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Review

A Review of Green Supplier Evaluation and Selection Issues Using MCDM, MP and AI Models

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Abstract: For any industry to improve and expand, the proper evaluation and selection of suppliers is essential. In order to establish whether a supplier is appropriate for working with a company, a system for selecting green suppliers is required. A variety of Decision-Making (DM) models have been created by researchers to address the problems associated with evaluating and choosing green suppliers. In order to address the Green Supplier Evaluation and Selection (GSES) challenge, we did a thorough investigation of ten works of literature, in order to find out which approach is the most widely used and which is more efficient. This study primarily focuses on the findings of ten reviews that examined 1098 research publications from academic journals between 1990 and 2020. 271 DM models examined that were broken down into 170 individual models and 101 combination models, our analysis only looked at the single models. The method of Analytic Hierarchy Process (AHP) is the dominant model used by 160 articles, 122 studies used Data Envelopment Analysis (DEA), and finally 101 research works that utilized the Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) model. In addition, we found that the biggest percentage "62%" of studied articles used multi-criteria decision-making (MCDM) models. As a result, the most widely utilized Decision Making models to address the evaluation and selection of green supplier were found to be AHP, DEA, and TOPSIS.

Keywords: green supplier; supplier relationship management; supplier selection; supplier evaluation; decision-making; multi-criteria decision-making; mathematical programming models; artificial intelligence models

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1. Introduction

The supplier relationship management identifies new suppliers and fulfills tasks with key suppliers while lowering costs, assuring predictable and repeatable purchases, sharing buyer experience, and maximizing partnerships with suppliers. By offering an integrated and complete set of management tools for manufacturer-supplier interaction, it focuses on enhancing the value of a manufacturer's supplier base [1]. For the growth and improvement of any industry, proper supplier evaluation and selection are essential [2,3]. The primary objective of [4] is to select the most suitable supplier who can provide the customer with high-quality goods or services for a fair price, in the desired quantity, and by the deadline. A good supplier selection process is essential for efficient purchasing and manufacturing. Supplier evaluation and selection is a difficult decision for two reasons. First, suppliers can be evaluated based on several criteria. Second, each provider has different disciplines, so they have different standards. The Supply Chain Management (SCM) concept, on the other hand, has been used to define logistics activities both inside and outside of an organization, as well as the planning and control of commodities, information and materials flows [5]. Additionally, it seeks to improve management capabilities and practices, increase profitability through efficiency, and preserve customer satisfaction in order to provide value to the global supply system [6,7]

In recent years, the development of useful Green Supplier Evaluation and Selection (GSES) methods has increased [8]. Supplier selection thus comes under the category of decision-making issues (DM). Priorities must be established by businesses before selecting the best provider for their work environment and sector. Multi-Criteria Decision-Making (MCDM) models, mathematical programming (MP) models, and artificial intelligence (AI) models are the most DM techniques that have been developed by various academics, delivering a workable and efficient answer to the supplier selection issue.

Different decision-making models are used to support GSES problems. This mainly involves basic models such as simple Weighted Sum Method from model (WSM) to more complex models such as Analytic Hierarchy Process (AHP) and data wrapping Analysis (DEA), Analytical Network Process (ANP), ELECTRE (Elimination and choice Expressing the Reality), Fuzzy Approach, PROMETHEE (Prioritizing organization method for enrichment evaluation), Artificial Neural Network based approach (ANN) and Simple multi-attribute evaluation method (SMART). Several researchers have conducted literature reviews on this subject [2,8–16]. However, the purpose of this study is to provide a thorough analysis of 10 literature reviews on green supplier evaluation and selection models. Those reviews are choosing based on four criteria that is: the data based quality "WOS and SCOPUS", the time horizon between 1990 and 2020, the number of studies articles: focusing on the biggest number of articles and the topic that would help us achieve our objectives to identify the MCDM, MP and AI models using to solve GSES problems. 1098 articles in all, published between 1990 and 2020, were located. Therefore, our contribution is analyses the result of all those 1098 articles founded on the 10 literature reviews, and then find which are the most popular MCDM, MP and AI models using to solve GSES problems. The structure of this article is as follows: Section 2 presents the context of this work. Section 3 presents the findings of the evaluated research, while Section 4 presents the discussion and analysis of the 1098 recognized publications. Finally, Section 5 presents our study's conclusion.

2. Research Method

2.1. Research Questions

The systematic literature review is the method of assessing, examining, and analyzing all available literature pertaining to a particular research issue, subject area, or interesting phenomenon. This is a useful method for synthesizing previous research, identifying gaps in the literature, and paving the way for new research directions. In this review, we study the following research questions:

- RQ1: What are the relevant literature reviews that worked on the DM models to solve the issues of assessment and choice of green supplier between 1990 and 2020?
- RQ2: What are the most often utilized DM models in the literature to address the problems for evaluation and selection the green supplier?

2.2. Research Process of the Systematic Literature Review

Our research process began by first using a two-step keyword-driven database to find potentially important sources of information, and then collecting primary surveys to manually select search results. During this phase, Scopus and WOS, especially some major databases such as Elsevier, Springer, Emerald, Taylor & Francis, were used. With the exception of four articles in French, most of the articles on this subject are in English. Our research is based on articles published in the last 30 years from 1990 to 2020.

The survey method consisted of four phases a shown in Figure 1. Each of these phases consisted of two phases, initially searching a database using keywords to identify possibly relevant sources, followed by manually filtering the search results. The three writers carried out the manual filtering procedure independently. The first and second writers used qualitative coding to retrieve data from the primary studies they had chosen. After collecting and analyzing the coding of the primary documents, the results were obtained.

The third author coached and audited the entire procedure. The investigation process consisted of four phases, as shown in Figure 1.

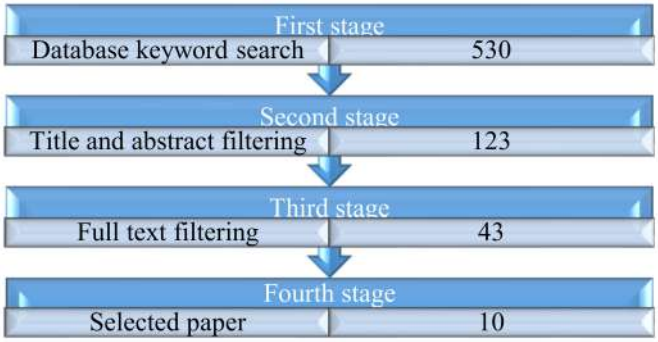

Figure 1. The systematic literature review protocol.

2.2.1. First Stage: Database Keyword Search

Several preliminary studies were conducted before proceeding to identify the primary study. Preliminary search had the ability to create and analyze various search terms. In addition, we used search to define a collection of related articles that the actual search must match. First, we used keyword-based searches as widely as possible to identify potentially relevant sources (Table 1). Based on this preliminary study, 530 papers were selected.

Table 1. Keywords used in english.

Keywords Used in English
Supplier selection and evaluation models
DM models to solve GSES problems
Green supplier evaluation and selection problems
MCDM models for GSES
MP method for solving GSES issues
GSES and AI thechnique

2.2.2. Second Stage: Title and Abstract Filtering

The second stage was based on the titles and abstract filtering of the 530 papers produced in the final stage. The two authors have grouped the titles and summaries of these papers into three categories: inclusion, exclusion, and uncertainty. According to the objectives of our paper. Agreed to exclude 407 and include 123. We selected 123 papers in this phase.

2.2.3. Third Stage: Full Text Filtering

Full-text filtering was performed by analyzing the text of each 123 articles in order to response to our research questions. Articles were only excluded at this point if both researchers determined that they were clearly unimportant, including the uncertainties of full-text filtering. For this reason, 43 articles were selected for full-text analysis.

2.2.4. Fourth Stage: Maintained Papers

In the final phase, we evaluated all 43 complete filter papers, but performed only 10 literature searches that were useful in processing the topic.

3. Background

3.1. Supplier Relationship Management (SRM)

3.1.1. Generality of SRM

According to [17–20] SRM system's objective is a strategic alliance with suppliers, which enables a business to produce items effectively and compete with other businesses

by developing new products. As a result, problems including designing a procurement strategy, selecting suppliers, coordinating, and managing suppliers have received a lot of attention.

The authors [1] SRM was described as a method for selecting new suppliers and maintaining existing ones while reducing costs, guaranteeing predictable and repeatable purchases, exchanging buyer insights, and maximizing supplier relationships. It is concentrated on giving an integrated and comprehensive set of management tools for manufacturer-supplier interactions, hence increasing the value of a manufacturer's supply base.

According to [21], Supplier relationship management is a management style that encourages businesses to form and maintain a variety of relationships with different types of suppliers based on their needs, with a focus on establishing long-term partnerships with third-party vendors in order to reduce commercial costs, improve purchasing efficiency, and gain a competitive advantage.

3.1.2. The Issues Related to SRM

Based on the literature there are several issues that should be addressed in order to manage the supplier relationship namely shaping purchasing strategies, supplier selection, collaboration, supplier management and integrated approaches, etc. However, the most important issue is suppliers' selection and evaluation. According to [20], since raw material costs make up the majority of the price of a finished product, supplier selection is important for businesses. Choosing the proper suppliers lowers purchasing costs while also increasing corporate competitiveness. According to [22] one of the challenges is determining how to choose good suppliers. The Supplier relationship management (SRM) entails categorizing suppliers, selecting suppliers, and creating and maintaining relationships. The selection of suppliers is the most important among them [21]. The authors [16] consider that one of the most significant responsibilities in SRM is supplier selection, because working with the right suppliers allows the company to produce a sufficient amount of high-quality goods.

Supplier Selection and Evaluation

For efficient purchasing and manufacturing, a good supplier selection procedure is critical. The evaluation and selection of a supplier is a difficult decision to make for two reasons. For starters, suppliers might be assessed on multiple criteria. Second, every supplier has a particular specialization, necessitating the use of a different standard.

Furthermore, there are two problems that come up throughout the supplier selection process [23]. The first is the single supply dilemma, where the objective is to meet all of the needs of the buyer from a single source. The manager must pick the best provider in this case. The second problem is a multiple supplier conundrum, in which no single source can satisfy all of the buyer's demands. According to [24], the management must first choose a number of suppliers before distributing supplies to them. Due to this, the following two criteria for selecting a vendor must be met [20]:

- Determination of the criteria to be used in the evaluation of Suppliers.
- The use of vendor evaluation methodologies in the decision-making process to ensure proper vendor selection.

The primary goals of the supplier selection process include reducing purchasing risk, increasing total value to the buyer, and building enduring partnerships between suppliers and clients. In the distribution chain of supply chains, coordination between a manufacturer and suppliers is frequently a challenging and crucial stage. Various criteria are taken into consideration for solving supplier selection and assessment problems, and several supplier selection models have been developed based on very basic notions of the decision-making process [25].

Other Issues

- Shaping purchasing strategies

There are two different types of purchasing strategies. One is the competitive method, which posits that purchasers may receive items at the lowest cost through competing with suppliers. Second is the cooperative strategy, in which the provider and buyer develop a strategic partnership and work together to attain a long-term goal [26].

- Collaboration

There are two approaches to analyse studies on supplier-buyer collaboration: by concentrating on the collaboration strategy or by putting the collaboration strategy into practice using an SRM system.

- Supplier management

A supplier evaluation entails determining a supplier's worth by assessing their capacity and performance. The evaluation's findings are utilized to choose a supplier and segment them for differentiated supplier development [27].

- Integrated approaches

There are two different sorts of integrated approaches when it comes to the topic of purchasing integration in the context of production and business strategy. The first category is process integration, which refers to a group of techniques for successfully integrating manufacturers, suppliers, warehouses, and retail establishments. Solving method integration is under the second type.

3.2. Green Supplier Relationship Management (GSRM)

The administration and planning of all activities is known as supply chain management (SCM) from sourcing and purchasing to manufacturing and distribution [18]. SCM seeks to enhance the global logistics chain through the use of management tools and processes, value creation, productivity growth through efficiency, and customer satisfaction [28,29].

The GSCM is a method for incorporating environmental concerns into the supply chain management process, beginning with product design and continuing through product selection and sourcing, production, final product distribution, and life cycle management [28,30]. Greater collaboration between working firms is necessary to make the supply chain efficient and guarantee sustainable productivity. Environmental, economic, and social goals must be incorporated into performance standards for individual businesses as well as for the administration of the global supply chain. [18,31–33]. Cost savings and supplier participation in a decision-making process that promotes environmental innovation are two benefits of greening a SC [34]. Waste reduction, material substitution using ecologically acceptable raw material sourcing, and hazardous waste minimization are the three focuses of green procurement. To achieve such goals, green supplier relationship management (GSRM) is essential. As a result, GSRM is described as evaluating suppliers' environmental performance more than ever before to make sure that the products and machinery they provide are manufactured with environmentally friendly materials and practices [35].

Despite the fact that Ref. [36] defined GSRM as a fundamental competence, the study of SRM's role in achieving sustainability is still in its early stages [37]. It is particularly ambiguous how businesses handle inherent supplier risk in the context of sustainability [38] or how they link their purchasing and supply management operations with the company's corporate sustainability, policy if one exists.

The importance of supplier evaluation and selection is underscored by the fact that it has a significant impact on business operations. Consequently, the ability to apply green concepts has become an essential part of a supplier's total success. Therefore, while being a relatively new research topic, green supplier selection and evaluation has grown quickly. It develops and researches supplier evaluation and selection methods that take environmental considerations into account [39]. Suppliers are essential for a firm to achieve its sustainability objectives as upstream supply chain partners. Choosing the most competent green supplier in a supply chain is therefore a crucial strategic choice

for an organization's ability to compete globally various variables and criteria must be addressed in the green supplier selection process in order to achieve high quality and environmental requirements. Therefore, selecting sustainable suppliers might be seen as a challenge decision-making issue aimed at ensuring greater performance from an organization's suppliers [8].

3.3. Generality of DM

A decision-making model, in general, is a technique that aids managers and decision-makers in selecting the best choices for their business. They provide a number of methods for analysing a situation and figuring out potential solutions. According to [12], these methods can be divided into three groups: mathematical programming (MP) models, AI models, and multicriteria decision-making (MCDM) models.

3.3.1. MCDM Models

MCDM model is a branch of operations research that explicitly assesses numerous competing criteria when making decisions.

Analytic Hierarchy Process (AHP)

The authors [40] used the fashion sector as an example, a model based on AHP was proposed to handle the vendor evaluation and selection problem. The focus of the essay was on the garment industry's popular fast reaction (reactive) technique. The criteria were divided into two groups: performance criteria and criteria based on the company's strategy, according to the researchers. In order to have a strategic match with the supplier, twenty-nine criteria were chosen, of which nineteen belonged to the performance group and the other criteria were based on the company's strategy.

The AHP was employed in the study by [41] to ascertain the relative ranking of suppliers. It requires decision makers to utilize a ratio scale to compare all pairings of criteria and suppliers. The paper outlined a three-step process for calculating vendor performance scores and choosing the best provider. Using data from a multinational transformer firm, the researchers were able to validate the proposed model. Authors [42] evaluate and select logistics outsourcing service suppliers using the AHP approach. An actual case was used. An analytical hierarchy process (AHP)—based supplier selection decision support approach was put forth by [43], which used the automobile industry in Pakistan as a case study.

Technique for Order Performance by Similarity to Ideal Solution (TOPSIS)

The Ref. [44] chose an Entropy-TOPSIS-F method to aid in the decision-making process in selecting a green supplier for the furniture sector. Several environmental factors were discovered and seven were defined for use in the analysis based on the relevant literature and the opinions of 32 furniture specialists. Ref. [45] Employed fuzzy TOPSIS to get a supplier's total performance score. To exemplify the efficacy of the proposed method, a numerical example is provided. The Ref. [46] proposes an intuitionistic fuzzy TOPSIS technique for selecting the best sustainable supplier for an automobile spare parts manufacturer, which includes nine criterion and thirty sub-criteria. A real-world case study validates the suggested approach, which gives an accurate sustainable rating of providers and a trustworthy solution for sustainable sourcing decisions. According to [47] Decision-makers and criteria can be easily evaluated using the Intuitionistic Fuzzy TOPSIS approach. The hybrid method developed by fusing the intuitionistic fuzzy set with TOPSIS is particularly good at selecting the supplier who best fits the requirements set forth by the order of significance.

Analytic Network Process (ANP)

The paper [48] used the analytic network process (ANP) for evaluating and selecting suppliers for an electronic company based on the evaluation of the relationships between

supplier selection criteria. The writer establishing 10 evaluation standards that were grouped into clusters of supplier performance and capability, the Ref. [49] created an ANP approach for choosing the best supplier. In [50], the weighted average of the several factors employed in the sustainable supplier selection decision model is calculated using fuzzy ANP. The goal of [51] is to present a new hybrid MCDM strategy that can identify the structural links and interrelationships between all elements of the assessment and provide support for the method for dealing with the intricate and interactive problem of supplier evaluation and selection. The Analytic Network Process (ANP) determines the proper weights for each dimension and criterion in the evaluation model by combining the opinions of several experts.

Fuzzy Logic

Based on a number of factors including time constraints and a lack of domain knowledge, the Ref. [52] suggest a framework based on fuzzy set theory, and robust systems, to find sustainable Solved the multi-criteria decision problem for selecting suitable suppliers. It focuses on the skills and capabilities of suppliers in delivering their products. The Ref. [53], a green supplier selection using a fuzzy-based method based on quantitative and qualitative environmental parameters was developed. The scalable fuzzy membership functions used in the hierarchical fuzzy system impart user priorities into the system, which might mildly or strongly influence the supplier selection process. Paper of [54] used both quantitative and qualitative data for supplier selection, with the main goal of calculating the supplier's ability to create value for the customer. Fuzzy Theory was applied to establish an overall ranking of supplier appropriateness. To deal with the supplier evaluation and selection challenge, the Ref. [55] proposed twenty criteria using fuzzy set theory (FST). To determine the final scores of the suppliers, they combined the criterion data using the Dempster Shafer theory (DST).

Elimination and Choice Expressing Reality (ELECTRE)

The Ref. [56] solved the supplier selection problem using the ELECTRE (Elimination and Choice Expressing the Reality) method. The utility function was used to analyse different alternatives in the article, which utilized ELECTRE for multi-criterion evaluation.

A hybrid MCDM model was used in the article [57] to analyse and prioritize providers of green polarizers. Senior management received ranking data from the ELECTRE III approach, and the compromised weights of the criteria were quantified using the AHP and entropy methodology.

Utilizing the ELECTRE technique and a combined strategy based on rough set theory, the article of [58] evaluated and selected the best suppliers. To exemplify the application and promise of the approach, a case study of sustainable supplier selection for a solar air-conditioner manufacturer is offered.

Multicriteria Optimization and Compromise Solution (VIKOR)

A variety of MCDM techniques, including the VIKOR model, can be utilized to support decision-makers [59]. A few examples of papers that did are included below.

By combining the picture fuzzy distance operators with the VIKOR method, paper of [60] develops a sustainable supplier selection methodology. The new methodology can control the traditional VIKOR method's attitudinal nature, allowing a decision maker to make decisions based on his or her preferences.

A multi-criteria group decision-making (MCGDM) dilemma, green supplier selection (GSS) involves choosing suppliers based on a number of subjective and conflicting criteria. In an interval type-2 fuzzy environment, the Ref. [61] provides an integrated methodology based on BWM and VIKOR to handle this issue.

The Ref. [62] added a system for extracting and deploying objective weights based on Shannon's entropy idea to the VIKOR approach in order to address supplier selection difficulties.

3.3.2. MP Models

Mathematical programming methods were used to handle problems with multiple sources. Additionally, this kind of approach can address the issue of supplier variety related to the risk of the green supply chain [13].

Data Envelopment Analysis (DEA)

The Ref. [63] created a DEA-based methodology for evaluating technology vendors based on three primary criteria. The proposed method is demonstrated using a numerical example. The goal of the authors [64] is to present a complete strategy to supplier selection that encompasses a wide range of suppliers, caters to practically all organizations, and is both environmentally friendly and robust. Ref. [65] used DEA to give decision-makers a well-organized framework to aid them in selecting the best supplier for their company. Allocation and selection were two separate but connected steps in the suggested concept. Ref. [66] analyze and enhance the green performance of suppliers utilizing (DEA) with incomplete data. The DEA approach is used to parameterize related data.

Linear Programming (LP)

A linear programming model was developed by [67] to aid decision-makers or purchasers in choosing and assessing alternative providers. The methodology is based on numerical measurements for a major, international telecoms corporation to identify future suppliers while considering the strengths of current suppliers and to eliminate underperforming providers. Integer linear programming is used to solve the inventory gives an estimate and supplier selection problems under non-stationary dynamic settings with all-units quantity discounts and fill rate constraints [68].

Multiobjective Programming (MOP)

To address the supplier assessment and selection issue, Ref. [69] presented a multiobjective programming (MOP) model, with the price, lead-time, and rejects minimization functions. Three alternative solution techniques—weighted objective, goal programming, and compromise programming method—were used to separate and contrast the solutions in the situations.

3.3.3. AI Models

The objective of this method is finding approximations to challenging optimization issues, below are a few examples of this type:

Genetic Algorithm (GA)

To help customers evaluate and choose suppliers, the Ref. [70] provided a new simulation optimization methodology. The researchers described a Genetic Algorithm (GA)-based optimization methodology. The suggested method featured a supply chain modelling framework, a GA optimizer, and a discrete event simulator. The key performance metrics were used to confirm the alternative configurations offered by the providers. The Ref. [71] study provides a bi-objective LSS & CoPS model that balances procurement and operating costs by taking into account the operating stage of CoPS. To tackle the bi-objective problem, a hybridization of the Pareto genetic algorithm (PGA) with the multi-intersection and similarity crossover (MSC) technique is proposed. The variable-length chromosome is also represented by a dual-chromosome. Finally, an ideal cement equipment supplier for a cement equipment business is supplied. In order to enhance sustainable multimodal freight delivery integrating road, rail, and canal in an inland transportation, the Ref. [72] article examines freight transport and logistics framework. We take into account a genetic algorithm model that accounts for time, space, and CO_2 emissions.

Grey System Theory (GST)

In order to create a paradigm for reducing purchasing risks associated with suppliers that does not require any probability distribution or fuzzy membership function, Ref. [73] combined grey system theory with uncertainty theory. The suggested supplier selection approach not only determines the best-suited supplier(s) under stochastic and recognitive uncertainty, but also allocates the best buy quantity.

4. Result

In this section, we will discuss the findings from 10 literature studies that we conducted on the topic of evaluating and choosing green suppliers. These reviews concentrated on three different types of models: MCDM, MP, and AI. The sources of the references, the study periods, and the number of articles covered, and the number of models utilized are all listed in Table 2, while the quantity of articles is shown in Tables 3–6. Four columns are shown in these tables, depending on the models applied to attain this goal: references, the most popular models and their acronyms, and then statistics on how frequently these models are utilized.

Table 2. The studied review result related to GSES.

Sources	Review Number	Time Horizon	Reviewed Studies	Models Number
[8]	Rev 1	2009 to 2020	193	47 Single Models and 23 Combined models
[9]	Rev 2	2000 to 2017	122	10 Single Models
[10]	Rev 3	2000 to 2020	161	7 Combined Models
[2]	Rev 4	2000 to 2011	68	9 single Models
[11]	Rev 5	2000 to 2008	78	8 single models and 19 Combined Models
[12]	Rev 6	2008 to 2012	123	26 single models
[13]	Rev 7	1997 to 2014	143	22 single models
[14]	Rev 8	1997 to 2011	33	3 single models
[15]	Rev 9	2013 to 2018	95	30 single models and 5 combined models
[16]	Rev 10	1990 to 2019	82	15 single models and 47 Combined models

The purpose of [8] is to provide a complete review of research studies that were carried out between 2009 and 2020 with the purpose of creating models and processes to help businesses find and choose the best green suppliers. The 193 articles were found to be relevant in order to accomplish this goal and a variety of models and approaches to address the choice of Green Supplier (47 single techniques and 23 combined techniques) have been proposed and put into practice. Figure 2 displayed the percentage of each model out of the 193 papers examined in the initial evaluation [8], with 18 (9%) papers using the DEA model and 21 (11%) articles using the TOPSIS model (Tables 3 and 6). As a result, The TOPSIS (MCDM model) and DEA strategies are the two often-utilized methods for addressing the issue of selecting green suppliers (MP model).

The Ref. [9] focuses on order allocation and supplier selection problems (SSP), and it also provides a wide range of (MCDM) strategies and mathematical techniques for SSP. A new taxonomy and framework for ongoing research streams are also provided by the study. Between 2000 and 2017, 122 articles were reviewed, and 10 Single Models were found to address GSES issues. The percentage of each model from the 122 papers examined by the second review is shown in Figure 3 [9]. As a result, 47 (38%) of the studies reviewed used AHP, while 26 (21%) used TOPSIS to accomplish this goal.

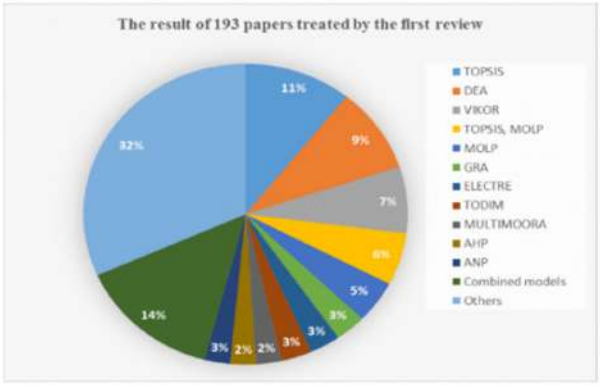

Figure 2. The result of 193 papers treated by the first review.

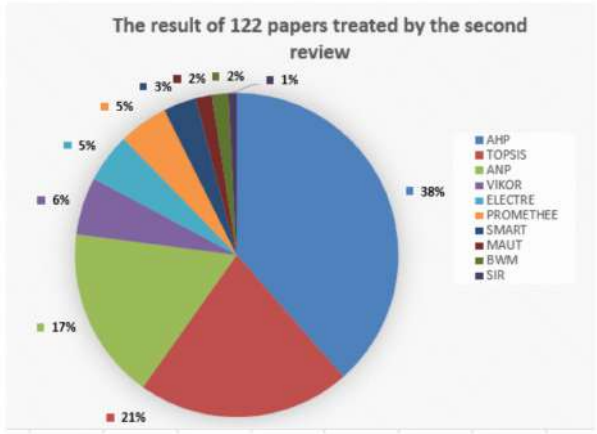

Figure 3. The result of 122 papers treated by the second review.

Table 3. Frequency distribution of MP models for GSES.

Sources	The Most Prominent Models	Article Quantity
[8]	DEA	18
[10]	DEA	45
[2]	DEA	20
	MP	12
[11]	DEA	14
	MP	9
	LP	19
[12]	DEA	13
	MOP	13
	GP	7
	GST	6
	NLP	6
[13]	DEA	12
[14]	MP	1
[15]	LP	19
	SP	11
	NLP	9
	MILP	9
	GP	7
	MOP	6

The Ref. [10] offer a thorough examination of 161 articles on the topic of supplier selection using DEA that were released between 2000 and 2020. There are seven recognized Combined Models with DEA. The percentage of each model among the 161 people

investigated for the third review is shown in Figure 4 [10]. As a result, the most frequently employed models by 45 and 21 publications, respectively, are DEA (28%) (See Table 3, MP models) and Fuzzy DEA (13%) (Table 5).

In order to address the supplier evaluation and selection process, numerous MCDM approaches (9 single Models) have been reviewed in [2] and have been documented in the literature between 2000 and 2011. According to Figure 5's breakdown of the percentages of each model from the 68 papers examined by the fourth study [2], the top models discovered by this analysis were the DEA and MP, which were used in 20 articles (29%) and 12 papers (18%), respectively, to handle GSES problems (Table 3).

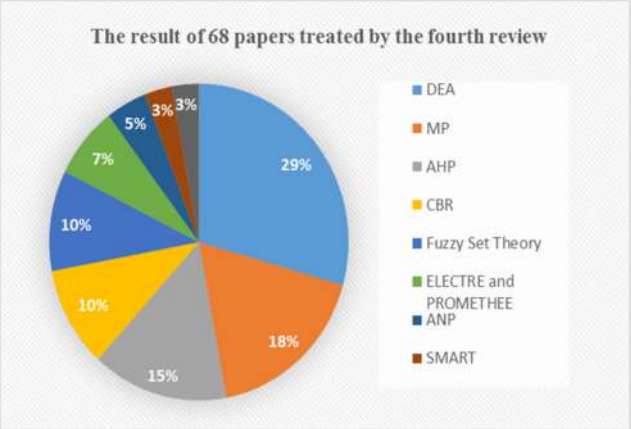

Figure 4. The result of 161 papers treated by the third review.

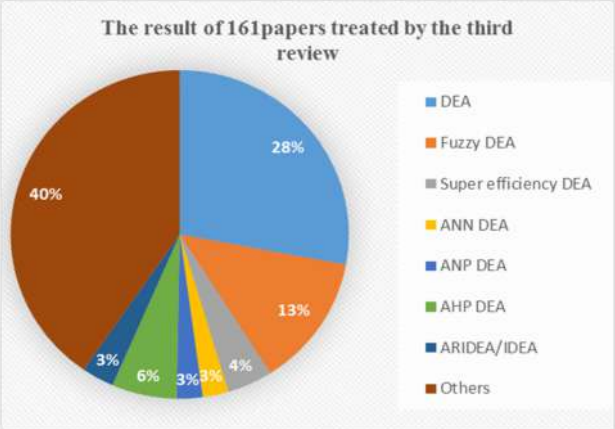

Figure 5. The result of 68 papers treated by the fourth review.

Table 4. Frequency distribution of AI models for GSES.

Sources	The Most Prominent Models	Article Quantity
[8]	GRA	6
[2]	CBR	7
	GA	2
[11]	CBR	7
	GA	1
[12]	GA	8
	NN	5
[13]	GRA	7

Table 5. Frequency distribution of combined models for GSES.

Sources	The Most Prominent Models	Article Quantity
[8]	TOPSIS, MOP	11
	Others Combined models	28
	Others Single models	66
[10]	Fuzzy DEA	21
	Super efficiency DEA	7
	ANN DEA	4
	ANP DEA	4
	AHP DEA	10
	ARIDEA/IDEA	5
	Others Combined models	65
[11]	Others Single models	9
[12]	Others Single models	31
[13]	Others Single models	25
[14]	Others Combined models	8
	Others Single models	14
[15]	Others Single models	7

Eight single models and 19 combined models are discussed in the [11] found 78 literature pieces on MCDM approaches for selecting the supplier in the period of 2000 and 2008. Figure 6 displays the percentage of each model from the 78 papers examined by the fifth study [11]. Of the 14 publications that apply DEA and 9 that employ MP, this review found that these two models are the most popular ones.

The Ref. [12] systematically examines 123 papers that were published between 2008 and 2012 on the use of decision-making (DM) techniques for supplier selection. The percentage of each model throughout the 123 papers examined by the sixth review is shown in Figure 7 [12]. 26 unique models are discovered in this work, while 30 publications (18%) utilized AHP, 18 (11%) used TOPSIS, and 19 used LP (Tables 3 and 6). The most number of articles are represented by these three techniques.

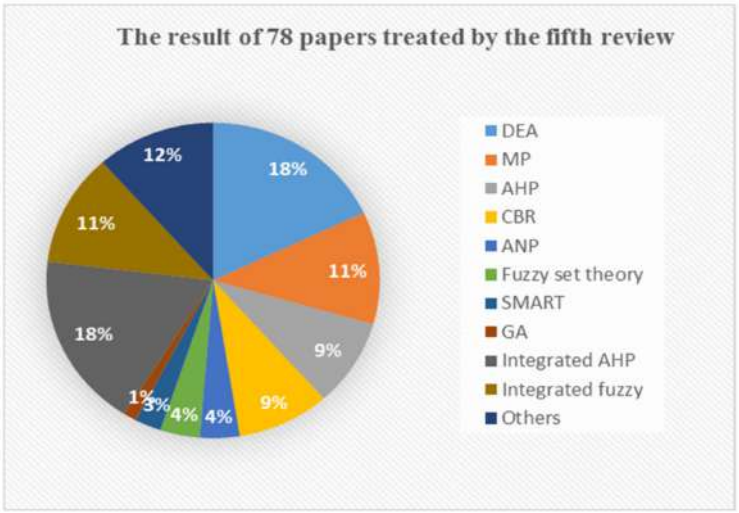

Figure 6. The result of 78 papers treated by the fifth review.

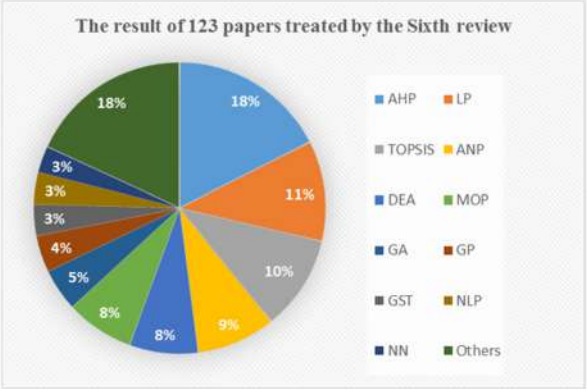

Figure 7. The result of 123 papers treated by the sixth review.

The goal of the study [13] is to assess and evaluate 143 academic works on green supplier that were released during 1997 and 2014. A special focus is placed on 22 individual models that aid in DM for the selection of sustainable suppliers. The percentage of each model among the 143 papers examined by the seventh review is displayed in Figure 8 [13]. As a result, the models with the most papers are fuzzy logic (31%), followed by AHP (19%), with 45 articles (Table 6).

In the work [14], research on 33 articles about choosing green suppliers in the period of 1997 and 2011 is examined. There were three separate models and additional composite models found. The percentage of each model from the 33 papers examined by the eighth review [14] is shown in Figure 9. The most frequently used models by six (18%) and four (12%) publications, respectively, are AHP and ANP (Table 6).

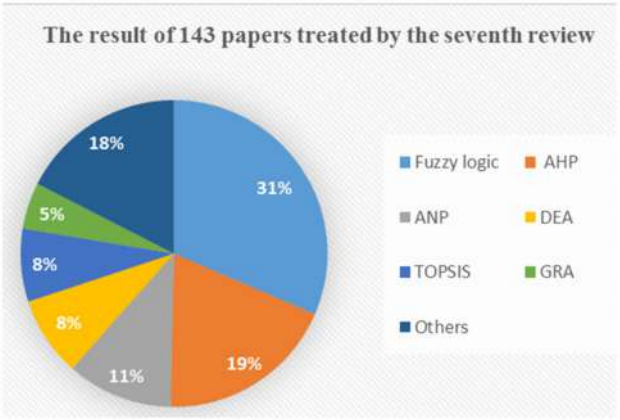

Figure 8. The result of 143 papers treated by the seventh review.

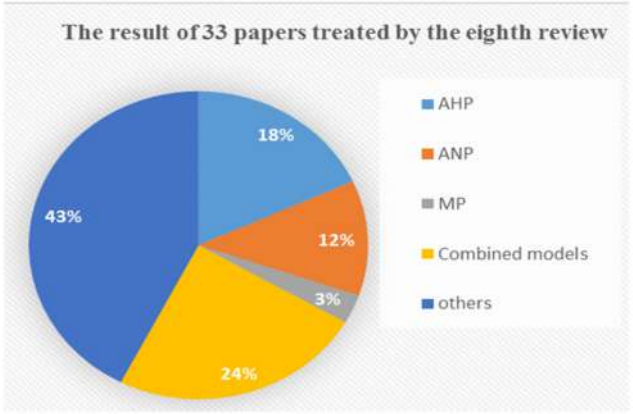

Figure 9. The result of 33 papers treated by the eighth review.

In order to address the supplier selection issue between 2013 and 2018, Ref. [15] systematically evaluates 95 relevant pieces of literature, choosing multiple DM procedures. 30 individual models and 5 integrated models were evaluated using a recognized methodology. The percentage of each model from the 95 papers examined by the ninth review [15] is displayed in Figure 10. The most frequently used models by 19 (20%) and 13 (14%) articles, respectively, are LP (Table 3) and AHP (Table 6).

In order to address the issue of sustainable supplier selection, Ref. [16] conducted research to determine the most popular MCDM approaches (15 single models and 47 combined models) and how they are applied—alone or in conjunction with other approaches. In this study, 82 articles from 1990 to 2019 were examined. The percentage of each model from the 82 papers examined by the ninth review [16] is shown in Figure 11. Due to this, TOPSIS and AHP are the most frequently used models, accounting for 17 and 15 papers, respectively (18% and 16%).

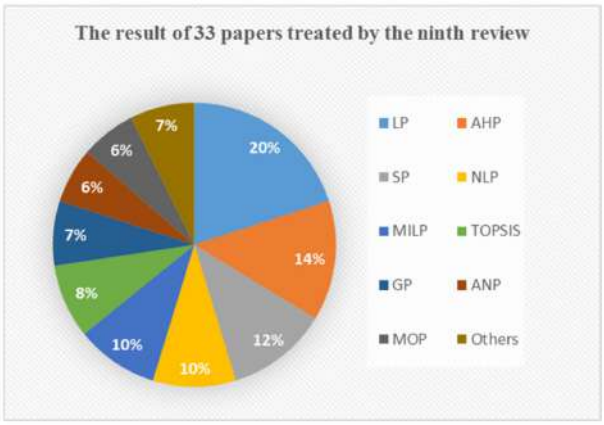

Figure 10. The result of 95 papers treated by the ninth review.

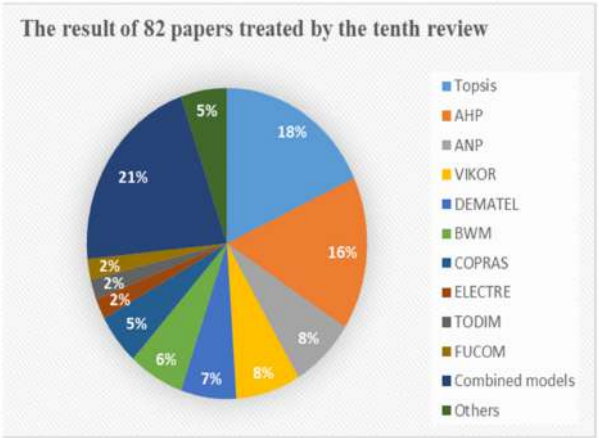

Figure 11. The result of 82 papers treated by the tenth review.

Table 6. Frequency distribution of MCDM models for GSES.

Sources	The Most Prominent Models	Article Quantity
[8]	TOPSIS	21
	VIKOR	14
	ELECTRE	6
	TODIM	6
	MULTIMOORA	5
	AHP	5
	ANP	5

Table 6. *Cont.*

Sources	The Most Prominent Models	Article Quantity
[9]	AHP	47
	TOPSIS	26
	ANP	21
	VIKOR	7
	ELECTRE	6
	PROMETHEE	6
	SMART	4
	MAUT	2
	BWM	2
	SIR	1
[2]	AHP	10
	Fuzzy Set Theory	7
	ELECTRE and PROMETHEE	5
	ANP	3
	SMART	2
[11]	AHP	7
	ANP	3
	Fuzzy set theory	3
	SMART	2
[12]	Integrated AHP	14
	Integrated fuzzy	9
	AHP	30
	TOPSIS	18
	ANP	15
[13]	Fuzzy logic	45
	AHP	27
	ANP	16
	TOPSIS	11
[14]	AHP	6
	ANP	4
[15]	AHP	13
	TOPSIS	8
	ANP	6
[16]	Topsis	17
	AHP	15
	ANP	7
	VIKOR	7
	DEMATEL	6
	BWM	6
	COPRAS	5
	ELECTRE	2
	TODIM	2
	FUCOM	2
	Combined models	20
	Others	5

5. Discussion

This section will give a discussion of 1098 papers published between 1990 and 2020 (see Table 7), based on the examination and evaluation of the findings of the ten literature reviews. More exactly, 271 models on the subject of evaluating and choosing green suppliers are broken down into 170 individual models and 101 mixed models.

The time frame for every paper is depicted in Figure 12. The Ref. [16] review covers a span of 29 years, and is preceded by [10,13] (20 years) and [17] (17 years). The most current journals cover 8 years from 2009 to 2020 and 10 years from 2000 to 2020.

Table 7. The reviewed result quantity.

Sources	Review Number	Reviewed Studies
[8]	Rev 1	193
[9]	Rev 2	122
[10]	Rev 3	161
[2]	Rev 4	68
[11]	Rev 5	78
[12]	Rev 6	123
[13]	Rev 7	143
[14]	Rev 8	33
[15]	Rev 9	95
[16]	Rev 10	82
Sum of the reviewed studies		=1098

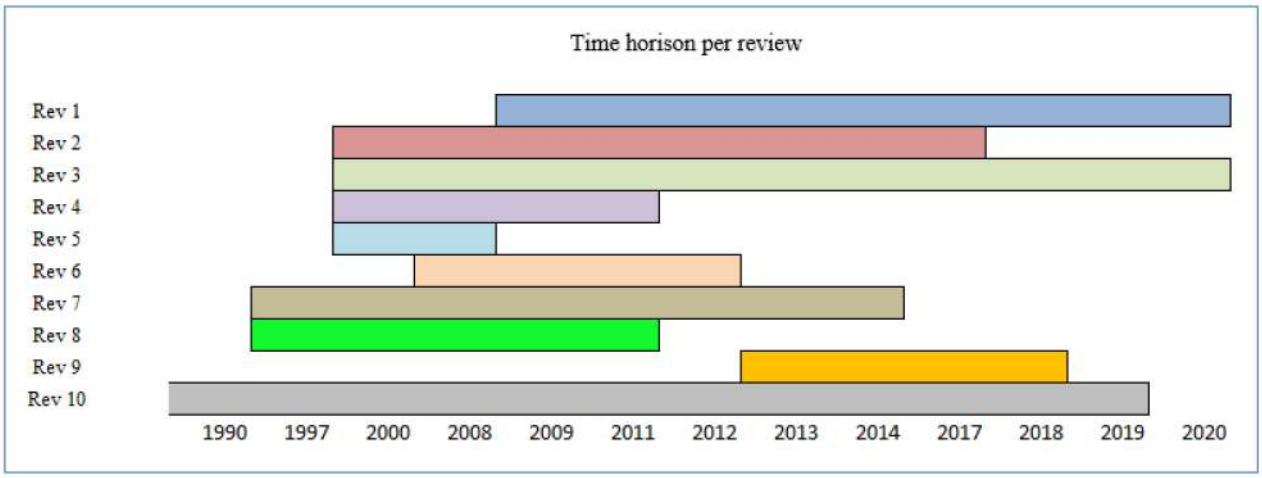

Figure 12. Time frame per literature review.

Figure 13 illustrates the distribution of the 271 models that were discovered after the study of the outcomes from the 1098 articles. For simple models 47 is the maximum number of modes utilized in the article [8,15,20] come next, with 30 and 26 models, respectively. In other cases, article 15 dealt with the often-combined models (47), while articles 8 and 12 dealt with 23 and 19 mixed models, respectively.

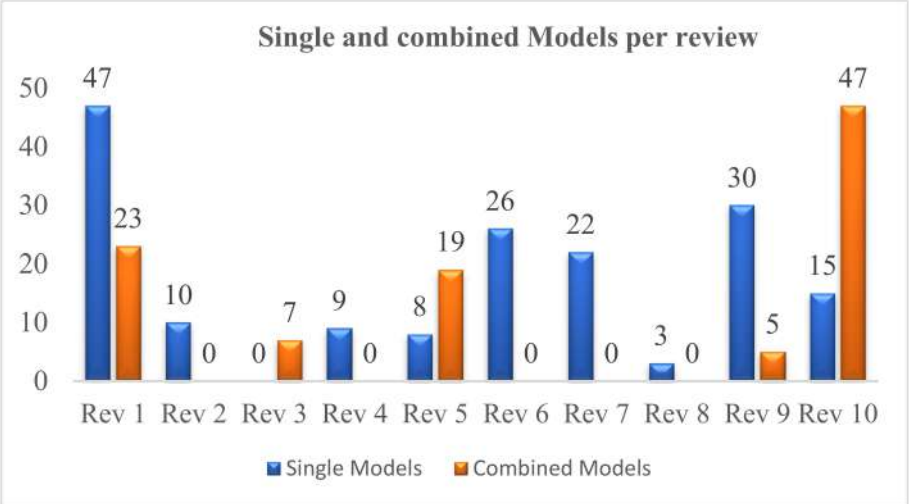

Figure 13. Single and combined Models per review.

Figure 14 presents the numbers of articles that used MCDM method to solve GSES problems based on the result of the ten reviews between 1990 and 2020. It is obvious that the AHP method is the one that is used the most. Since 1990, 32% of all publications published have employed the AHP approach. Followed by TOPSIS 20% and the third most used method is ANP with 16%, Figure 15 shows the number of articles that decided to solve the problem of green supplier evaluation and selection using mathematical programming (MP) models. We can observe that DEA is the most prominent model used to achieve this goal by 47%. Another interesting result shows that there is a large margin between the first model and the other models, confirming the reliability of the DEA method in solving this type of problem. Figure 16 shows the item number to which the AI model applies. It is observed that the number of papers for the four models are very close. In addition, the number of articles that chose this type of model to solve these problems during "1990–2020" is limited, for a total of 44 articles.

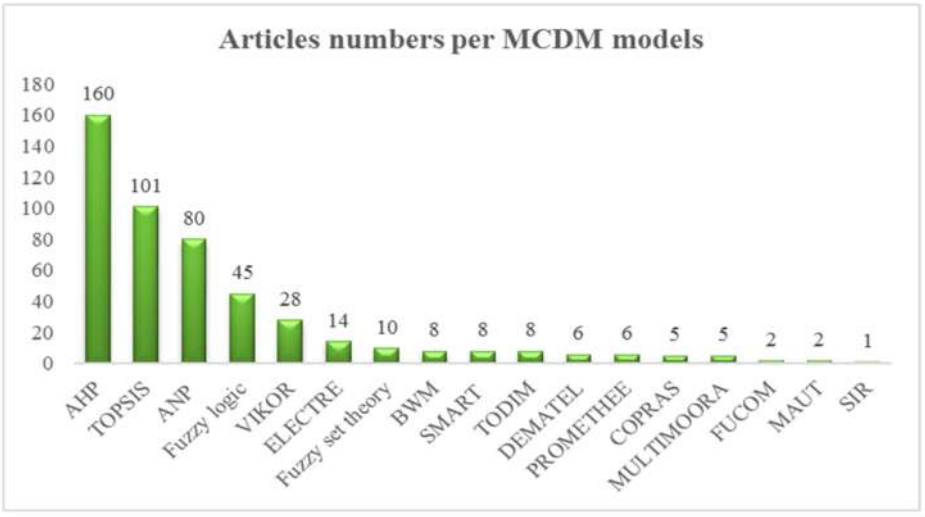

Figure 14. Number of articles per MCDM models.

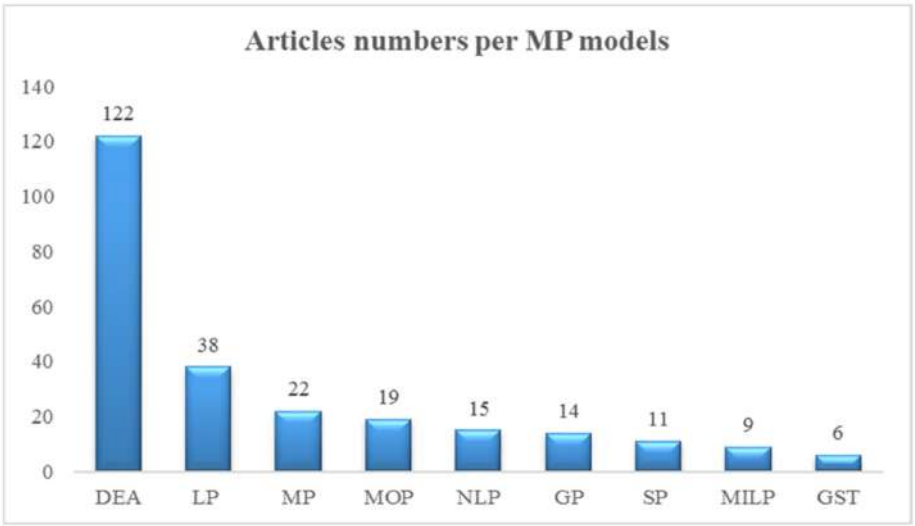

Figure 15. Number of articles per MP models.

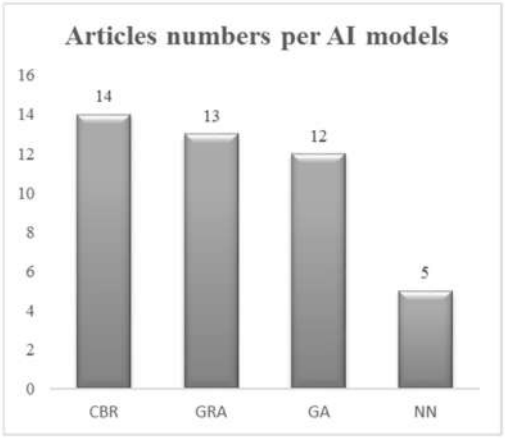

Figure 16. Number of articles per AI models.

Figure 17 shows an overview of the percentage of articles based on the analysis of 1098 papers results that applied each type of model. The usage of MCDM method presents the higher percentage 62%, which gives an idea of the positive results obtained by this model. Followed by the MP models with 32% and just 6% of articles that have chosen AI models to solve this problem.

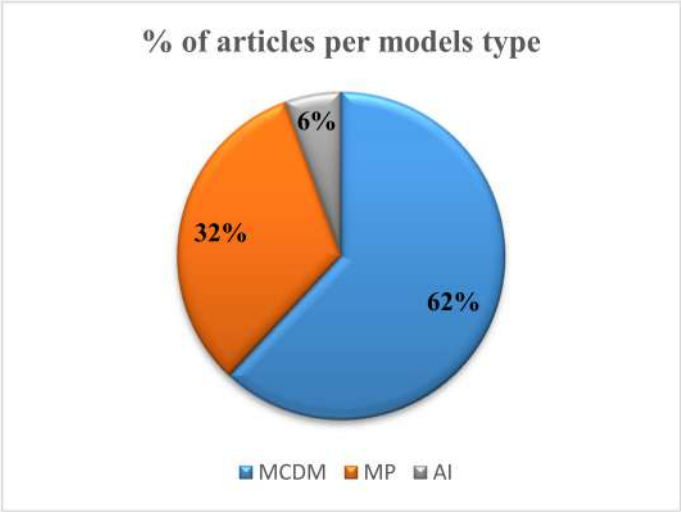

Figure 17. Percentage of articles per models type.

The analysing of the ten reviews allowed us to determine the most popular DM approaches that were addressed in the 1098 articles that dealt with the evaluation and selection of green suppliers between 1990 and 2020. There were 271 DM models employed by the various research, but we only selected the top ten for each of the three categories—MCDM, MP, and AI (see Figure 18). Due to the small number of AI models, only MCDM and MP models were taken into account in the ten models that were chosen, hence we did not go into detail for the combination models.

The articles number that used each model to address the GSES problem is shown in Figure 18. The AHP model, used in 160 articles, is the most used DM technique for single models, followed by DEA, which was used in 122 publications to do this. The third most widely used model, TOPSIS was used in 101 studies. ANP was utilized in 80 publications, Fuzzy approach in 45 papers, LP in 38 works, VIKOR in 28 papers, MP in 22 papers, ELECTRE in 14 papers, and MOP in 19 papers. On the other hand, 118 paper were utilized for the total of all the models. Other DM models were employed in 351 research. As a result, the AHP, DEA, and TOPSIS are the often utilized DM techniques to address the problem of evaluating and selecting green suppliers. Therefore, after analyzing these results, we can

conclude that using these three methods in all these articles demonstrates the reliability of these methods in solving the green supplier evaluation and selection problem.

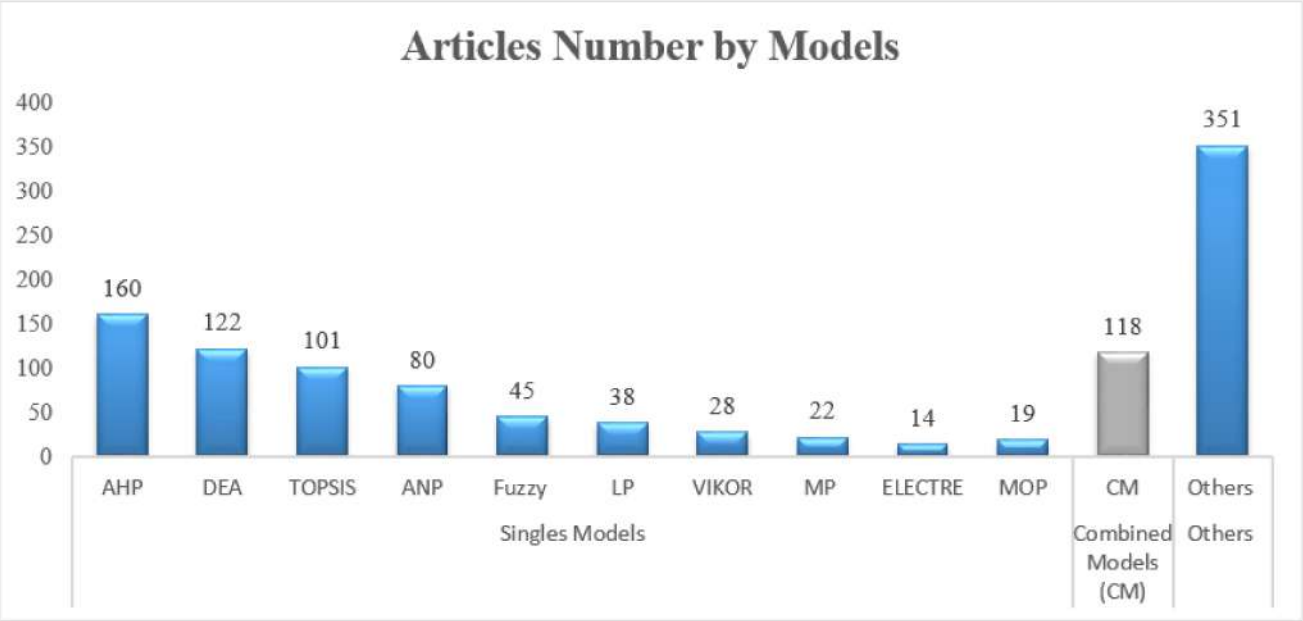

Figure 18. Number of articles per Models.

6. Conclusions

For every industry to expand and develop, the proper assessment and selection of suppliers is essential. In the last decade, Businesses have been implementing GSCM in their supply chain operations to get the best results. As a result, numerous methods for assessing and choosing green suppliers have been developed and published in the literature. To assist practitioners in choosing the best model to address these concerns, this research provided a thorough analysis of 10 literature studies on green supplier assessment and choice models. The identification of 1098 publications published between 1990 and 2020 treated 271 DM techniques, which were split into 170 individual methods and 101 mixed methods. As a result, the MCDM model is the most commonly used type by 62%, the AHP model is the most well-known DM method was used in 160 papers, and then the DEA was used in 122 studies to achieve this goal. TOPSIS is the third model used in 101 studies. Finally, the most widely utilized DM techniques to address the assessment and selection of green supplier challenge were found to be AHP, DEA, and TOPSIS. Therefore, after analyzing these results, using these three methods in all these articles demonstrates the reliability of these methods in solving the green supplier evaluation and selection problem.

The limitations of this paper is that the plurality of the review articles were found using the Scopus and WOS databases, Scopus and WOS are large databases of management and science journals, However, the collection does not contain all peer-reviewed articles; as a result, a few significant papers on GSES problem may have been missed. Furthermore, since the study focuses on just single models analysis, a few other analysis by combined models would not have been included. Finally, the criteria of green supplier evaluation and selection used in DM models is not identify, which can more help researchers to choice the appropriate model for their GSES problems according to [74,75]. In the future research, we can working on GSES criteria using in top identified DM models. In addition, we can studding the combined models used to solve GSES issues. Finally, we will conduct a case study of our work by using the most popular models that we have found as result in this work (AHP, DEA or TOPSIS) to select and evaluate a green supplier for an automotive industry.

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