed and nonlinear variables, and MILP solves decisions with integer variables and linear constraints. BST improves efficiency by dividing problems into subproblems. Integrating these methods enables effective, robust and risk-managed supplier selection and allocation.
(Amoujavadi & Nemati, 2024)	Multicriteria Decision Making (MCDM) methods are used to evaluate the viability of cloud service providers. These methods identify, rank and weight key criteria such as sustainability, resilience, agility and security. By structuring these criteria in a hierarchical manner, the study facilitates

	a comprehensive and balanced evaluation of providers, considering multiple factors that affect their performance and reliability.
(Singh et al., 2024)	The PLS-SEM (Partial Least Squares Structural Equation Modeling) method to analyze an empirical model that includes seven latent variables and 67 indicators. This approach allows evaluating the relationships between factors such as risk mitigation in the supply chain through additive manufacturing, the determinants of success in its incorporation and the supplier selection frameworks facilitated by this technology.
(Nemati, 2024)	The BWM assigns weights to criteria by comparing the best and worst criteria. The MABAC selects alternatives by measuring their distance to an ideal boundary. The MULTIMOORA combines three approaches for a comprehensive evaluation. The combination of these methods allows an accurate selection of suppliers considering resilience and sustainability under uncertainty.
(Aungkulanon et al., 2024)	FAHP assigns weights to criteria by handling uncertainty with fuzzy logic. PROMETHEE II ranks suppliers based on multiple criteria according to the decision maker's preferences. Factor Analysis (FA) identifies and groups relevant risk factors, simplifying data complexity. Finally, HSOMASS integrates sensitivity analysis and optimization to assess the impact of parameter changes, ensuring robust decisions. Together, these methods enable accurate and adaptive selection of resilient suppliers.
(Sun et al., 2024)	PULT handles uncertainty by allowing subjective evaluations to be expressed in linguistic terms and probabilities. The BWM assigns weights to the criteria comparing the best and worst criteria to reduce inconsistencies. The extended version of TOPSIS ranks suppliers considering the proximity to an ideal solution with a probabilistic approach. These combined methods allow for resilient and accurate supplier selection under uncertainty.
(Ben Abdallah et al., 2024)	The FAHP assigns weights to criteria by handling uncertainty with fuzzy logic. The FMABAC ranks farmers according to their proximity to an ideal

	solution. The AHP structures the decision problem into hierarchical levels to facilitate evaluation. This hybrid approach allows a comprehensive and accurate selection, considering social, environmental, economic and resilience criteria.
(Agarwal & Nishad, 2024)	EDAS, MCDM, and TFNS methods are used. EDAS evaluates suppliers by measuring their distance from an average solution. The MCDM allows multiple criteria to be considered for a comprehensive evaluation. TFNS handles uncertainty by representing imprecise data with triangular fuzzy numbers. The combination of these methods facilitates sustainable and resilient supplier selection in complex and uncertain contexts.
(Ghazvinian et al., 2024)	SEM (Structural Equation Modeling) is used to validate the relationships between LARGS and IF-TOPSIS criteria to rank suppliers in fuzzy environments. SEM confirms the structure and relevance of the criteria, while IF-TOPSIS handles uncertainty and subjectivity in selecting suppliers close to an ideal solution. These combined methods provide a robust framework for effective selection of sustainable and resilient suppliers.
(Gökler & Boran, 2024)	DEMATEL is used to identify interrelationships between selection criteria and D-AHP is used to assign weights by handling uncertainty with D-numbers. The combination of these methods facilitates accurate supplier evaluation by considering dependencies between criteria and incomplete information, achieving a more resilient and sustainable selection.
(Eghbali-Zarch et al., 2023)	Fuzzy Theory, SECA, Mathematical Programming and GAIA are applied to select resilient and sustainable suppliers. Fuzzy Theory handles uncertainty in the data, SECA evaluates criteria and alternatives simultaneously, Mathematical Programming optimizes the selection process, and GAIA visualizes the relationships between criteria and suppliers. These combined methods enable comprehensive and efficient supplier selection.
(Althaqafi, 2023)	TOPSIS and GRA are applied to select green suppliers. TOPSIS ranks suppliers according to their closeness to an ideal solution, while GRA

	evaluates their performance against an ideal benchmark. The combination of these methods allows for effective selection considering environmental and social factors in uncertain environments.
(Tavakoli et al., 2023)	QFD, Markov Chains and FBWM are used to select sustainable and resilient suppliers. QFD identifies customer needs and translates them into technical criteria. Markov Chains model changes in customer preferences over time. FBWM assigns weights to criteria by handling uncertainty with fuzzy logic. This combination enables dynamic and accurate supplier selection aligned with customer priorities.
(Nayeri et al., 2023)	SFBWM manages uncertainty by assigning weights to supplier selection criteria. MOM optimizes supplier selection and order allocation by considering multiple objectives. SARIMA forecasts demand with seasonality for efficient planning. These combined methods enable sustainable and resilient order selection and allocation in healthcare supply chains.
(Pamucar et al., 2023)	FRN-MACBETH and FRN-CODAS are used to select suppliers under uncertainty. FRN-MACBETH assigns weights to criteria using qualitative judgments with imprecise data. FRN-CODAS ranks suppliers by calculating their distance to an ideal negative solution, handling uncertain information. The combination of these methods facilitates robust supplier selection in the healthcare supply chain during the pandemic..
(Suryadi & Rau, 2023)	AHP, Linear Programming (LP) and MCDM-Optimization are applied to select resilient suppliers. AHP prioritizes selection criteria and evaluates regional risks. Linear Programming optimizes resource allocation to maximize performance under constraints. The combination of these methods enables robust decisions, incorporating mitigation strategies such as geographic diversification and inventory management to strengthen supply chain resilience.
(Bonab et al., 2023)	BWM and TRUST are used to select resilient and sustainable suppliers. BWM assigns weights to criteria by comparing the most and least

	important, ensuring consistency in the evaluation. The TRUST method ranks suppliers by managing uncertainty and subjectivity. Integrated with spherical fuzzy sets, these methods facilitate accurate selection of suppliers for IoT implementation.
(Kayani et al., 2023)	AHP and Fuzzy TOPSIS are applied to optimally select suppliers and allocate orders. AHP assigns weights to selection criteria using a hierarchical structure, while Fuzzy TOPSIS ranks suppliers by managing uncertainty in evaluations. The combination of these methods facilitates more sustainable and resilient supplier selection, strengthening the pharmaceutical supply chain.
(Hailiang et al., 2023)	Fuzzy Set Theory and the Fuzzy Best-Best-Worst Method (FBWM) are employed to address the selection of sustainable and resilient suppliers. Fuzzy Set Theory handles uncertainty and imprecision in the evaluation data, allowing for a more realistic representation of the subjective perceptions and judgments of experts. FBWM determines the optimal weights of the selection criteria by identifying the best and worst criteria, and comparing the others relative to these extremes, which improves consistency and accuracy in the evaluation. The combination of these methods provides a robust framework for decision making in supplier selection, considering both sustainability and resilience in the supply chain.
(Rostami et al., 2023)	GP-FBWM and FVIKOR are applied to supplier selection in the medical device industry. GP-FBWM combines goal programming with the fuzzy best-worst method to assign weights to selection criteria, handling uncertainty and decision maker priorities. FVIKOR then ranks suppliers by evaluating their proximity to an ideal solution, identifying the most suitable option. This combination allows for accurate and feasible supplier selection by considering multiple criteria and process uncertainty.
(Azizi et al., 2023)	Linear Programming (LP) is used to improve the Analytical Hierarchical Process (AHP). This method overcomes problems of inconsistency and

	non-linearity, allowing to calculate weights and priorities more accurately. The application of LP facilitates a more reliable and efficient selection of sustainable suppliers..
(Tavassoli & Ghandehari, 2023)	F-MIP and FS-DEA are used to select and rank sustainable and resilient suppliers. F-MIP optimizes resource allocation by handling uncertainty with fuzzy constraints, while FS-DEA evaluates supplier efficiency by considering imprecise data and zero values. These combined methods enable accurate supplier classification and prediction in environments with uncertainty and incomplete data..
(Khan et al., 2023)	SCOR 4.0 and BWM are applied to select resilient and sustainable suppliers. SCOR 4.0 identifies and structures the critical elements of supplier performance, while BWM assigns weights to these elements according to their importance. This combination enables an accurate assessment to strengthen supply chain resilience and sustainability.
(Mohammed et al., 2022)	FAHP, FTOPSIS and FMOPM are applied to optimize supplier selection and order allocation in digitized supply chains. FAHP assigns weights to selection criteria by managing uncertainty in evaluations. FTOPSIS ranks suppliers according to their proximity to an ideal solution in fuzzy environments. FMOPM optimizes order allocation by balancing multiple objectives under uncertainty. This combination of methods enables supply chain managers to evaluate and select suppliers effectively, considering economic, ecological and resilience criteria in a context of digitalization.
(Ghamari et al., 2022)	BWM and TOPSIS are applied to improve supplier selection. BWM is used to determine the importance of critical factors such as environmental sustainability, quality and resilience in risk situations. TOPSIS then ranks suppliers based on their closeness to an ideal solution, facilitating the identification of those that best meet the requirements of the steel industry. This framework helps companies strengthen their supply chain, ensuring that selected suppliers can meet challenges and comply with sustainable standards.

(Sonar et al., 2022)	Interpretive Structural Modeling (ISM) is applied to analyze key criteria in supplier selection under the LARGS approach. ISM identifies the interdependencies between criteria and establishes a hierarchy, revealing that factors such as location and delivery time have a high influence on decision making. This method helps companies develop strategies that strengthen supply chain resilience and sustainability.
(Afrasiabi et al., 2022)	FBWM, GRA, and TOPSIS are applied to select sustainable and resilient suppliers in the manufacturing sector. FBWM assigns weights to evaluation criteria by managing uncertainty, while GRA and TOPSIS rank suppliers according to their proximity to an ideal solution. This model identifies suppliers that meet economic, social and environmental criteria, strengthening the resilience of the supply network.
(Tao et al., 2022)	MOLP and RMCGP are mentioned to optimize supplier selection in the LED industry. MOLP addresses objectives such as minimizing costs, rejects and delays by balancing multiple factors. RMCGP allows different levels of aspiration to be set for each objective, providing greater flexibility in planning. These combined methods improve the sustainability and resilience of the supply network by facilitating efficient selection of suppliers that meet economic and operational criteria.
(Fazlollahtabar & Kazemitash, 2022)	The Fazl-Tash method is introduced, which integrates 114 criteria to evaluate and select suppliers in a sustainable and resilient manner. This method simplifies the complexity of previous models, facilitating the identification of optimal suppliers. Applied in an industrial company, Fazl-Tash proved effective in improving the sustainability and resilience of the supply chain, enabling more informed decisions aligned with the organization's strategic objectives.
(Kazemitash & Fazlollahtabar, 2022)	The Best-Worst Method (BWM) is applied to select suppliers in environments with advanced information systems. The BWM assigns weights to criteria such as quality, cost, sustainability and technological capability, comparing the most and least important criteria. This approach improves the consistency and accuracy of the evaluation,

	facilitating efficient and effective supplier selection in IT-dependent industries.
(Shafiee et al., 2022)	AUGMECON2 is introduced to optimize supply networks with lean, resilient and sustainable practices. AUGMECON2 converts multi-objective problems into single-objective problems, making it easier to obtain Pareto optimal solutions. In the study, it is used to balance costs, minimize environmental impacts and improve resilience. This approach enables the design of efficient and sustainable supply networks, adapting to disturbances effectively in different industries.
(Tavana et al., 2021)	FG-BWM and FCoCoSo with Bonferroni functions are used to select suppliers in reverse supply chains. FG-BWM assigns weights to criteria considering uncertainty and opinions of various experts, while FCoCoSo with Bonferroni functions ranks suppliers by evaluating interrelationships and reducing the impact of extreme data. This combination improves the accuracy and robustness of supplier selection, optimizing efficiency in reverse supply chains.
(Fallahpour et al., 2021)	FDEMATEL, FBWM, FANP and FIS are used to select sustainable and resilient suppliers. FDEMATEL identifies causal relationships between criteria, FBWM assigns weights to these criteria, FANP adjusts the weights considering interdependencies, and FIS evaluates suppliers based on this data. Applied to the Malaysian palm oil industry, this framework facilitates accurate supplier selection, strengthening the sustainability and resilience of the supply network.
(Pramanik et al., 2020)	FAHP, Fuzzy Entropy and Fuzzy ARAS are applied to select resilient suppliers in the automotive industry. FAHP assigns weights to the selection criteria by handling uncertainty, while Fuzzy Entropy calculates the importance of these criteria. Fuzzy ARAS then ranks suppliers by evaluating their relative performance. This integrated approach facilitates the identification of suppliers capable of strengthening a resilient and adaptive supply network in the face of uncertainty and disruptions.

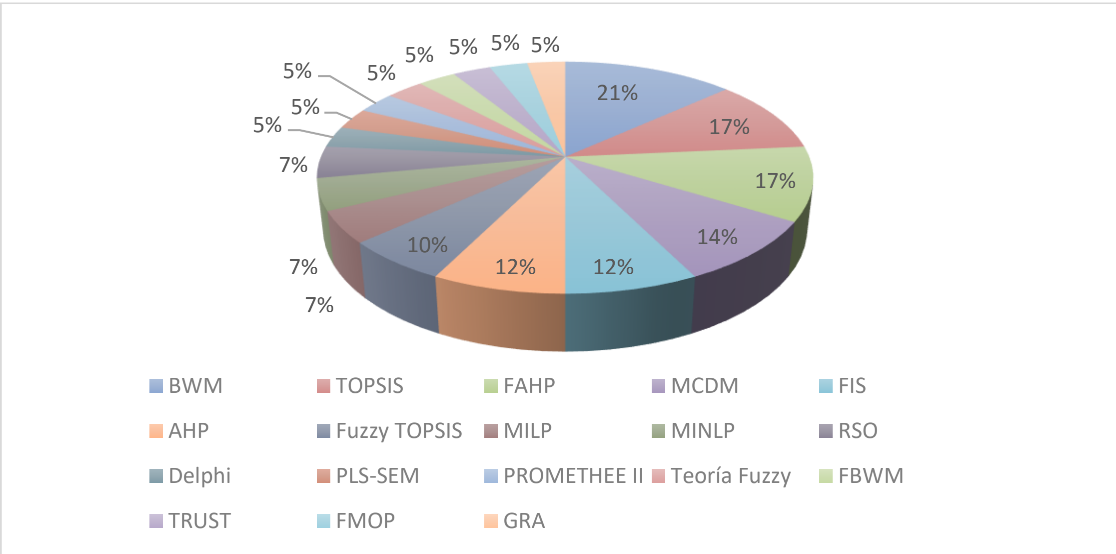
(Xiong et al., 2020)	It applies BWM, WASPAS, TOPSIS and IFWA to select resilient and environmentally friendly suppliers. BWM assigns weights to selection criteria, WASPAS evaluates suppliers by combining sum and weighted product, and TOPSIS ranks suppliers according to their proximity to an ideal solution. IFWA aggregates expert evaluations by managing uncertainty and hesitation. This approach enables the selection of suppliers that strengthen the sustainability and resilience of the supply network in industrial environments.
(Amindoust, 2018)	The FIS Model and DEA/AR Model methods are used to select resilient and sustainable suppliers. The FIS Model handles uncertainty through fuzzy rules, while the DEA/AR Model evaluates efficiency by combining data analysis and artificial reasoning. Applied in the manufacturing industry, this approach optimizes supplier selection, strengthening sustainability and operational resilience to disruptions.
(Vahidi et al., 2018)	It uses a bi-objective mixed programming model that combines stochastic and possibilistic approaches in two stages. This model handles random uncertainty and imprecision in the data to optimize supplier selection and order allocation. Applied to the automotive industry, it allows identifying sustainable suppliers and strengthening the resilience of the supply network in the face of possible operational disruptions.

When analyzing the quantitative methods used in supplier selection, it is observed that Multi-Criteria Decision Making (MCDM) approaches are widely used. Within this category, specific methods such as TOPSIS and the Fuzzy Analytical Fuzzy Hierarchical Process (FAHP) stand out, both with 17% of mentions. Other relevant MCDM methods include the Fuzzy Inference System (FIS) with 12%, the Analytic Hierarchy Process (AHP) also with 12%, and Fuzzy TOPSIS with 10%. In addition, approaches such as PROMETHEE II and FBWM account for 5% each.

On the other hand, the Best-Worst Method (BWM) stands out with 21% of mentions, although it is not part of the MCDM methods themselves. Finally, other approaches are identified as mathematical optimization methods, e.g., MILP (Mixed Integer Linear Programming), MINLP (Mixed Integer Non-Linear Programming) and RSO (Robust Stochastic Optimization), each with 7%. Figure 8 clearly reflects this distribution, showing the diversity of methods applied in supplier selection and their effectiveness in addressing different levels of complexity and uncertainty.

Figure 8

Methods used for supplier selection



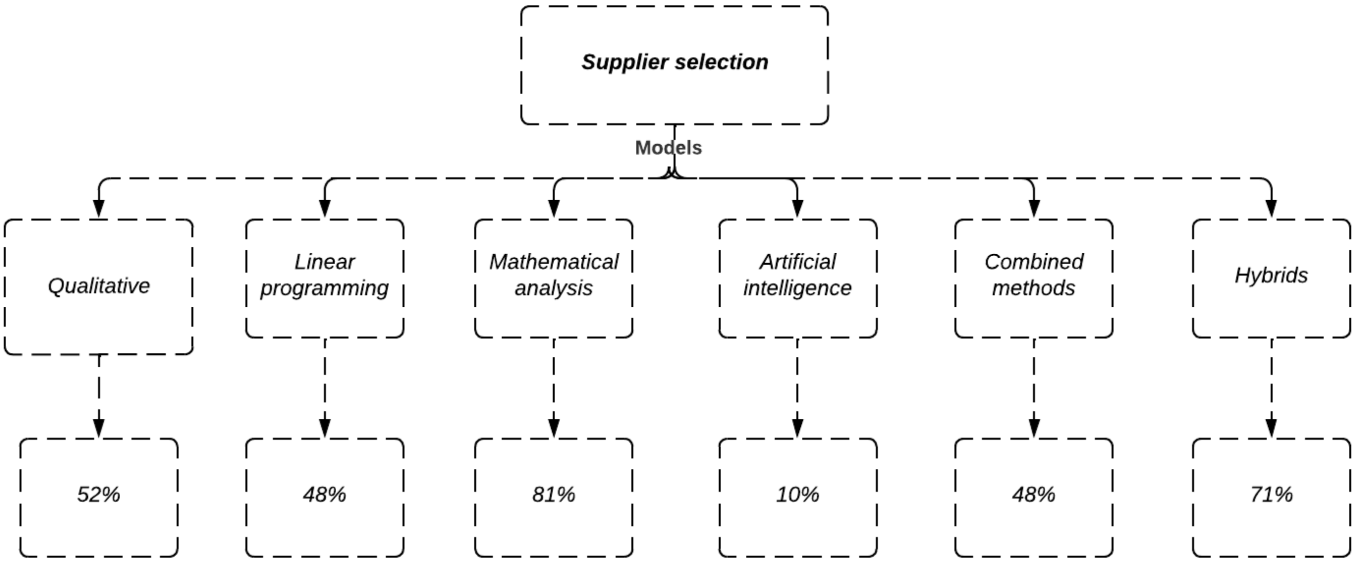
The methods used for supplier selection show a clear inclination towards quantitative and combined approaches. Mathematical analysis, with 81%, is the most widely used due to its accuracy and ability to optimize decisions. Hybrid models, 71% applied, reflect a preference for combining different approaches to achieve greater flexibility. Qualitative methods have an application rate of 52%, indicating that subjective factors are also relevant in the process.

Linear Programming and Combined Methods, both with 48%, show a balance between optimization and adaptability. Finally, Artificial Intelligence, with only 10%, shows a low adoption, possibly due to technological barriers or lack of training.

Figure 9 shows this distribution, reflecting a general preference for quantitative approaches and combined methods to optimize supplier selection.

Figure 9

Percentage distribution of the models used in the analyzed articles.

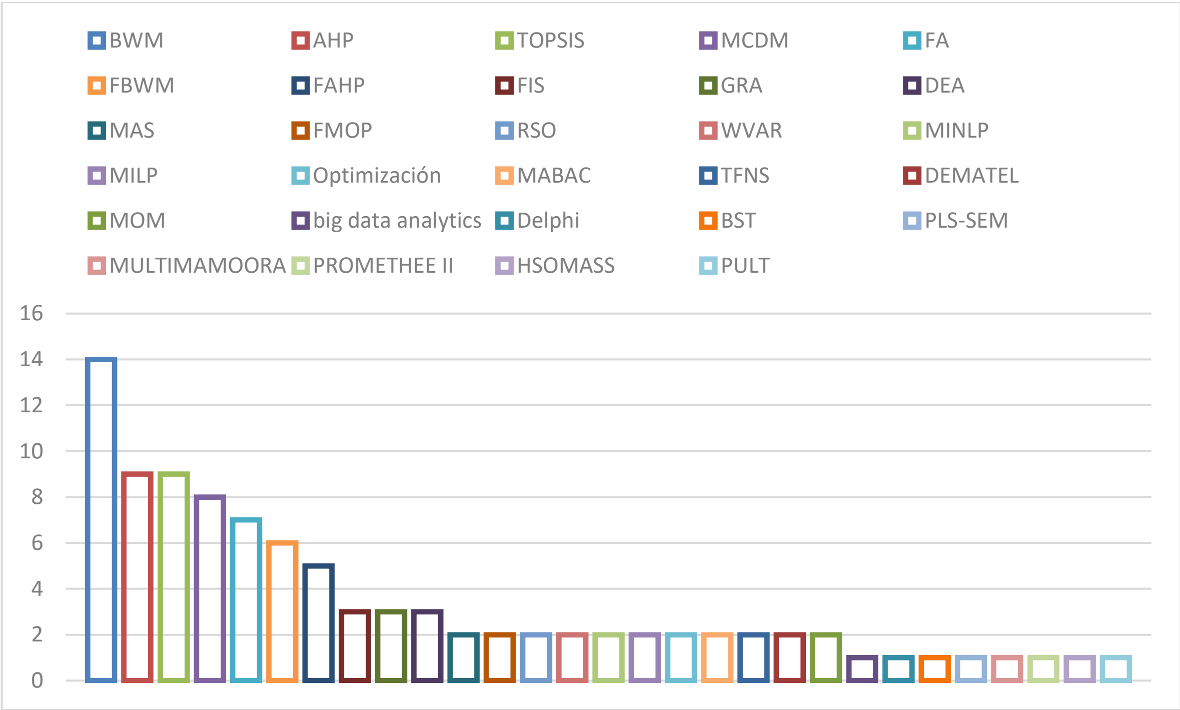


On the other hand, the use of quantitative methods for supplier selection shows a clear preference for certain specific techniques. This trend reveals that, although there is a diversity of methods available, a limited group dominates current practice. Figure 10 shows the distribution of these techniques, highlighting which are the most commonly used and allowing to identify patterns in the choice of methods to optimize the selection process.

The BWM (Best-Worst Method) is the most used quantitative method, mentioned in 14 articles. It is followed by TOPSIS and AHP, each with 9 mentions, while MCDM appears in 8 articles. Other methods such as FA (Factor Analysis) and FBWM (Fuzzy Best-Worst Method) have a minor presence, with 7 and 6 mentions, respectively. Most of the other methods are only used in 1 or 2 articles, reflecting a concentration in the use of certain specific methods and considerable diversity in the rest. This pattern suggests that, although there is a wide variety of methods available for quantitative analysis, a small group of methods is preferred by researchers.

Figure 10

Frequency of Quantitative Methods in Research Articles



5 Conclusions

In the context of sustainable and resilient supplier selection, quantitative models play an essential role in integrating economic, environmental and social criteria for more robust and adaptive decisions. Among the most widely used models are the Best-Worst Method (BWM), valued for its accuracy in assigning weights to criteria through clear and systematic comparisons, and the Fuzzy Analytical Fuzzy Hierarchical Process (FAHP), which facilitates the handling of uncertainty and subjectivity through fuzzy logic.

The TOPSIS method allows ranking suppliers based on their closeness to an ideal solution, providing a structured and objective evaluation. In addition, advanced tools such as Multi-Agent Systems (MAS) and Big Data Analytics optimize selection by processing large amounts of data in real time and coordinating tasks efficiently. Methods such as Mixed Integer Linear Programming (MILP) and Mixed Nonlinear Linear Programming (MINLP) help solve complex problems with specific constraints, while Fuzzy Theory and Fuzzy Inference Systems (FIS) allow handling imprecise data effectively. The implementation of these models not only improves efficiency and accuracy in supplier selection, but also strengthens the resilience and sustainability of the supply chain, facilitating rapid adaptation to disruptions and ensuring more competitive operations aligned with companies' sustainability goals.

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