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Review

Sustainable Supply Chain Management and Multi-Criteria Decision-Making Methods: A Systematic Review

Ananna Paul [1,*], Nagesh Shukla [1], Sanjoy Kumar Paul [2,*] and Andrea Trianni [1]

[1] School of Information, Systems and Modelling, University of Technology Sydney, Sydney, NSW 2007, Australia; Nagesh.Shukla@uts.edu.au (N.S.); Andrea.Trianni@uts.edu.au (A.T.)
[2] UTS Business School, University of Technology Sydney, Sydney, NSW 2007, Australia
* Correspondence: ananna.du@gmail.com (A.P.); sanjoy.paul@uts.edu.au (S.K.P.)

Abstract: Multi-criteria decision-making (MCDM) methods are smart tools to deal with numerous criteria in decision-making. These methods have been widely applied in the area of sustainable supply chain management (SSCM) because of their computational capabilities. This paper conducts a systematic literature review on MCDM methods applied in different areas of SSCM. From the literature search, a total of 106 published journal articles have been selected and analyzed. Both individual and integrated MCDM methods applied in SSCM are reviewed and summarized. In addition, contributions, methodological focuses, and findings of the reviewed articles are discussed. It is observed that MCDM methods are widely used for analyzing barriers, challenges, drivers, enablers, criteria, performances, and practices of SSCM. In recent years, studies have focused on integrating more than one MCDM method to highlight methodological contributions in SSCM; however, in the literature, limited research papers integrate multiple MCDM methods in the area of SSCM. Most of the published articles integrate only two MCDM methods, and integration with other methods, such as optimization and simulation techniques, is missing in the literature. This review paper contributes to the literature by analyzing existing research, identifying research gaps, and proposing new future research opportunities in the area of sustainable supply chain management applying MCDM methods.

Keywords: literature review; multi-criteria decision-making; MCDM methods; sustainable supply chain management; SSCM

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1. Introduction

In this competitive era, every business is part of a supply chain which involves efficient and effective movement of products or services from suppliers through to customers via manufacturers, distributors, and retailers. A typical supply chain involves multiple businesses, resources, people, technologies, and information for buying, manufacturing, distributing, storing, and selling products [1]. Several activities within a supply chain present direct social, environmental, and economic impacts [2]. These impacts are referred to as the triple bottom line (TBL) in sustainable supply chain literature. Social impact includes modern slavery, gender discrimination, unfair wages, child labor, and so on [3,4]. Environmental impact includes emission of carbon dioxide, polluting water and the environment, global warming, and so on [5,6]. Economic impact includes the return of investment, impact on profit, and productivity [2]. Considering their significant impact on society, the environment, and the economy, every supply chain is now taking steps to ensure sustainability.

Sustainable supply chain management (SSCM) integrates the economic, social, and environmental goals of the supply chain to improve long-term performance [7], evaluating and monitoring business performance against social, environmental, and economic dimensions [2]. Any good social and environmental performance with economic performance ensures better sustainability; however, ensuring all three performances are good creates the best sustainable supply chain [8]. Some recent studies have considered the triple bottom line (TBL) aspect of supply chain sustainability [9–15].

Examples of social sustainability include ensuring fair policies, ethical practices, equal opportunities, diversity, and so on [16–18]. Several papers in the literature focused on different social sustainability dimensions in supply chains, such as wages, child labor, equal opportunities, discrimination, ethics, corruption, health safety, diversity, equity, human rights, labor practice, training, and slavery [16,17,19–21]. A summary of social sustainability in SSCM literature is presented in Table 1. Empirical research, together with the application of different MCDM methods, were widely used to identify and analyze the social dimension of SSCM (see Table 1). From the contributions presented in Table 1, one can note that most of the research studies analyzing social sustainability focused on barriers, enablers, criteria in service, and manufacturing supply chains.

When a supply chain is environmentally sustainable, it is known as a green supply chain [22]. Examples of an environmentally sustainable supply chain include the treatment of waste, recycling, environmental education and training, green purchasing, green manufacturing, and green design [23,24]. In recent studies in this area, MCDM methods were widely applied (see Table 2). Looking at Table 2, most of the research studies focused on evaluating or analyzing factors, indicators, criteria, practices, performances, and suppliers in green supply chains. Different characteristics, including recycling, remanufacturing, greenhouse gas emissions, waste management, environmental education and training, green design, green/cleaner production, green purchasing, green logistics/distribution, and energy consumption are considered [22–29]. We have summarized the different characteristics of environmental sustainability and their source studies in Table 2.

Table 1. Different characteristics of social sustainability studied under SSCM literature.

Reference	Characteristic Name													Contribution	Methodology
	Wages	Child Labor	Equal Opportunity	Discrimination	Ethics	Corruption	Health-Safety	Diversity	Equity	Human Right	Labor Practice	Training	Slavery		
[19]	√	√	√	√	√		√	√	√	√	√	√		Identification and analysis of different dimensions of social sustainability in supply chains in India	Semi-structured interview
[16]	√	√					√	√	√	√	√			Analyzing forces for adopting social sustainability in emerging Indian and Portuguese economies	Empirical study
[30]	√	√				√				√	√		√	Analyzing modern slavery in supply chains perspective of United Kingdom from the clothing and textile sector	Secondary data analysis
[31]	√	√	√	√			√	√	√	√	√	√		Analyzing relationships between enablers to the social sustainability	ISM-MICMAC
[18]							√			√	√	√		Selecting supplier bases social sustainable criteria	Grey BWM–grey TODIM
[21]	√	√		√	√	√	√	√	√	√		√	√	Investigating integrated aspects of social sustainability	Empirical study
[4]	√	√		√		√	√					√		Analyzing enablers in social sustainability in footwear supply chains	BWM
[17]	√	√	√		√	√	√			√		√	√	Addressing social sustainability in supplier selection processes	Exploratory case study
[32]					√		√		√	√		√		Analyzing dimensions of social sustainability in healthcare supply chains	Stochastic exponential distribution model
[33]							√			√	√	√		Investigating social sustainability criteria	BWM
[34]			√		√		√		√			√		Identifying motivators, barriers, and enablers of social sustainability	Empirical study
[20]	√	√	√	√	√		√			√	√	√	√	Developing a taxonomy of supply chain social sustainability practices	Empirical study

Table 2. Different characteristics of environmental sustainability studied under SSCM literature.

Reference	Characteristic Name												Contribution	Methodology
	Recycling	Remanufacturing	Circular Economy	Greenhouse Gas Emission	Waste Treatment/Management	Use of Natural Resources	Environmental Education and Training	Green Design	Green/Cleaner Production	Green Purchasing	Green Logistics/Distribution	Energy Consumption		
[25]	√			√			√	√		√			Identifying critical dimensions and factors in green supply chains	DEMATEL and cast study
[26]	√	√		√	√			√	√	√	√		Evaluating indicators in green supply chains	Fuzzy VIKOR
[22]	√			√	√	√		√	√	√		√	Evaluating suppliers in green supply chain	Literature review
[29]	√	√		√	√			√		√		√	Analyzing critical green supply chain practices	FIPA approach
[23]	√			√	√	√	√	√	√	√	√	√	Analyzing criteria for green supply chains	Fuzzy DEMATEL
[28]	√		√	√	√			√	√	√	√	√	Developing an assessment framework for green supply chain management	Conceptual study
[27]			√					√	√	√			Evaluating performance of green supply chain management	Fuzzy inference system
[24]	√	√		√	√		√	√		√	√	√	Evaluating green suppliers	TOPSIS

Examples of economic sustainability include cost reduction, on-time delivery, reliability, and quality [11]. Sustainable supply chains simultaneously assess supply chain performance in terms of social, environmental, and economic aspects.

In the last few years, a good number of studies have been conducted on different dimensions of SSCM, including a number of review papers, such as a:

- review of green supply chain management [35–37];
- review of different theories in sustainable supply chains [38];
- review of the evolution of and future challenges in sustainable supply chain management [8,39–41];
- review of trends and future directions in social aspects of sustainable supply chains [42];
- review of SSCM in global supply chain context [43];
- review of drivers in SSCM [44]; and
- review of MCDM methods in green supply chains which focuses only on the environmental dimension of supply chain management [22,45].

In order to become more sustainable, supply chains should implement sustainable practices, with a certain impact on various TBL areas; however, decision makers need to consider multiple criteria to evaluate suppliers, practices, success factors, drivers, and challenges in SSCM in smart ways. For this purpose, MCDM methods have been widely applied in the area of SSCM [46]. In spite of having a reasonable number of contributing articles which applied different MCDM methods in SSCM, earlier literature is lacking a review on different MCDM methods applied to SSCM areas considering the social, environmental, and economic dimensions. In this paper, we aim to fill this gap by conducting a literature review on different MCDM methods applied in SSCM, contributing to the literature by analyzing existing studies systemically and proposing a future research framework in the area of MCDM methods in SSCM.

The paper is organized as follows. In Section 2, the scope of the literature review is described. The review of both individual and integrated MCDM methods is conducted in Section 3. Section 4 explains the bibliometric analysis for published articles. Section 5 summarizes the review and research gaps. Finally, conclusions and future research directions are presented in Section 6.

2. Scope of the Literature Review

The Scopus database was used to collect the relevant articles with the following phrases in the article's title, abstract, and keywords: "sustainable supply chain" and "multi-criteria decision making" or "multi-criteria decision analysis" or "MCDM". From the preliminary search of the literature, most of the studies in the area of SSCM modelling were found to be published since 2010, which is shown in Figure 1. Based on this observation, in this paper, the literature on MCDM methods applied in the area of SSCM is reviewed from 2010 to 2020.

After the preliminary search in Scopus, the search database was refined using the following criteria:

- Document type: article
- Source type: journals
- Year: 2010–2020
- Language: English

Other databases, such as the Web of Science and Google Scholar, were used to enhance the search. After a first screening of the articles (by title and abstract), the final subset of 106 relevant manuscripts for review was created. The inclusion criteria were articles focused on any dimension of supply chain sustainability and the search phrases appeared in the body text. The exclusion criterion was one or more keywords presented in the text or reference list without discussing supply chain sustainability using MCDM methods. After finalizing the list of articles, a deep review was conducted of the applications of different

MCDM methods in SSCM, and a bibliometric analysis was carried out within the set of finalized articles.

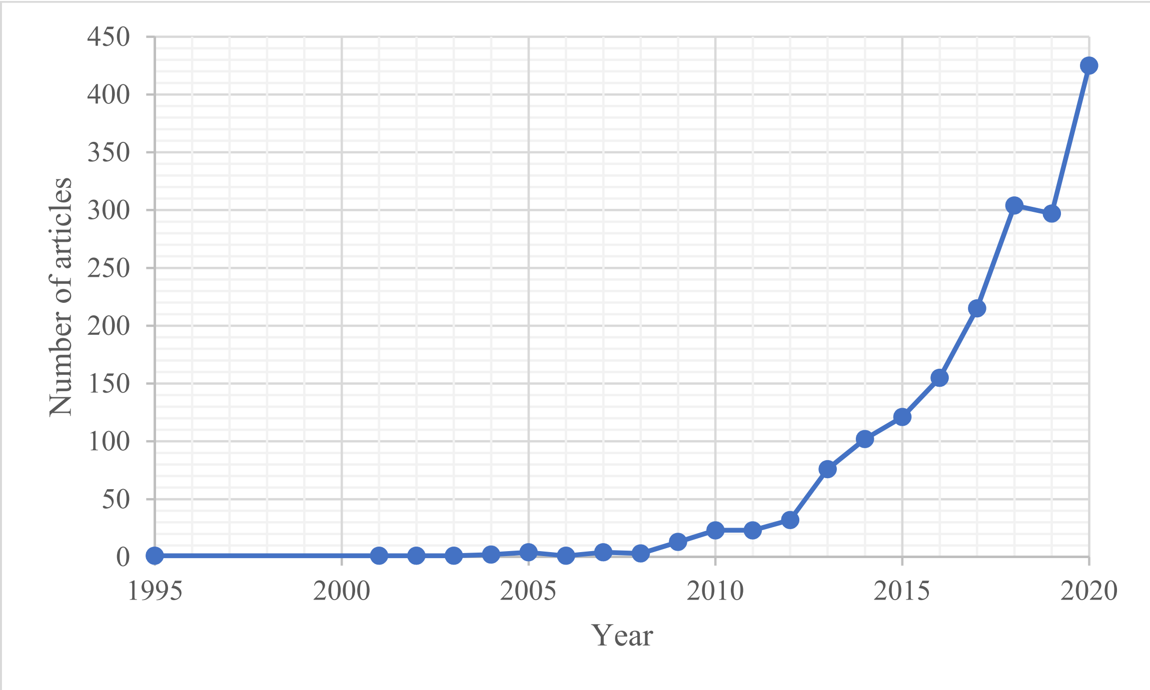

Figure 1. Number of articles published on SSCM modelling (Source: Scopus).

3. Review of Applications of MCDM Methods in SSCM

This section reviews the articles on MCDM methods applied in SSCM areas. The following sub-sections review the applications of both individual and integrated MCDM methods in detail.

3.1. Applications of Individual MCDM Methods

From the literature search, 59 articles applied individual MCDM methods in SSCM. The names of the methods and their abbreviated terms are as follows:

i. Decision-making trial and evaluation laboratory (DEMATEL) and Fuzzy/Grey DEMATEL
ii. Analytical hierarchy process (AHP) and Fuzzy AHP
iii. The technique for order of preference by similarity to ideal solution (TOPSIS) and Fuzzy TOPSIS
iv. Best–worst method (BWM)
v. VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) and Fuzzy VIKOR
vi. Rough set
vii. Elimination et choix traduisant la realité (ELECTRE) and Fuzzy ELECTRE
viii. Analytical network process (ANP)
ix. Rough strength-relation analysis method (RSRAM)
x. Rough simple additive weighting (RSAW)
xi. Interpretive structural modelling (ISM)
xii. Preference ranking organization method for enriched evaluation (PROMETHEE)

3.1.1. DEMATEL and Fuzzy/Grey DEMATEL

DEMATEL and Fuzzy/Grey DEMATEL are the most applied methods in SSCM. Between 2010 and 2020, a total of 15 articles have been published on this method. Among these, six articles applied DEMATEL, four applied grey DEMATEL, and five articles applied fuzzy DEMATEL.

In particular, applications of DEMATEL include the identification and analysis of success factors for sustainability initiatives (grey [47]), sustainable food supply chain management [48], green supply chain practices (fuzzy [49]), SSCM for Industry 4.0 [50], and implementing green supply chain management [51]. In addition, DEMATEL was used in a number of studies to analyze and evaluate barriers or challenges for sustainable development [52], remanufacturing (grey [53]), and green supply chain [54]. A few studies also analyzed drivers for sustainable consumption and production adoption applying grey DEMATEL [55] and drivers to ICT for sustainability initiatives in supply chains using a fuzzy one [56]. DEMATEL was used in other applications including the analysis of criteria and alternatives in sustainable supply chains (grey [57]), evaluation of influential indicators for adopting sustainable supply chains [58], analysis of causal relationships between practices and performance in green supply chains (fuzzy [59]), assessing performance in green supply chains considering economic, logistics, operational, organizational, and marketing aspects (fuzzy [23]), and selection of suppliers based on multiple criteria (fuzzy [60]).

3.1.2. AHP and Fuzzy AHP

AHP is one of the most widely applied MCDM methods in SSCM. Eleven articles applied AHP or Fuzzy AHP. Among these, six articles applied AHP, and the remaining five articles applied the fuzzy AHP method.

Six studies applied AHP to evaluate barriers to adopting sustainable consumption and production initiatives [61], to analyze criteria for improving effectiveness in green supply chain management implementation [62], to analyze challenges for industry 4.0 initiatives toward SSCM [63], to evaluate pressures to implement GSCM [64], to evaluate manufacturing practices for sustainability [65], and to analyze drivers for sustainable manufacturing processes [66]. Fuzzy AHP was also used to identify and analyze risks in green supply chains [67], analyze success factors for sustainable food supply chain management [68], evaluate indicators of SSCM [69], assess the supply chain performance based on sustainability criteria [70], and evaluate European countries for renewable energy sectors [71].

3.1.3. TOPSIS and Fuzzy TOPSIS

Earlier studies applied TOPSIS (two articles) or fuzzy TOPSIS (six articles) in the context of SSCM. The applications encompass the suppliers' evaluation and selection in sustainable and green supply chains based on multiple criteria. These criteria include applications of TOPSIS in selecting sustainable suppliers [72,73] and applications of fuzzy TOPSIS in evaluating green supplier performance [74,75], evaluating sustainable and green suppliers [24,76,77], and assessing areas for improvement in implementing green supply chain initiatives [78].

Researchers applied TOPSIS and Fuzzy TOPSIS to select suppliers and performance in sustainable or green supply chains based on identified multi-criteria.

3.1.4. BWM

The eight articles which have applied BWM in SSCM include an assessment of sustainability in green supply chains in an emerging economy [79], assessment of social sustainability in supply chains [33], evaluation of external forces for sustainable supply chains in the context of the oil and gas industries [80], analysis of enablers for social sustainability in an emerging economy [4], evaluation and prioritization of criteria for sustainable innovation [13], analysis of product-package alternatives in food supply chains [81], ranking sustainable suppliers [82], and analyzing barriers for sustainable supply chain innovation [83].

3.1.5. VIKOR and Fuzzy VIKOR

Five articles applied VIKOR or fuzzy VIKOR in SSCM. These articles include evaluating green supply chain management practices using fuzzy VIKOR [26], selecting development programs for green suppliers using fuzzy VIKOR theory [84], evaluating green environmental factors in reverse logistics using fuzzy VIKOR [85,86], and assessing green supply chain initiatives using a probabilistic linguistic VIKOR method [87].

3.1.6. Rough Set

The Rough set method has been applied in SSCM to select suppliers with sustainability [88], analyzing relationships between organizational attributes, supplier development programs, and performance in green supply chains [89], evaluating a selection, performance measurement, and program development tool in green supply chains [90], and measuring SSCM performances [91].

3.1.7. ELECTRE and Fuzzy ELECTRE

ELECTRE and fuzzy ELECTRE have been applied in SSCM to classify suppliers in the manufacturing industry using the ELETCRE TRI-nC method [92] and to evaluate supplier performance in green supply chains using the fuzzy ELECTRE method [93].

3.1.8. ANP

Two studies applied the ANP method in SSCM. The applications include selecting suppliers for managing sustainability [94] and selecting suppliers integrating the triple-bottom-line aspect [95].

3.1.9. Rough Strength-Relation Analysis Method, RSAW, ISM, and PROMETHEE

One article applied the Rough strength-relation analysis method for analyzing risk factors in SSCM [96], the RSAW for sustainable supplier selection [97], the ISM for ranking of barriers in SSCM [98], and the PROMETHEE for analyzing alternatives of biomass [99].

3.1.10. Summary of Applications of Individual Methods

Researchers applied DEMATEL and Fuzzy/Grey DEMATEL, AHP, and BWM mostly for analyzing success factors, barriers and challenges, drivers, and enablers for different aspects of SSCM. Success factors are the important factors decision makers should consider to ensure success in different dimensions of SSCM. Barriers and challenges are the causes preventing the success of any dimension of SSCM. Drivers and enablers are the aspects driving toward the achievement of sustainable performance within any dimension of supply chain sustainability. The different MCDM methods applied to analyze and prioritize success factors, barriers and challenges, and drivers and enablers in SSCM are summarized in Tables 3–5, respectively.

Table 3. Application of MCDM methods to analyze success factors.

Analyzed Success Factors in SSCM	Reference	Method
Green design, recovering and recycling, green purchasing, environmental performance, supplier collaboration, and regulation	[49]	Fuzzy DEMATEL
Government regulations and standards, top management commitment, environmental certifications, adoption of new technology and processes, reverse logistics, and training of suppliers and employees	[51]	DEMATEL
Logistics integration, social development, and environmental development	[50]	DEMATEL

Table 3. *Cont.*

Analyzed Success Factors in SSCM	Reference	Method
Technology development and process innovation, training, reverse logistics and waste minimization, ecological considerations in organizations' policies and missions, green design and purchasing, societal considerations, ethical and safe practices, and community welfare and development	[47]	Grey DEMATEL
Climatic change, implementing green practice, governance and cooperation, technological innovation, and government regulation	[48]	DEMATEL
Proper use of irrigation, demographic and environmental conditions, risk analysis, government policies, and food packaging	[68]	Fuzzy AHP

Table 4. Applications of MCDM methods to analyze barriers and challenges.

Analyzed Barriers and Challenges in SSCM	Reference	Method
Lack of sufficient governmental policies, poor infrastructure, low level of integration, skill shortage, and poor quality of raw materials	[52]	DEMATEL
Lack of channels to collect used products, imperfect legal system, consumption attitude, customer willingness to return the products, uncertainty in demand of remanufactured product, uncertainty in quality, and quantity and timing of returned products	[53]	Grey DEMATEL
Lack of environmental regulation, lack of potential liability, high cost of disposal of hazardous materials, poor environmental performance, lack of information, lack of governmental support, high cost for renewable energy, lack of new technology, insufficient societal pressure, poor legislation, lack of adoption of green practices, health and safety issues, employment stability, less profit in remanufacturing, lack of adequate training, and lack of management support	[54].	DEMATEL
Lack of support from management, lack of innovative methods, lack of technology developments, communication gap, lack of rewards and encouragement programs, lack of governmental regulations, lack of promotion of ethical and safe practices, reluctance of consumers toward sustainable development practices, lack of promotion of sustainable products, and lack of knowledge among stakeholders	[61]	AHP
Low understanding of industry 4.0 implications, poor research and development of industry 4.0 adoption, legal issues, low management support and dedication, lack of global standards and data-sharing protocols, security issues, lack of governmental support and policies, and financial constraints	[63]	AHP
Technological, regulatory, social, cultural, organizational, market, and networking barriers	[83]	BWM

Table 5. Applications of MCDM methods for analyzing drivers and enablers.

Analyzed Drivers and Enablers in SSCM	Reference	Method
Top management role and support, government support systems and subsidies, information systems network design, socio-environmental impacts of the products, culture related factors, approach to ICT to adopt sustainability, understanding the nature of sustainability, security and support services, and human expertise	[56]	Fuzzy DEMATEL
Management support, dedication and involvement, educating suppliers and vendors, understanding the customer requirements about sustainability, governmental policies and regulations, information flow and sharing among supply chain members, competency and skill of workforce, integration of social, environmental, and economic advantages, and understanding the importance of sustainability	[55]	Grey DEMATEL
Market capabilities, compliance with regulations, green purchasing, green innovation, environmental conservation, education and training, and employee welfare	[66]	AHP
Commitment to continual improvement and pollution prevention, commitment to comply with legislation, framework for setting and reviewing environmental goals, legal and other requirements, environmental objectives and targets, environmental education and training, green teamwork, best practices, identification of culture, monitoring culture change, quantity of waste released at each stage, and communication between top management and employees	[62]	AHP
Waste management, reuse and recycle, renewable energy usage, resource utilization, land, air and water pollution, government regulations, and use of hazardous materials	[79]	BWM
Wages and benefits, customer requirements, workplace health and safety practices, food, housing, and sanitation, child labor or forced labor, commitment of top management, education and training of employees, non-discrimination, anti-corruption, and working hours	[4]	BWM
Sustainable product cost reduction, financial availability for innovation, enhanced sustainability value to customers, investment in R&D for sustainable products, designing sustainable products, green logistics capabilities development, green manufacturing, environment management commitment, conducting regular environmental audits, enhancing the social image of the organization, corporate social responsibility initiatives, cultural, social values and norms, occupational health, and safety and rights of the employees	[13]	BWM

Researchers applied TOPSIS, Fuzzy TOPSIS, VIKOR, Rough Set, and ANP to analyze and evaluate suppliers and practices in sustainable or green supply chains based on sustainable criteria. These studies are summarized in Table 6.

Table 6. Summary of applications in analyzing and evaluating suppliers and practices.

Sustainable Criteria Considered	Application Area	Reference	Method
Pollution controls, pollution prevention, environmental management system, resource consumption, employment practices, health and safety, local communities influence, stakeholders influence, cost, quality, and innovation	Supplier selection in sustainable supply chain	[73]	TOPSIS
Cost reduction activities, products' quality improvement, increase in supply flexibility, green design of products, green purchasing, green production, internal management support for green development, green logistics, provision for health and safety, protection of employee's rights, human rights, and fair-trading and against corruption	Supplier selection in sustainable supply chain	[72]	TOPSIS
Quality of products, service performance, cost, environmental efficiency, green image, pollution reduction, green competencies, health and safety, and employment practices	Supplier selection in sustainable supply chain	[77]	Fuzzy TOPSIS
Cost, financial capability, flexibility, innovation, service capability, environmental management system, green image, greenhouse gas emission, reuse/recycling, pollution control, energy and resource consumption, economic welfare and growth, social responsibility, job safety and labor health, the interest and rights of employees, and job opportunities	Supplier selection in sustainable supply chain	[76]	Fuzzy TOPSIS
Green design, green purchasing, green production, green warehousing, green transportation, and green recycling	Green practice evaluation	[26]	Fuzzy VIKOR
Cost, resource usage, energy usage, water consumption, emission and waste generation, green manufacturing, product design, transportation, warehouse and procurement, and reverse logistics	Evaluation of green supplier development program	[84]	VIKOR
Cost, quality, time, flexibility, innovation, culture, technology, relationships, pollution control and prevention, resource consumption, health and safety, employment practices, and local community influence	Supplier selection in sustainable supply chain	[88]	Rough Set
Quality, price, on-time delivery, lead time, flexibility, community initiatives, ethical behavior, health and safety, diversity, waste reduction, recycling, and reverse logistics	Supplier selection in sustainable supply chain	[95]	ANP

3.2. Applications of Integrated MCDM Methods

A total of 47 articles applied integrated MCDM methods in SSCM. Among these, AHP or Fuzzy AHP were most widely integrated with other methods such as DEMATEL, ELECTRE, ISM, TOPSIS, VIKOR, and SOWIA, followed by TOPSIS or Fuzzy TOPSIS with

FPP, Rough set, CRITIC, and VIKOR. Researchers have applied more integrated MCDM methods in recent years, making a significant methodological contribution; this section summarizes such studies.

AHP and Fuzzy AHP are mostly integrated with TOPSIS or fuzzy TOPSIS and VIKOR and fuzzy VIKOR. AHP-TOPSIS is widely applied in selecting sustainable or green suppliers, evaluating third-party logistics (3PL) service providers, and prioritizing solutions and responses in different aspects of SSCM [100–105]. AHP-VIKOR (with their fuzziness) integrated method was mostly applied for selecting a sustainable supplier and management practices in green supply chain management [106–108]. Other integrations of AHP or fuzzy AHP with DEMATEL or fuzzy DEMATEL, ELECTRE or fuzzy ELECTRE, ISM, and SOWIA were applied in analyzing success factors [109], barriers [110], enablers [111], and strategy decisions [112] in SSCM or green supply chain management.

ANP is mostly integrated with quality function deployment (QFD) to analyze supplier selection and environmental sustainability, and for designing sustainable supply chains [113–116]. Other integrations of ANP with VIKOR [117] and grey rational analysis (GRA) [118] were applied in green/sustainable supplier evaluation.

BWM or fuzzy BWM is mostly integrated with VIKOR or fuzzy VIKOR for evaluating transportation service providers and outsourcing partners based on sustainable criteria [119,120]. Other applications of integrated BWM or fuzzy BWM include evaluating dimensions of human resources in green supply chains using BWM-DEMATEL [121], selecting sustainable suppliers in manufacturing supply chains by integrating BWM and an alternative queuing method (AQM) [122] and selecting sustainable suppliers using integrated BWM and combined compromise solution [123].

TOPSIS or Fuzzy TOPSIS is mostly integrated with VIKOR or fuzzy VIKOR, fuzzy preference programming (FPP), Rough set, and criteria importance through intercriteria correlation (CRITIC). TOPSIS-VIKOR (and their fuzziness) integrated methods [124,125] were applied in selecting third-party reverse logistics service providers and classifying rural areas based on social sustainability criteria. TOPSIS-VIKOR-GRA (integrating three methods) was applied in analyzing locations for remanufacturing plants based on multiple criteria [126]. Other applications of integrated TOPSIS or fuzzy TOPSIS include evaluating supply chain practices by integrating TOPSIS and Rough set [127], analyzing risk factors in SSCM using TOPSIS-CRITIC [128], and selecting sustainable suppliers using TOPSIS-FPP [129].

Other integrated methods, such as ELECTRE with VIKOR, were applied in environmental performance evaluation [130]; DEMATEL with MABAC was applied in sustainable freight transport systems [131]; RSAW with MABAC applied in sustainable supplier selection [132]; factor relationship (FARE) with MABAC for selecting third-party logistics provider [133]; step-wise weight assessment ratio analysis (SWARA) and fuzzy complex proportional assessment of alternatives (COPRAS) were used for analyzing risks and solutions in sustainable manufacturing supply chains [134]; and fuzzy entropy and fuzzy multi-attribute utility were applied for sustainable performance measure in supply chain [135].

In summary, most of the integrated MCDM methods in SSCM were used for evaluating or analyzing suppliers, service providers, barriers, enablers, success factors, and evaluating performance. A summary of different integrated MCDM methods applied in SSCM is presented in Table 7.

Table 7. Summary of integrated MCDM methods applied in SSCM.

Method Name	Integrated with														References	Area of Application
	DEMATEL/ Fuzzy/Grey DEMATEL	ELECTRE/ Fuzzy ELECTRE	ISM	TOPSIS/ Fuzzy TOPSIS	VIKOR/ Fuzzy VIKOR	SOWIA	GRA	QFD	Rough Set	CRITIC	FPP	MABAAC	AQM	TODIM		
AHP/Fuzzy AHP	√														[109]	Evaluating success factors of green supply chain
		√													[110]	Analyzing barriers to green supply chain management
			√												[111]	Analyzing enablers in SSCM
				√											[100–105,123,136,137]	Selecting sustainable/green supplier, prioritizing solutions for reverse logistics, prioritizing the responses to manage risks, third party logistics (3PL) selection, and analyzing key factors for supply chain sustainability
					√										[106–108]	Evaluating green supply chain management practices, and sustainable supplier selection
ANP/Fuzzy ANP				√		√									[112]	Analyzing supply chain strategy decisions
							√								[118]	Green supplier selection
								√							[113–116]	Analyzing environmental sustainability, designing a sustainable maritime supply chain, global logistics service provider, and sustainable supplier selection

Table 7. *Cont.*

Method Name	Integrated with														References	Area of Application
	DEMATEL/ Fuzzy/Grey DEMATEL	ELECTRE/ Fuzzy ELECTRE	ISM	TOPSIS/ Fuzzy TOPSIS	VIKOR/ Fuzzy VIKOR	SOWIA	GRA	QFD	Rough Set	CRITIC	FPP	MABAAC	AQM	TODIM		
BWM/Fuzzy BWM					√										[117]	Sustainable supplier evaluation
	√				√										[138]	Sustainable supplier selection
	√		√												[139]	Investigating agri-produce sustainable supply chains
	√			√											[140]	Sustainable supplier selection
	√														[121,141]	Evaluating human resource dimensions of green supply chain
					√										[119,120]	Evaluating sustainable transportation service providers, sustainable outsourcing partner selection
													√		[122]	Sustainable supplier selection in watch manufacturing
					√									√	[142]	Evaluating measurement for sustainable supply chain finance
TOPSIS/Fuzzy TOPSIS					√										[124,125,143]	Third-party reverse logistics provider selection, classification of rural areas based on social sustainability indicators
					√		√								[126]	Location for remanufacturing plant
									√						[127]	Green supply chain practices evaluation

Table 7. *Cont.*

Method Name	Integrated with														References	Area of Application
	DEMATEL/ Fuzzy/Grey DEMATEL	ELECTRE/ Fuzzy ELECTRE	ISM	TOPSIS/ Fuzzy TOPSIS	VIKOR/ Fuzzy VIKOR	SOWIA	GRA	QFD	Rough Set	CRITIC	FPP	MABAAC	AQM	TODIM		
										√					[128,144]	Evaluation of sustainable supply chain risk management
											√				[129]	Sustainable supplier selection
							√								[145]	Sustainable supplier selection for building materials
ELECTRE					√										[130]	Supply chain environmental performance evaluation
DEMATEL												√			[131]	Sustainable freight transport system evaluation

4. Bibliometric Analysis on MCDM Methods Applied to SSCM

This section presents a bibliometric analysis of MCDM methods applied to SSCM. From the finalized literature search (see Section 2), we can note a lack of reviews, with only five studies (about 4.5%) reviewing particular topics such as: (i) green supplier evaluation and selection [22]; (ii) modelling approaches in SSCM [146]; (iii) MCDM approaches in green supply chains [45]; (iv) hybrid MCDM for general sustainability [147]; and (v) sustainable supplier selection [148]. In total, 106 contributing articles (about 95.5%) applied MCDM methods to better understand SSCM issues; this means, Figure 2 presents the keyword network obtained from the keywords used in each of the contributing articles. It is evident that supply chain management, decision-making, sustainable development, sustainability, and green supply chains, environmental management, and sustainable supply chains are the top keywords. Figures 3 and 4 present the citation networks of selected contributing papers based on source journals and authors, respectively. The Journal of Cleaner Production and International Journal of Production Economics are two leading cited journals. Govindan, K., and Mangla, S.K. are two leading cited authors.

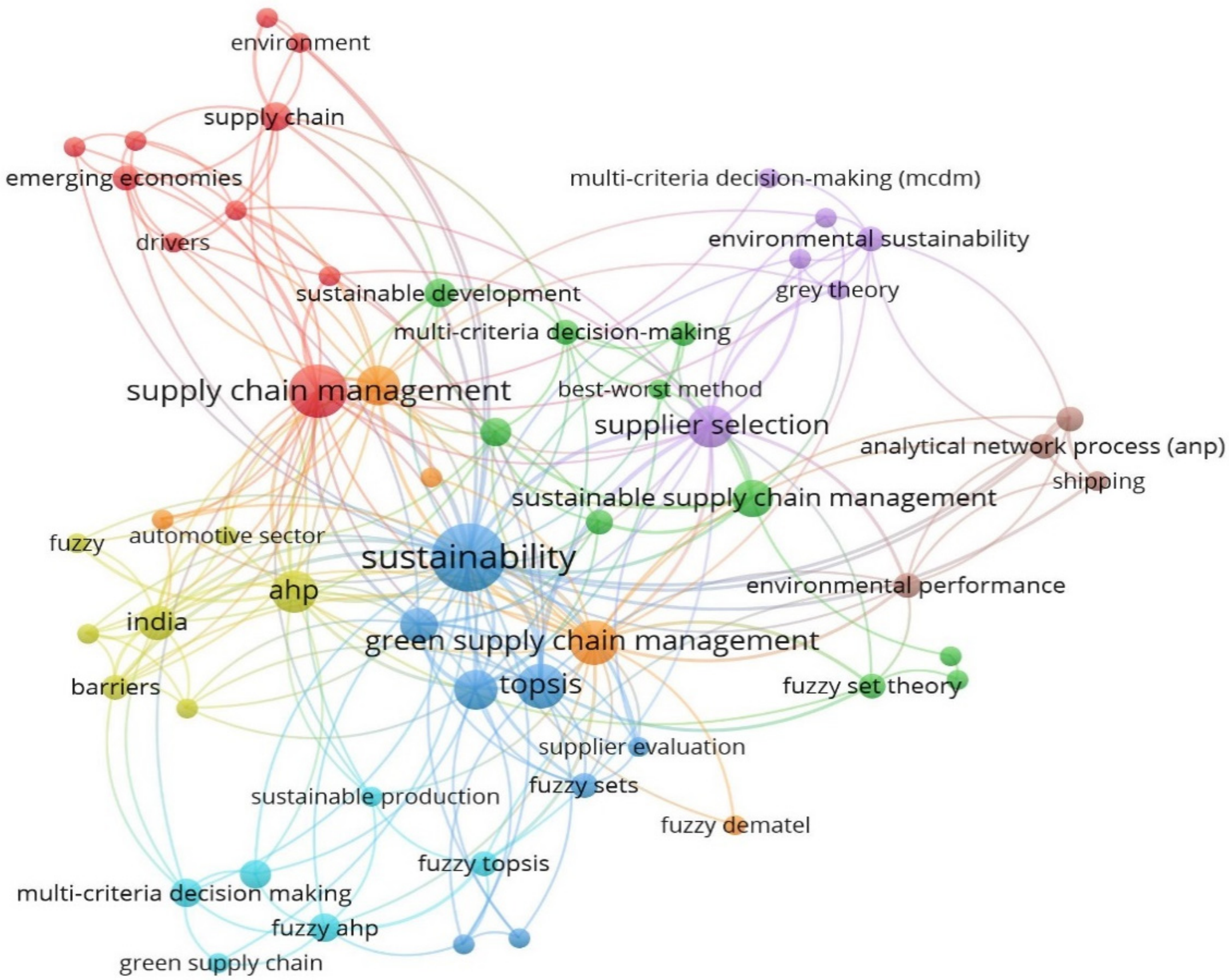

Figure 2. Co-occurrence of keywords used in the selected contributing papers (source: VOSviewer).

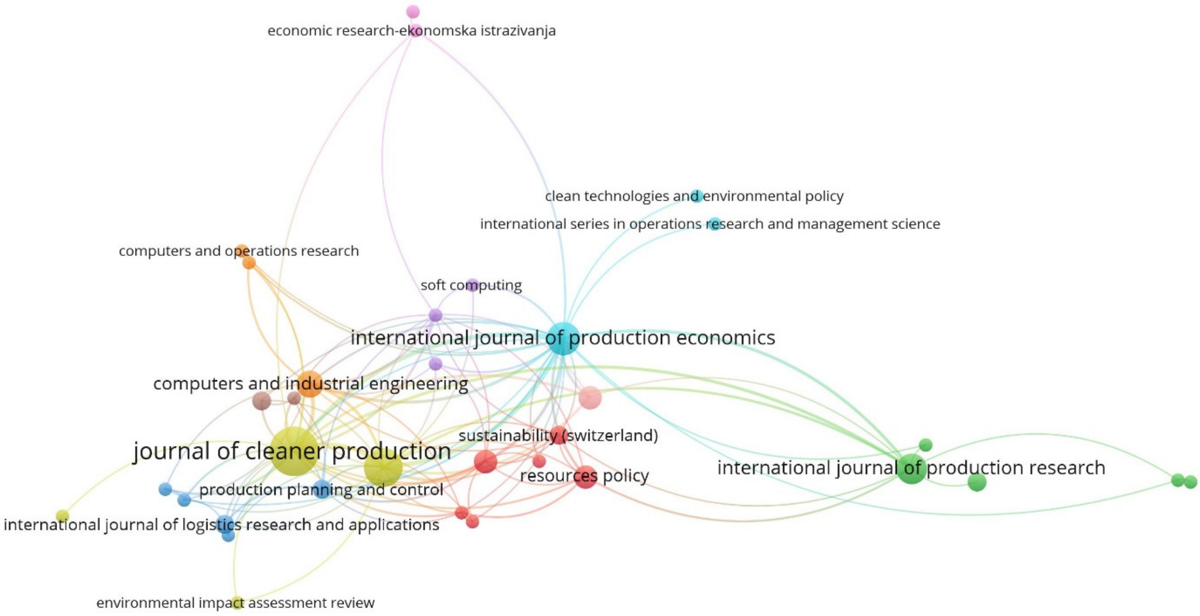

Figure 3. Co-occurrence of citation network from the source journals of the selected articles (source: VOSviewer).

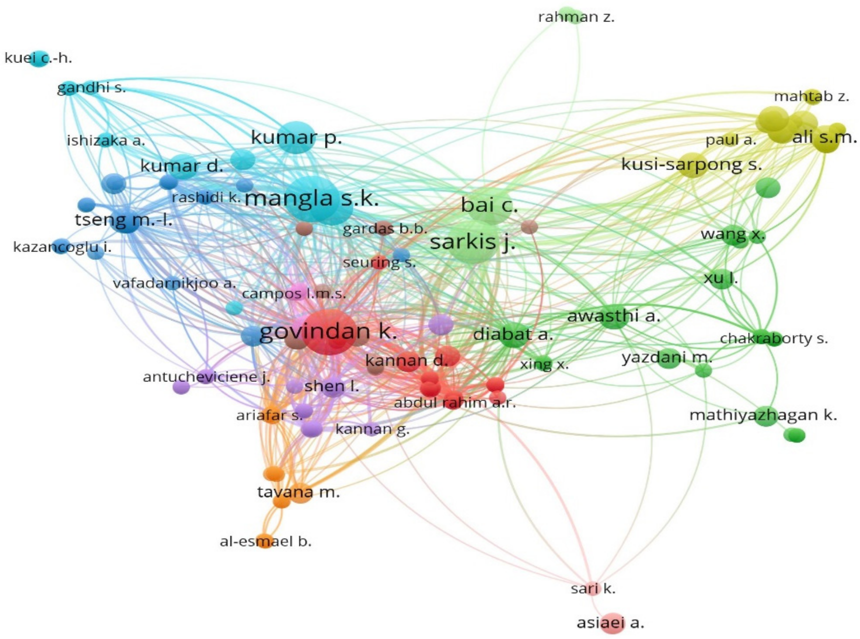

Figure 4. Co-occurrence of citation network from the authors of the selected articles (source: VOSviewer).

The number of contributing articles published from 2010 to 2020 is shown in Figure 5. From 2015, researchers started publishing an increasing number of articles applying MCDM methods in SSCM. The Journal of Cleaner Production (Publisher: Elsevier, Amsterdam, The Netherlands) has published the highest number of articles (18 articles), followed by Resource, Conservation and Recycling (Publisher: Elsevier), the International Journal of Production Economics (Publisher: Elsevier), Sustainability (Publisher: MDPI, Basel, Switzerland), and the International Journal of Production Research (Publisher: Taylor and Francis, Oxfordshire, UK). The number of articles published in each of these journals is presented in Figure 6.

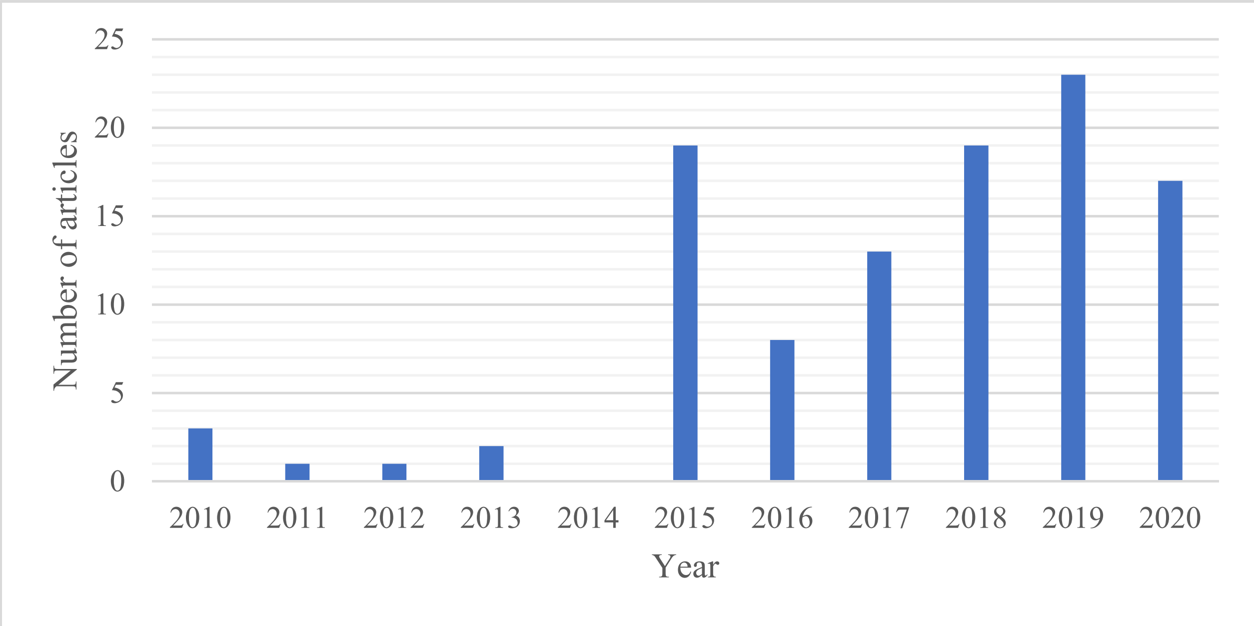

Figure 5. Number of articles published from 2010 to 2020.

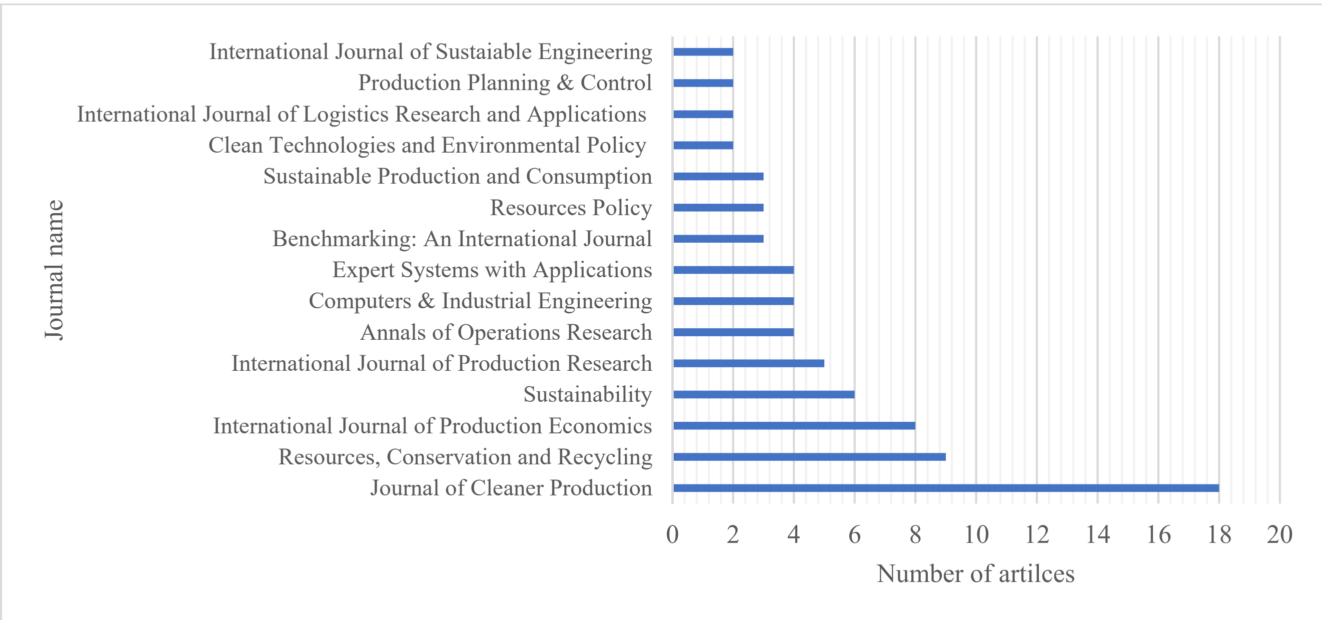

Figure 6. Number of articles published in different journals (N $\geq$ 2).

Figure 7 presents the authors who published the most articles in the area of MCDM for SSCM. Both Govindan, K. and Mangla, S.K. are at the top of the list, with 10 published articles, followed by Sarkis, J., Bai, C., and Luthra, S. with 9, 7, and 6 articles, respectively.

The affiliation by authors' institutions is also presented in Figure 8. Syddansk Universitet (University of Southern Denmark) is at the top of the list with 12 articles, followed by the Indian Institute of Technology Roorkee (India) and Dalian University of Technology (China). The affiliated countries which published most articles are presented in Figure 9. India is at the top of the list with 27, followed by China, the United States, and Denmark with 19, 15, and 12 articles, respectively.

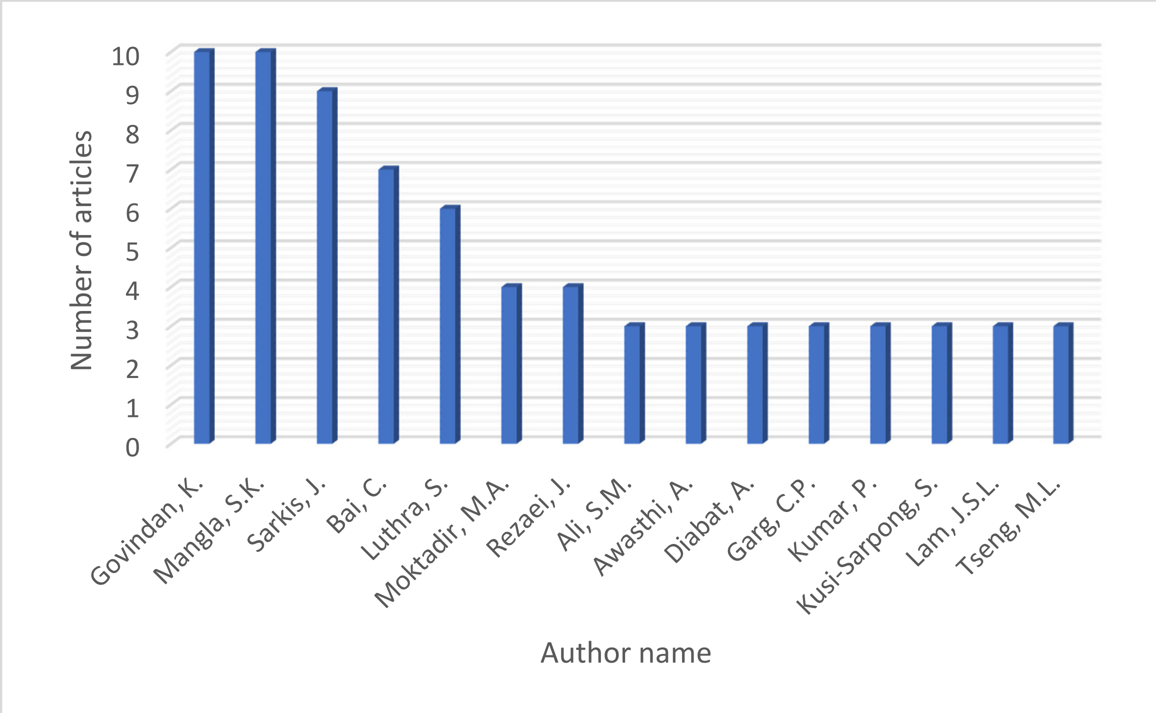

Figure 7. Articles published by different authors (N ≥ 3).

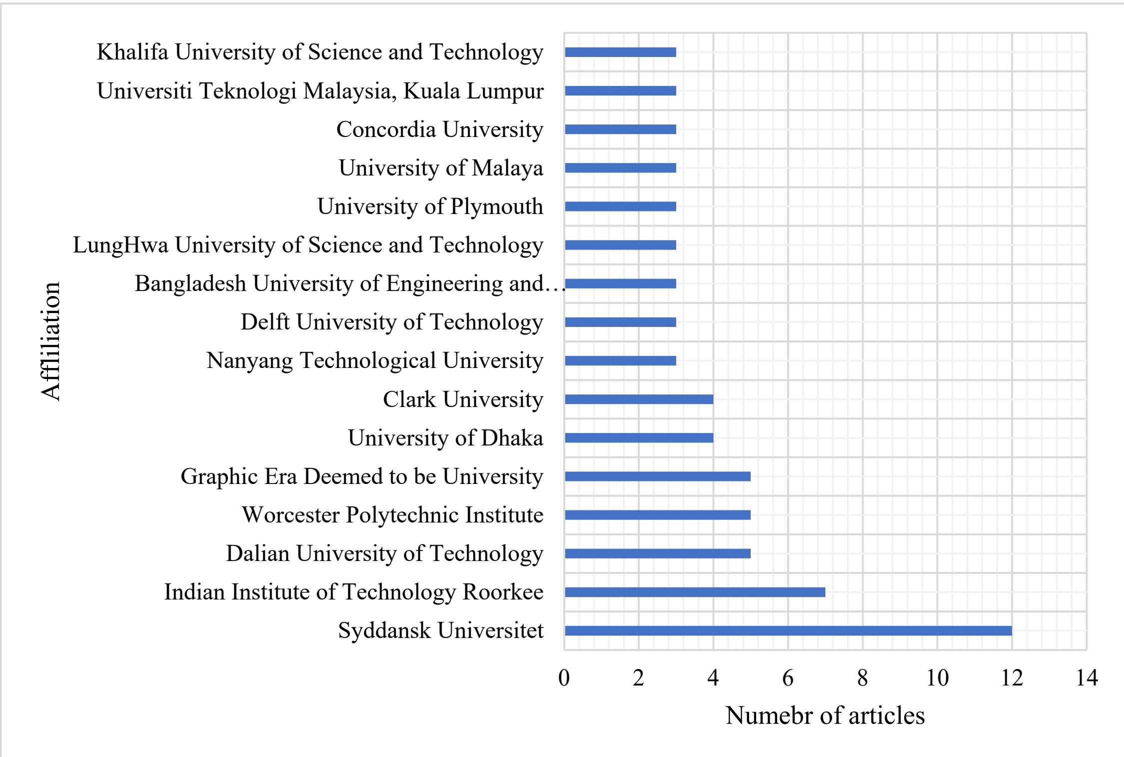

Figure 8. Most affiliated institutions (N ≥ 3).

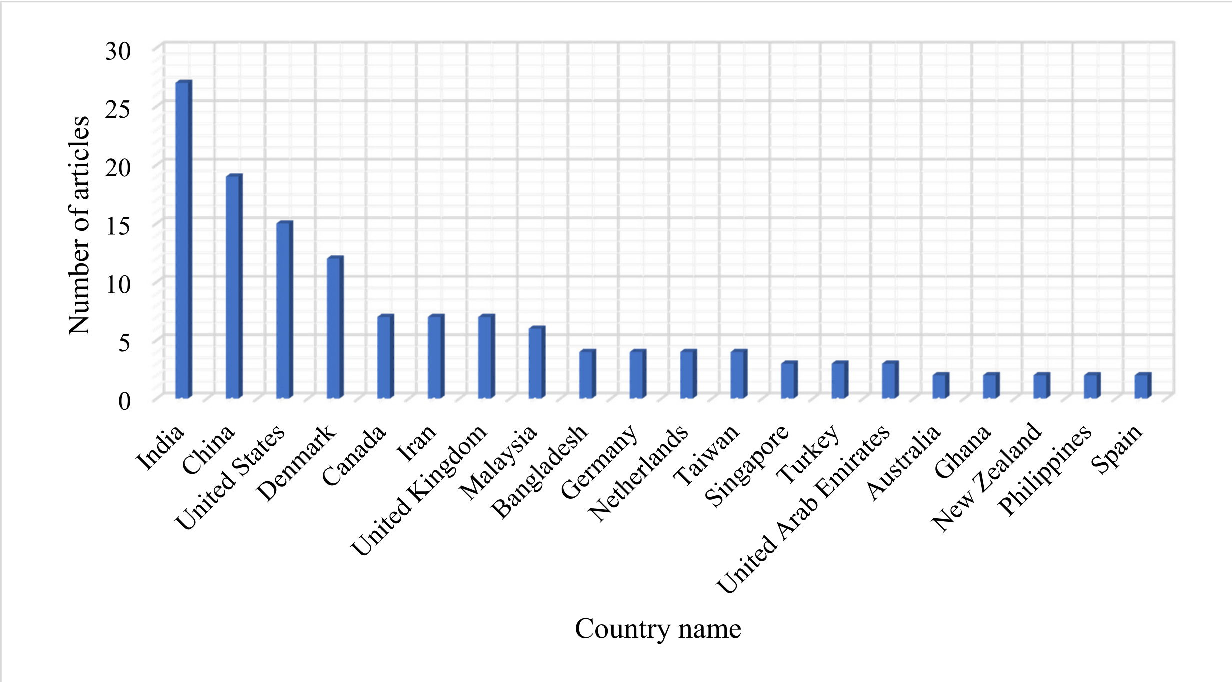

Figure 9. Source countries for publications (N ≥ 3).

Fifty-nine articles (about 56%) used individual MCDM methods for problem analysis, while the remaining 47 articles (about 44%) used integrated (two or more methods) methods. Figure 10 shows that integrated or hybrid MCDM methods were mostly applied in SSCM. Within individual MCDM methods: DEMATEL, AHP, and TOPSIS are the top three methods applied in SSCM literature.

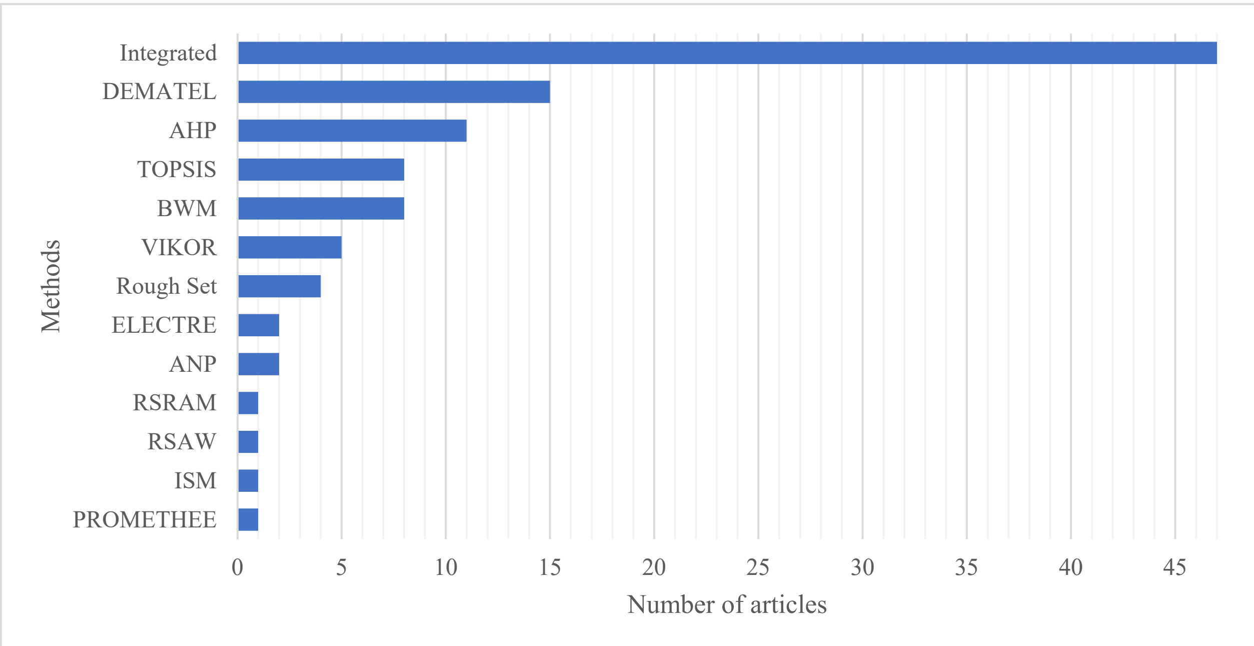

Figure 10. Distribution of contributing articles under different MCDM methods.

5. Summary of the Review and Research Gaps

The following key points present a summary of the extensive literature review and its findings.

Firstly, Section 3 described the application of different MCDM methods in SSCM, showing most studies applied an individual or two integrated MCDM methods, with a lack of studies integrating three or more MCDM methods for analyzing different dimensions of sustainability in supply chain management. Only a few studies integrated three methods (see Table 7); for example, AHP integrated with SOWIA and TOPSIS [112], TOPSIS integrated with GRA and VIKOR [126], and ANP integrated with DEMATEL and TOPSIS [140].

Secondly, in SSCM, most of the studies contributed to advancing the methodology by integrating different MCDM methods. MCDM methods were integrated within AHP, ANP, BWM, TOPSIS, ELECTRE, DEMATEL, ISM, VIKOR, SOWIA, GRA, QFD, Rough set, CRTIC, FPP, MABAAC, and AQM along with their fuzzy sets (see Table 7). It was observed that both single and integrated MCDM methods were applied, but there is a lack of studies which integrate MCDM methods with other operations research methods to improve the accuracy in decision making. For example, the integration of MCDM methods with mathematical modelling and optimization could help to obtain optimal decisions in SSCM.

Thirdly, most of the research considered social sustainability, environmental sustainability, and/or triple bottom line in the scope of their studies. Tables 6 and 7 presented the areas of application of individual and integrated MCDM methods. The application areas of MCDM methods were limited to different aspects of sustainability. Most of the studies integrated MCDM methods in models for green supply chains (see Table 7). Most of the studies on individual MCDM methods applied them in evaluating factors, barriers, challenges, drivers, enablers, and suppliers in different SSCM areas (see Tables 3–6).

Fourthly, most SSCM researchers limit their studies to analyzing factors, barriers, challenges, drivers, enablers, and suppliers (see Section 3). There are fewer studies that integrate sustainable strategies and performance with barriers/challenges and drivers/enablers using integrated MCDM methods.

Fifthly, from Section 3, most of the studies explained their results using individual or integrated MCDM methods. There are limited studies which compared the results between different MCDM methods. For example, there is only one study comparing fuzzy DEA and fuzzy TOPIS in sustainable supplier selection [76].

Finally, earlier literature largely overlooked small and medium enterprises (SMEs) and the emerging economy as study contexts for MCDM applied in SSCM. A small number of articles considered SMEs as their context, analyzing drivers for integrated lean-green manufacturing [149], innovation ability for supplier selection [150], determinants for cloud computing adoption [151], and entrepreneurship policies [152].

6. Conclusions and Future Research Directions

This paper presented a literature review on MCDM methods applied in different dimensions of SSCM. Although there have been many papers published in the area of SSCM, there are very few review papers published. A systematic literature analysis and review to identify different domains of supply chain sustainability and applications of different MCDM methods was lacking. Contributing to the academic discussion on this topic, this is the first effort to analyze both individual and integrated MCDM methods applied in different areas of supply chain sustainability.

Findings revealed the following important aspects of previous studies.

i. Most of the research applied either individual or integrated methods of two MCDM techniques. All of the integrated MCDM methods applied were carried out in recent years, i.e., after 2015.
ii. Since 2015, environmental and social sustainability have been garnering the attention of researchers (see Tables 1 and 2). In recent years, several MCDM methods, such

as ISM-TOPSIS [31], grey BWM-grey TODIM [18], and BWM [4,33] were applied in social sustainability while DEMATEL [25], fuzzy DEMATEL [23], fuzzy VIKOR [26], and TOPSIS [24] were applied in environmental sustainability areas.

iii. Most of the individual methods analyzed barriers, drivers, enablers, challenges, success factors, forces, and criteria in SSCM and green supply chains (see Tables 3–6).

iv. Integrated MCDM methods were applied in evaluating and analyzing sustainable suppliers and different alternatives in SSCM (see Table 7).

v. There are very few studies which integrated three or more MCDM methods and applied them in SSCM [112,126].

In conclusion, we would like to acknowledge some study limitations and propose some future research directions. At present, the study has been limited to three databases: Scopus (primary), Web of Science, and Google Scholar. Therefore, potential additional sources of information and knowledge such as conference proceedings or books not indexed in the three databases have not been included. Further, the research was limited to documents published in English exclusively, therefore potentially excluding local contributions redacted in other languages. Additionally, as there is limited research on the integration of three or more MCDM methods, it would be interesting to develop new integrated methodologies with three or more MCDM methods for decision-making in SSCM. Moreover, the fuzzy BWM method is a newly developed tool that can optimize a decision based on multiple criteria [153]. Currently, few studies apply BWM and fuzzy BWM in SSCM [4,13,79,119–122]. In the future, BWM and Fuzzy BWM could be applied widely in SSCM. In addition, the literature is lacking contributions able to integrate barriers and challenges with strategies and analyzes using an integrated MCDM method. In this regard, further research could explore the following research question: 'How can sustainable strategies be analyzed along with barriers and challenges to extend the current studies using MCDM methods?'

In the current literature, there is no study that correlated success factors, enablers, and drivers with sustainability performance analyzed using integrated MCDM methods. Hence, future research could address how barriers, challenges, drivers, enablers, and/or success factors can be linked with strategies and performance in one study, so as to develop a unique research framework using MCDM methods. In addition, it would be significantly new to the literature to integrate different aspects of SSCM with other supply chain areas such as risk management, lean supply chains, quality management, and supply chain network design. For example, the recent coronavirus (COVID-19) pandemic has impacted supply chains significantly [154]. It would be worth investigating the impacts of large-scale disruptions such as the COVID-19 pandemic in supply chain sustainability. Different MCDM methods can be applied to investigate different aspects of impacts on sustainable practices.

Our review pointed out that though service supply is an important area, research on applications of MCDM methods in sustainable service supply chains is very limited [130]. Different dimensions of sustainability in service supply chain management could be explored using MCDM methods.

In the future, another research direction could be integrating MCDM methods with operations research techniques, such as mathematical modelling and optimization, to make decisions more accurate. For example, integration of MCDM methods with mathematical modelling and optimization techniques could help to take optimal and accurate decision making in SSCM. Moreover, as there is only one study comparing the results of MCDM methods [76], it is necessary to develop benchmark problems and compare the results obtained from different MCDM methods used in SSCM. It would also be interesting to compare the sustainability results between supply chains from developed and emerging economies.

Finally, as SMEs and emerging economies play significant roles in local and global supply chains [155,156], it is important to analyze the sustainability of supply chains of SMEs and emerging economies. Usually, SMEs and emerging economies have fewer resources to deal with supply chain sustainability challenges. Hence, it is essential to analyze their supply chain sustainability and develop policies for improving sustainability practices. However, in the literature of MCDM methods and SSCM, SMEs and emerging economies were widely ignored. It would be interesting to develop decision-making tools using MCDM methods for analyzing different aspects of supply chain sustainability in the context of SMEs and emerging economies.

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