sustainability

MDPI

Article

A Decision Support Tool for Supplier Evaluation and Selection

Ana Paula Lopes [1,*] and Nuria Rodriguez-Lopez [2]

1 Centre for Organizational and Social Studies of Polytechnic of Porto, Porto Accounting and Business School, Mathematics Department, Polytechnic of Porto, 4200-465 Porto, Portugal
2 Faculty of Business Sciences and Tourism, Vigo University, 32004 Orense, Spain; nrl@uvigo.es
* Correspondence: aplopes@iscap.ipp.pt

Abstract: The supplier selection process is considered one of the most relevant decisions in supply chain management due to its effect on the product quality and on buyer performance. Supplier selection is often unstructured, and is generally based on the lowest-price proposal. However, this type of selection involves a high risk, sometimes resulting in project delays, poor quality of acquired goods, and large financial losses. Price is undoubtedly an important criterion when choosing a supplier; however, other equally important criteria must be considered. Therefore, supplier selection should be formulated as a multi-criteria decision-making (MCDM) problem. This study uses the PROMETHEE-GAIA (Preference Ranking Organization Method for Enrichment of Evaluations—Geometrical Analysis for Interactive Assistance) method to classify and select suppliers in an agrifood company. One of the advantages of this method is that it allows decision-makers to set their preferences considering all the relevant criteria simultaneously, and their relative importance. The case study demonstrates that PROMETHEE constitutes a flexible MCDM tool for supplier evaluation and selection, rank the different alternatives, and provide valuable insights. The results show that the supplier selection process has a strong point related to the existence of two groups of suppliers, one focused on economic criteria and other related to the innovative capacity. However, a flaw emerges, as little relevance is associated to the environmental criterion.

Keywords: supply chain management; multiple criteria analysis; PROMETHEE-GAIA; decision making; logistics

Citation: Lopes, A.P.; Rodriguez-Lopez, N. A Decision Support Tool for Supplier Evaluation and Selection. *Sustainability* **2021**, *13*, 12387. https://doi.org/10.3390/su132212387

Academic Editors: Dimitrios Vlachos, Naoum Tsolakis and Dimitrios Bechtsis

Received: 27 September 2021
Accepted: 5 November 2021
Published: 10 November 2021

1. Introduction

The role of small and medium-sized enterprises (SMEs) in market revitalization, and therefore in economic development, is as important as that of big companies. Today, with globalization and technological progress, SMEs are under increasing pressure to use technology in more sophisticated ways to meet their customers' expectations, reduce costs, and remain innovative and competitive. The good performance of enterprises, in particular, that of SMEs, depends on several decisions; one of these decision is supplier selection. SME performance, and eventually competitive advantage, depend on these decision-making processes [1].

The literature shows many different approaches or techniques to solve the problem of supplier selection and evaluation; most of the approaches are based on multi-criteria decision making frameworks [2–6], using two methods [7] the so-called "American School" of multi-criteria decision support [8] and the "European School" [9]. In the area of the American School, for example, Analytic Hierarchy Process (AHP) [10,11] Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [12–14], Analytic Network Process (ANP) [15–17], VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) [18,19] or Decision-Making Trial and Evaluation Laboratory (DEMATEL) [20,21] methods demonstrated its effectiveness in supplier selection and evaluation problems. Moreover, the European School methods are extensively used in this subject and, for example, include methods such Elimination and Choice Expressing Reality (ELECTRE I) [22,23], ELECTRE II [24,25], ELECTRE III [26,27], PROMETHEE II [28–30] or Complex Proportional Assessment (COPRAS) [31,32]. There are numerous works that have used a kind of mixed-mode and fuzzy expansions of MCDM methods related with this issue, presented in [33,34] which have recognized their value in the supplier evaluation and selection problem. However, despite the extensive studies on the development of MCDA methods, it is noteworthy that none of them is universal and despite the same input data, the results obtained by using different MCDC methods may be different [35,36].

The main purpose of applying decision-making methods is that both alternatives and criteria are fixed a priori and the decision occurs once. Of course, this basic assumption limits the accuracy of the results, especially when values change over time and the pair-wise decision matrix is not fixed as is the case with the supplier selection problem.

Further, several researchers have highlighted the relevance of supply chain management in the food industry [37,38]. However, decision-making and supplier selection in the food industry have been scarcely addressed, and more research is needed to obtain an in-depth understanding of the selection criteria preferred by companies and to facilitate management's success in supplier selection. Therefore, the present study focused on a medium-sized agrifood company, in order to analyze its supplier selection process, the criteria used, their strengths, weaknesses and thus classify them, through the establishment of a ranking and so select suppliers.

A PROMETHEE-GAIA (Preference Ranking Organization Method for Enrichment of Evaluations—Geometrical Analysis for Interactive Assistance) method was applied. This method allows for the hierarchical organization of the firm's main suppliers according to a set of criteria. Our results can be useful in assisting the firm to improve its supplier selection process, but also in helping similar firms to provide a reference for the more relevant criteria and show the applicability of multiple criteria methods in the supplier decision-making process.

Therefore, the main goal of this study was to solve the previously defined problem by applying the PROMETHEE method with the use of expert knowledge from specialists as the efficient way for enhancing the quality of the decisions made while prioritizing the reliable supplier. Based on this, the subject of the research focused on the analysis of the ranking of the suppliers of this agrifood company. The methodology that is founded on the multi-criteria analysis represents a good basis for solving the proposed problem because it is possible to come to the priority list, based on ranking according to a variety of the criteria at the same time, and also, the results obtained by this analysis can represent a start value for further optimization methods.

As mentioned previously, the most well-known multi-criteria methods are evaluation models, analytic hierarchy process—AHP, analytic network process—ANP, technique for order preference by similarity to ideal solution—TOPSIS, and Preference Ranking Organization Method for Enrichment of Evaluations—PROMETHEE. This last method has a lot of advantages compared with other methods because of its simplicity and capacity for obtaining results in the contradictory condition and criteria.

In the next section, the supplier selection problem and supplier selection criteria are addressed with the purpose of developing the empirical analysis that is presented in the Sections 3 and 4. Finally, Sections 5 and 6 shows the results of the study and its main conclusions.

2. Literature Review

2.1. The Supplier Selection Problem

Supplier selection can be defined as a decision-making process by which potential suppliers are reviewed, evaluated, and selected to participate in the company's supply chain [39–41]. The importance of supplier selection stems from both external and internal factors. Concerning the former, factors such as global markets and increasing competitive pressure have rendered supplier selection increasingly important. The increasing number of competitors has forced companies to focus on core competences, and to outsource less profitable activities to suppliers [42]. Consequently, suppliers have turned out to be key in obtaining products of a higher quality in the required amount and time, at a reduced cost, and with the features demanded by the customer [19,43,44]. In this scenario, supplier selection has emerged as a critical decision, and the buyer–supplier relationship has become a strategic asset that is based on close collaboration and sustainability [2,45]. Competition is nowadays between supply chains rather than between companies [39].

Regarding internal factors, supplier selection has been pointed out as one of the most relevant activities of the purchasing function [16,41]. Purchased materials and components represent 40–60% of production costs [46], and can be as high as 70% [41]. Thus, supplier selection has a direct impact on supply chain operational performance [40]. Indeed, supplier selection affects inventory management, as well as production planning and control [41]; it supports product quality improvement, consumer satisfaction, reduction of operational and material purchasing costs [43], and a flexible and rapid material purchasing process [47]. Furthermore, it has been stated that supplier selection decisions affect the overall performance of an organization, its cash flow, and its profitability; as such, it is a critical factor for every company's prosperity, and for maintaining a strategically competitive position [38,41,48]. Supplier selection has frequently been highlighted as a critical management decision [16] and a potential source of competitive advantage [49].

2.2. Supplier Selection Criteria

In spite of the existence of different models to represent the supplier selection process, there is a concordance between the stages identified. De Boer's model [4,50] contains four steps—problem definition, criteria formulation, qualification, and final choice—and has been a guide for a number of works [4,16,41,51]. Later, this model was complemented with more stages around three groups of decisions: previous analysis, supplier evaluation, and final decision (Figure 1).

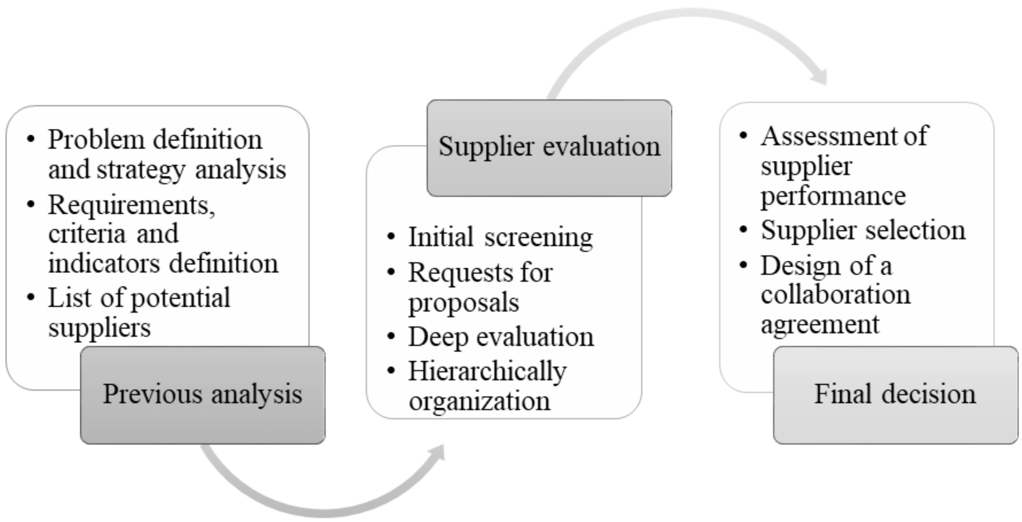

Figure 1. Supplier evaluation and selection process. Source: Adapted from Wetzstein et al. [12].

Previous analysis concerns the definition of requirements and strategy analysis, criteria selection and indicator development, and the compilation of a list of potential suppliers [51,52]. Supplier evaluation is an initial screening. At this point, the firm considers only the main criteria and reduces the number of potential suppliers to approximately eight. Then, the firm sends requests for proposals to those suppliers to obtain more information about them. This information allows the firm to use more criteria and to organize the candidates hierarchically [51]. The kind and number of criteria depend on the stage of the supplier selection process. Firstly, an initial set of suppliers is evaluated through a limited number of main criteria; then, the number of suppliers is narrowed down and the analysis intensifies with the use of more criteria. Finally, after negotiations with the potential suppliers [51] and assessment of their performance [52], one supplier is selected. Then, a collaboration agreement is designed, as well as a procedure to analyze procurement and sourcing [16].

The main stage in a supplier selection process is the definition of the evaluation criteria for the potential suppliers. A large number of papers address this topic, in which numerous criteria are collected (Table 1). This decision is even harder in the current context due to global competition and increasing customer expectations, which make supplier selection a multicriteria problem [43] with both quantitative and qualitative elements [53]. The criteria highlighted most often are quality, cost, and delivery [4,16,48,53,54]; in some cases, delivery refers to delivery, flexibility, and service level [42]. In addition to these factors, analysis of suppliers' facilities and capacity could also be considered. Therefore, factors such as cultural similarity, geographical location, historic performance, financial status, innovation capability, political situation, and risk are mentioned as secondary elements [4,48,53].

Recently, some authors have emphasized the importance of environmental and social factors, proposing the classification of criteria into three groups: economic, environmental, and social [2,5,49,55]. It is especially relevant to highlight the increasing environmental and sustainability concerns. These elements introduce a new requirement to supplier selection—that is, the green factors [47,49]—and supplier selection becomes an essential decision in developing a sustainable supply chain partnership [2,4]. In this way, economic and environmental factors are the focus of several works. However, social factors are barely addressed.

Based on the proposed criteria classification, the present study considers all the main economic criteria (cost, quality, and delivery), the relevant secondary economic criteria (geographical location, technology, and financial position), the environmental criteria, and the social criteria (Table 1). Cultural similarity, political situation, and risk are not included due to the scope of the analysis, which is focused on one country and one industry.

Table 1. Main criteria, description and authors.

Criteria	Description	Authors
ECONOMIC		
Quality	The capability to offer products that conform to specifications, meet customer requirements and government regulations. It relates to the use of quality systems and continuous improvement programs, material and process control, maintenance and calibration, planning, and staff training.	[3,19,40–42,48,50–52,56,57]
Delivery	Refers to the duration of time from placing to receiving an order (lead time), on-time delivery (as per time scheduled), and delivery reliability. In addition, the delivery conditions are also important, that is, product presentation, cleanliness and packaging, and provision of the standard documentation required throughout the process.	[3,16,19,41,44,48,50–52,56–58]
Cost	Includes the costs of transportation, inventory, material, maintenance, labour, and other elements related to product manufacturing. Thus, this attribute considers the total estimated cost for each alternative.Can be represented by productivity. Higher productivity indicate a greater supply, cost, and production control ability, better operating management efficiency, and better customer acceptance.	[3,16,40–42,44,48,50–52,56–58]

Table 1. *Cont.*

Criteria	Description	Authors
ECONOMIC		
Relationship	Concerns to the ability of the buyer and the supplier to complement each other's capabilities in order to maintain a long-term partnership with few reliable suppliers. The ability to maintain a good communication channel and a long-term relationship buyer-supplier is essential and they can even present a differential advantage when selecting a supplier.	[19,40–42,51,57]
Facilities and capacity	Evaluates the capacity of the firm to provide specific solutions to achieve the technical requirements and the company's desired specification. To this end, a proper infrastructure and resources, an undated assets maintenance (vehicles and equipment), and suitable work stations and physical location are required.	[3,40,44,50,51,57,58]
Service	Indicates the after-sales service level provided by the seller. It can include the supplier's service level in terms of lead time, flexibility, and customer service.	[3,42,44,48,51,57]
Flexibility	Indicates the ability to adjust product volume, product mix, product characteristics, or manufacturing processes as demanded by the buyer, using existing machines or equipment.	[19,41]
Culture	Relates to the generation of trust, both within the organization and among members in the supply chain, and to the management attitude towards the supplier, which allows him/her to successfully face unexpected future events.	[19,41]
Geographical location	It indicates how far the supplier is located from the company.	[42,44,48,50]
Performance history	Previous experiences in providing the service can influence future firm performance.	[40,48,58]
Financial status	The supplier's financial situation and stability and payment conditions are important factors to consider in this category.	[40,42,51,59]
Innovation	The capability of develop R&D activities in order to improve differentiation while reducing costs. Usually, a higher R&D expense on sales denotes stronger technology ability [57].	[42,51]
ENVIRONMENTAL	The presence of environmental controls and programs that ensure environment-friendly product characteristics. Hamdan and Cheaitou [43] classify these factors into two groups: product-related and organization-related. The first group relates to the use of environment-friendly resources and materials, as well as advanced technologies for recycling materials, to produce environment-friendly items. The second group relates to awareness about the environmental issues pertaining to the operations, structure, and culture of the organization. It refers to the existence of policies that enable the vendor to follow environmental norms.	[19,41,43,44,51]
SOCIAL (safety)	The supplier's concern about accidents, and the provision of a safe and healthy working environment. Security is one of the most important criteria, because accidents have a significant social, environmental, and financial impact.	[19,40,41,51]

3. Methodology

3.1. PROMETHEE I and II

PROMETHEE is an outranking method which considers the inner relationships of each evaluation fact during the decision-making process, initiated by Brans [60] and developed by Vincke and Brans [61], and it has been applied successfully to many interesting problems, including those in logistics, finance, management and human resources, in industries like chemistry, health care, and tourism [62]. Behzadian et al. [63] provide a comprehensive literature review. Some other recent applications of the PROMETHEE method include energy conversion [64], management of water supply systems [65], renewable energy sources [66], enterprise resource planning [67], equipment selection [68], stock trading [69], waste treatment [70], portfolio selection [6], material selection [71], innovation measurement [72], and the selection of team members [73].

PROMETHEE methods are commonly used due to their effortlessness for implementation. In the first stage, local scores of each criterion are generated through the comparison of the decision-maker preferences. Then, those scores are aggregated to obtain an incomplete rank (PROMETHEE I), and, finally, a complete rank (PROMETHEE II). From a mathematical perspective, the considered problem can be formulated in an evaluation matrix (Table 2), where the cells show de score of the alternatives $\{a_1, a_2, \ldots, a_n\}$, evaluated in terms of the decision criteria $\{f_1, f_2, \ldots, f_k\}$.

Table 2. Evaluation table.

	f_1	f_2	…	f_j	…	f_k
a_1	$f_1(a_1)$	$f_2(a_1)$	…	$f_j(a_1)$	…	$f_k(a_1)$
a_2	$f_1(a_2)$	$f_2(a_2)$	…	$f_j(a_2)$	…	$f_k(a_2)$
…	…	…	…	…	…	…
a_i	$f_1(a_i)$	$f_2(a_i)$	…	$f_j(a_i)$	…	$f_k(a_i)$
…	…	…	…	…	…	…
a_n	$f_1(a_n)$	$f_2(a_n)$	…	$f_j(a_n)$	…	$f_k(a_n)$

$f_j(a_i)$ shows the performance of the ith alternative on the jth criterion; $\{a_1, a_2, \ldots, a_n\}$ are the alternatives and $\{f_1, f_2, \ldots, f_k\}$ are the criteria.

The preference function P_j converts the difference between the scores of each alternative into a preference degree ranging from 0 to 1. Six basic types of preference function can be used: the Usual function, U-Shape function, V-Shape function, Level function, Linear function, and Gaussian function [61,62].

To evaluate the preferences two different threshold parameters are used:

- Indifference threshold (q_i): Two alternatives are indifferent when the difference between evaluations is smaller than the indifference threshold.
- Strict preference threshold (p_j): The second alternative is preferred to the first one if the difference between their evaluations is bigger than the preference threshold, (p_j).

Therefore, natural dominance relation is defined in such a way that one alternative is better than another if it is at least as good as the other on all criteria. If that alternative is better on a criterion s but worse on a criterion r, both alternatives are incomparable [62]. The selection of the preference functions and their parameters by the decision-maker clearly brings to bear the advantages and features of the PROMETHEE method.

To express with which degree one action is preferred to another over all criteria, the *aggregate preference* index is determined using a weighted sum of the preference values. The *weights* represent the relative importance of each criterion in order that the lower the weight, the less important the criterion. Thus, the PROMETHEE II method calculates a *net outranking flow* ($\varphi(a)$) for an alternative a, as the difference between the global preference of a (positive outranking flow, $\varphi^+(a)$) and the global weakness of a (negative outranking flow ($\varphi^-(a)$). The higher the value of $\varphi^+(a)$ and the smaller the value of ($\varphi^-(a)$), the better is $\varphi(a)$ and the better the alternative. Therefore, the net outranking flow is used when the decision maker requests a complete classification, where all the global weakness and strengths of all the alternatives are considered and, consequently, all the alternatives are comparable.

3.2. The GAIA Interactive Visual Tool

The foundations for the Geometrical Analysis for Interactive Aid (GAIA) plane are the net outranking flows [74]. GAIA plane represents the position of the actions, thus we can make comparisons between them identifying actions that have similar or opposed performance [75].

The set of n alternatives can be represented as a cloud of n points in a k-dimensional space [56]. As the number of criteria is larger than two, the goal of the GAIA plane is to reproduce the decision-maker options and their consequences as far as possible in a two-dimensional view. In GAIA plane, alternatives are represented by points, and the criteria are represented by axes, whose length represents their power between actions: the longer the vector, the more discriminating the criterion. When the axes are represented in the same direction, then those criteria have a similar pattern of preferences. However, when the direction is opposite, then the criteria are conflicting. In addition, in the GAIA plane the decision-maker's preferences (weights) can be represented by a vector called "decision stick".

The Delta-parameter (δ) indicates the quantity of information pondered in the GAIA plane. Values bigger than 70% can be considered suitable, indicating that few information was lost, and the GAIA plane offers a valid and accurate model of the decision problem. This means that PROMETHEE-GAIA's characteristics are well matched with the supplier decision-making processes, as is presented in the following case study.

4. Application of PROMETHEE—GAIA to the Supplier Selection Problem

Our study addresses the fresh fruit supplier selection model for the manufacture of food products in Northern Portugal. Portuguese food product manufacturing is one of the growth sectors in the current market, and a facilitator of economic growth due to its function of link between agriculture and the industrial sectors.

Changes in tastes, available technology and social factors are witnessed globally in food consumption habits, so that innovation continues to be a challenging and complex process in the management of a food processing industry. In spite of the importance of the food industry to national economies [7,38], the industry's supplier selection process has barely been addressed. Following a literature review of the multi-criteria decision-making approaches (MCDM) for supplier selection from 2000 to 2008, Ho et al. [53] showed that there were only five studies related to the food industry, of which only one was focused on the food manufacturing industry. This situation has not changed during subsequent years, and very few studies can be found on this topic. The special characteristics that are required to manage the food industry's supply chain are highlighted by Voss et al. [38] and Amorim et al. [57]. These authors point out that the perishability of raw materials and products, their continuous change, and their extreme vulnerability to contamination are features that render the supply chain more complex and harder to manage. In this sense, supplier selection should be tackled from a global perspective that considers tangible and intangible criteria [2].

The company analyzed is an SME, and a well-known manufacturer of food products; it is dedicated to the creation of innovative products, namely the processing of quality fruit and other raw materials into pastry and ice cream ingredients, such as fruit fillings, jams, creams, jellies, toppings, marmalade, and glazing. Their product is the fruit of nature and accomplishment, of their relationship with agriculture, and of their respect for the environment that they always support. For them, quality is much more than a political statement—it is their standard of living. As part of its food safety and quality management systems, the company seeks to establish strong and lasting ties with each value chain player—that is, with suppliers and customers—based on shared knowledge and value creation. Therefore, the fresh fruit purchase process is a determinant for the company success. To manage the supply chain, the company needs to purchase fresh fruit raw materials from several suppliers, for whom a spectrum of supplier properties need to be considered, including quality, price, flexibility, and service level. In this study, the main six suppliers of fresh fruit (named S1, S2, S3, S4, S5, and S6) were considered and analyzed according to the seven main criteria and eleven indicators for supplier evaluation (see Table 3).

Table 3. Criteria for fresh fruit supplier selection for an agrifood SME.

Main Criteria	Indicator	Description
C_1—Cost	C_{11}—Product Price	Lower fresh fruit price without compromising the quality
	C_{12}—Transportation Cost	Fixed transportation cost of the fresh fruit
C_2—Quality	C_{21}—Quality Assurance	Ensure superior quality control of the fruit, and provide quality related certificates such as ISO 9000
	C_{22}—Reject Rate	The percentage of supplied fruit that is rejected by quality control
C_3—Delivery	C_{31}—Delivery Capability	The ability of the supplier to fulfil the delivery schedule
	C_{32}—Order Fulfilment Rate	Conformity with the predefined order quantities
C_4—Protection	C_{41}—Environmental Protection System	Environmental protection system specification, such as ISO 14001 (contributes to the environmental pillar of sustainability)
	C_{42}—Safety	Use of protective equipment, accidents record
C_5—Distance	C_{51}—Road distance	Road distance between the supplier and the company
C_6—Technology	C_{61}—Technological capability	Related to product and process improvement; ownership of infrastructure for research and innovation
C_7—Financial Position	C_{71}—Financial Stability	Refers to financial stability and credit rating

These criteria represent the most significant factors for the supplier ranking process. The weights of the criteria were allocated by six experts (E1, E2, E3, E4, E5, and E6) from the company who work directly with suppliers. Each expert classified the importance of the criteria from 0 to 1, with the sum of all weights being one (see Table 4). The price of fresh Golden Apple (1 kg) was used as Product Price (C11).

Table 4. Value of weight coefficients assigned by the company experts.

	E1	E2	E3	E4	E5	E6	Mean
C_{11}—Product Price	-	-	-	-	-	-	-
C_{12}—Transportation Cost	0.11	0.10	0.11	0.09	0.10	0.11	0.10
C_{21}—Quality Assurance	0.21	0.18	0.19	0.20	0.20	0.19	0.20
C_{22}—Reject Rate	0.07	0.07	0.06	0.06	0.07	0.08	0.07
C_{31}—Delivery Capability	0.06	0.05	0.08	0.07	0.06	0.07	0.07
C_{32}—Order Fulfillment Rate	0.07	0.06	0.07	0.05	0.05	0.07	0.06
C_{41}—Environmental Protection System	0.04	0.03	0.05	0.04	0.03	0.03	0.04
C_{42}—Safety	0.04	0.07	0.04	0.05	0.04	0.04	0.05
C_{51}—Road distance	0.07	0.08	0.07	0.07	0.10	0.11	0.08
C_{61}—Technological capability	0.02	0.04	0.04	0.04	0.03	0.02	0.03
C_{71}—Financial Stability	0.12	0.11	0.09	0.12	0.12	0.10	0.11

Table 4 shows that the cost and quality criteria represent higher weights, indicating that experts consider the most important aspects as the price and quality of the fresh fruit that suppliers offer and sell. Further, the criteria related to technological capability and environmental protection are among the least important. This shows that the company's experts are not yet very sensitive to environment-related issues, safety, and technological development.

Supplier evaluation for this Portuguese company was done according to these criteria, through a survey in which the same six experts were asked to use a 5-point Likert scale, where the lowest mark is 1 (qualitative level—Very Low) and the highest is 5 (qualitative level—Very High). The fresh fruit supplier assessment value (mean of all the marks) attributed by the experts are provided in Table 5.

Table 5. Suppliers' marks assigned by the company experts with respect to the criteria.

	S1	S2	S3	S4	S5	S6
C_{11}—Product Price	-	-	-	-	-	-
C_{12}—Transportation Cost	3.6	4.2	4.1	4.8	4	3.9
C_{21}—Quality Assurance	3.9	3.7	4	4.5	4.8	3.8
C_{22}—Reject Rate	4	3.4	4.1	4.7	4.2	3.1
C_{31}—Delivery Capability	4.1	3.6	3.9	4.5	3.3	3.6
C_{32}—Order Fulfilment Rate	4.7	4	4.2	4	3.4	3.9
C_{41}—Environmental Protection System	4	4.1	4.8	3.4	3.9	4.2
C_{42}—Safety	3.8	3.9	2.7	4.1	3.8	4
C_{51}—Road distance	3.1	4.9	4.6	3.8	4.2	2.7
C_{61}—Technological	3.7	3.2	3.1	3.8	3.4	4.2
C_{71}—Financial Stability	4	3.3	3.8	4.1	4.5	4

5. Results and Discussion

The preference flows for each action are outlined in Table 6; the whole order achieved by PROMETHE II is centered in the difference concerning the strengths and the weakness of each alternative.

Table 6. The comprehensive, positive, and negative flows of the suppliers.

Rank	Actions	Net Flow (Phi)	Positive Flow (Phi+)	Negative Flow (Phi−)
1	Supplier 4 (S4)	0.2042	0.3464	0.1423
2	Supplier 6 (S6)	0.0784	0.2295	0.1512
3	Supplier 1 (S1)	0.0772	0.2572	0.1800
4	Supplier 5 (S5)	0.0197	0.2305	0.2107
5	Supplier 3 (S3)	−0.1833	0.1260	0.3093
6	Supplier 2 (S2)	−0.1962	0.0937	0.2898

The partial order obtained with PROMETHEE I allows the firm to refine its positioning strategies. As presented in Figure 2, Supplier 4 is, obviously, the leader in this set of suppliers and is followed by Suppliers 6 and 1, who present a relevant position with regard to the others. Nevertheless, the PROMETHEE I method shows that Suppliers 1 and 6 are described by variables that are not comparable, that is, they have different strong and weak points. Therefore, we cannot say that one is more competitive than the other is. It is clear that Supplier 1 ranks above Supplier 5, and Supplier 3 presents one of the weakest positions followed by Supplier 2 who has the worst position among the suppliers considered.

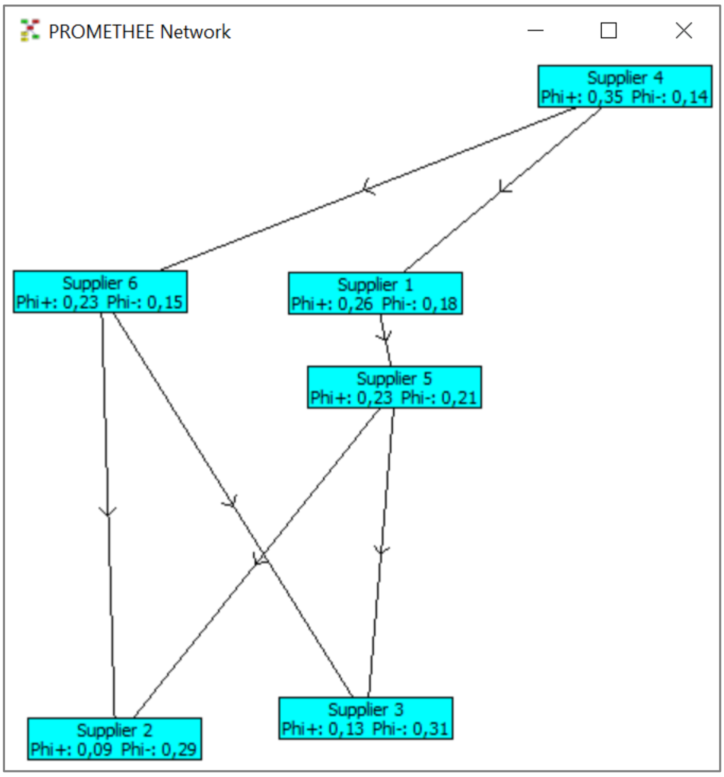

Figure 2. PROMETHEE Network, considering criteria values and weighting. Source: The results were generated by the PROMETHEE-GAIA software.

Figure 3 illustrates the PROMETHEE I partial ranking—calculated from positive and negative flows. In positive flow, suppliers are ranked in the order S4–S1–S5–S6–S3–S2, while there is a small difference in the order of the suppliers in negative flow: S4–S6–S1–S5–S2–S3. This ranking indicates that S4 is preferred to all other alternatives.

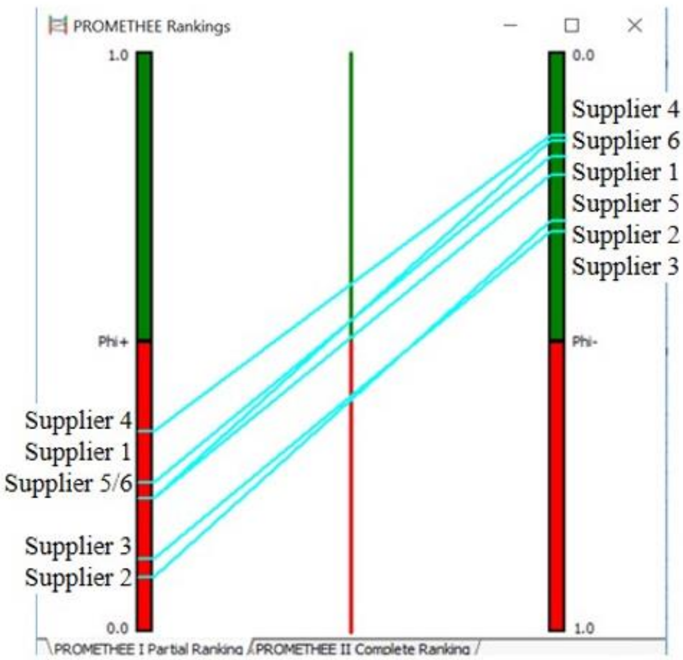

Figure 3. PROMETHEE I—Partial Ranking. Source: The results were generated by the PROMETHEE-GAIA software.

The complete order was obtained with PROMETHEE II and is based on the net flows (Table 5). From the complete ranking of PROMETHEE II, the upper half of the scale (green) corresponds to a positive Phi score and the bottom half (red) to negative score. Therefore, PROMETHEE II complete ranking confirms these results (Figure 4). The PROMETHEE II Complete Ranking shows that Supplier 4 (S4) is the alternative with the highest net outranking flow and a higher phi score (0.2042), followed by Supplier 6 (S6) with a phi score of 0.0784, and Supplier 1 (S1) with a phi score of 0.0772.

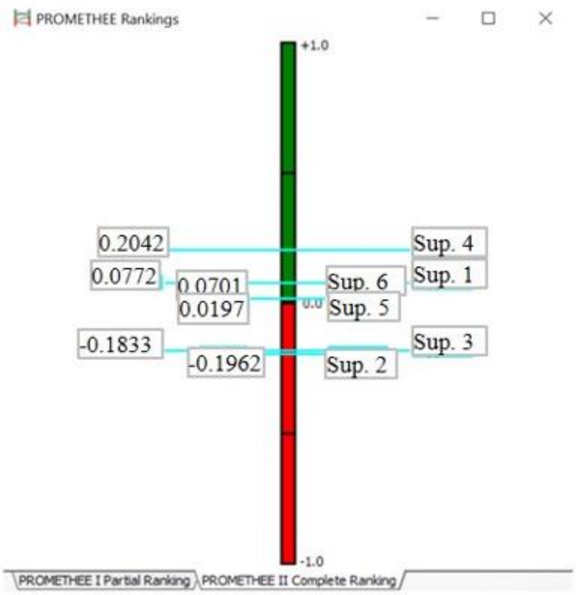

Figure 4. PROMETHEE II—Complete Ranking. Source: The results were generated by the PROMETHEE-GAIA software.

The stacked bar chart (Figure 5) shows the criteria that determine the strengths and weaknesses of each supplier, as well as to see the similarities and differences between suppliers. In addition, we can see whether the suppliers are balanced (such as Supplier 4), whether they display outstanding positive attributes (such as Suppliers 6, 1, and 5), or whether they clearly show negative traits (as is the case with Suppliers 3 and 2).

The GAIA plan (Figure 6) facilitates clear identification of the similarities between suppliers, as well as their relative strengths and weaknesses. The criteria are represented by vectors and the suppliers (alternatives) by points.

As showed in Figure 6, the measurement quality is approximately 84%, indicating that this problem has good solution accuracy. This implies that 16% of all information is eliminated by the projection. The analysis can be considered as sufficiently reliable, provided that the quality remains above 75% [28].

The competitive position of each supplier is shown in the distribution of criteria in the GAIA plan. This representation makes it possible to identify two groups of supplier selection criteria. The first group contains the criteria Transportation Cost, Quality, Safety, and Financial Stability; note that the Safety axis is larger than the others are which means that Safety has a greater influence. The second group includes Product Price, Delivery Capability, Road Distance, and Technological Capability; Product Price and Delivery Capability have a similar short length, indicating that their impact is low and that they have an analogous power of discrimination; Road Distance and Technological Capability have a greater influence. Regarding the criterion Environmental Protection Systems, it shows a long length but its different direction results in a low added value in the selection process.

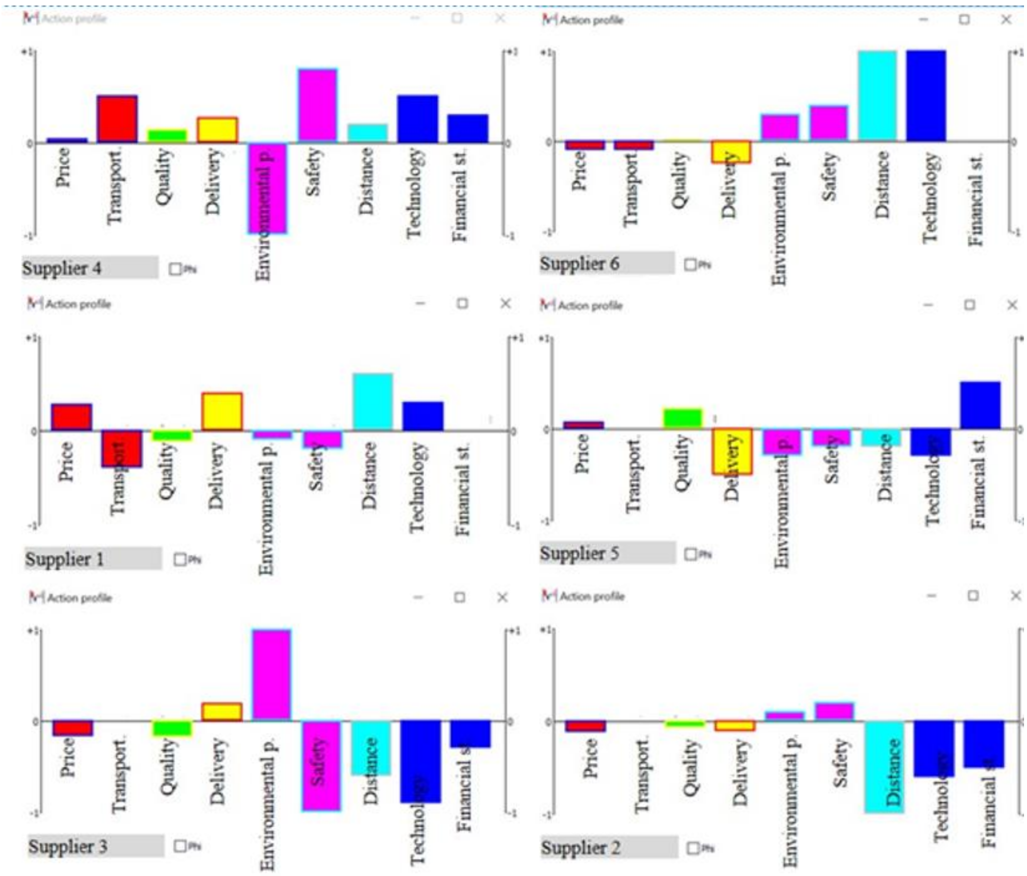

Figure 5. Stacked bar chart. Source: The results were generated by the PROMETHEE-GAIA software.

Supplier 4 is clearly the leader of the group of suppliers. In addition, the direction of the decision stick (D) shows that supplier 4 has different characteristics from the rest. Thus, while S4 highlights due to its good scores in the first group of supplier selection criteria (Transportation Cost, Quality, Safety, and Financial Stability), all other suppliers rank low in that criteria and present an opposite pattern of characteristics. S4 is therefore the best compromise; this supplier is preferred to all other alternatives that match the results stated previously. However, it is worth noting that Environmental Protection emerge as an important weakness of this supplier. Supplier 6 is the second supplier in the ranking. It also holds a clear position, with high scores for the innovation indicator, medium scores for the social and environmental indicators and low scores for the other economic indicators. Its greatest weakness is delivery capability.

In our study, supplier selection process seems to be developed using two different sets of criteria. The first set highlights the social criterion (safety) complemented with economic factors (transport cost, financial stability and quality); therefore, social and economic issues are the most relevant factors to select a supplier. The second set emphasizes that a supplier can also be valuable due to its innovation capability (technological capability) and geographical proximity. Finally, environmental criteria are shown as a less relevant criterion.

The results of this study indicate that economic criteria play a more important role in this case. In addition, social criteria seem to be important when selecting suppliers. However, environmental criteria are relegated to the background. These results make some theoretical and managerial issues regarding supplier selection visible. From a theoretical point of view, it is shown that there is a need to go deeper into the social criteria. Those criteria have scarcely been addressed in the academic literature. However, it is shown that they are relevant criteria in the selection of suppliers; in fact, safety have a significant social, environmental, and financial impact [40]. Thus, accidents and a safe and healthy working environment, and how this can affect performance, seem to be an interesting stream of future research.

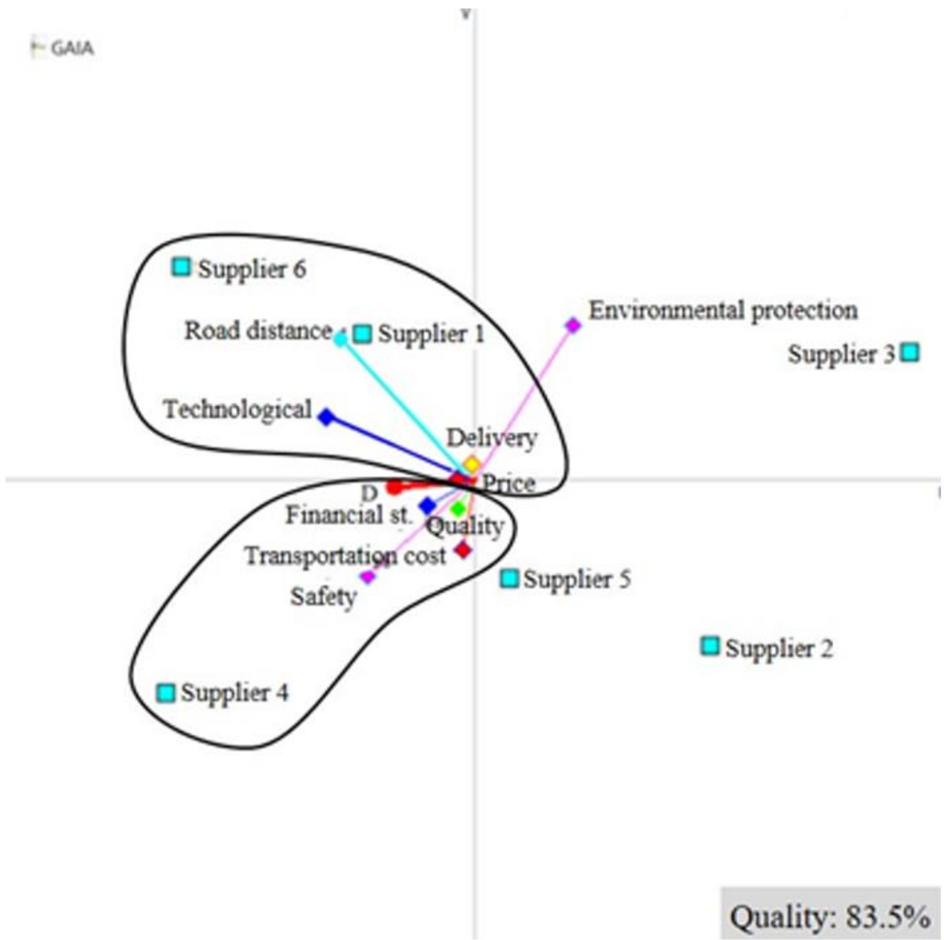

Figure 6. GAIA Plane. Source: The results were generated by the PROMETHEE-GAIA software.

From a managerial perspective, the results of this study can help decision-makers to evaluate the alignment between the supplier selection process and the strategy of the firm, in order to make changes that strengthen its competitive position. In this sense, it is highlighted a strength of the current supplier selection process, as they indicate that two complementary sets of criteria are followed. On the one hand, suppliers are selected to pursue economic criteria and this can favour the present performance of the firm. On the other hand, suppliers also can be selected because of their innovative capacity and this is according to the need to adapt to the context and the maintenance of a competitive position in the future.

However, the analysis shows a weak point of that process because the environmental criterion is not a relevant factor to select suppliers; they are not only considered of little relevance, but they do not enable suppliers to increase their probability of selection. Nevertheless, that criterion is one of the strategic lines of the firm and one important issue in the actual environment. This fact seems to be an important flaw of the actual decision-making process. Therefore, managers should pay more attention to environmental issues and look for sustainability through the entire supply chain.

6. Conclusions

The supplier selection problem is a difficult and critical decision-making consideration for most companies in search of competitive advantage in purchasing. According to the literature, the supplier selection problem in the food industry have been scarcely addressed.

This paper deals with that gap, applying a PROMETHEE method for the evaluation and selection of the most preferred supplier in an agrifood medium-sized enterprise in Portugal. After that, the visual PROMETHEE-GAIA software was used to interpret the ranking of suppliers. The visual PROMETHEE software has proved to be a valuable tool in considering the strengths and weaknesses of all the suppliers in all the criteria in order to rank and select suppliers. The contribution of this approach is significant in comparison with former approaches.

The ranking demonstrated that Supplier 4 (S4) was the leader of the group of six suppliers; it has a strong position in social and economic criteria but fails in environmental protection. Supplier 6 (S6) is the second-best option; this fact enhances the relevance of technological capability. From a theoretical perspective, these results raise awareness that there is a need to go deeper into the social criteria as they are important for the firms but scarcely addressed in the academic literature.

From a managerial perspective, the results of this study can help the decision-makers to evaluate and correct the alignment between the supplier selection process and the strategy of the firm. In this sense, a strength of the supplier selection process is selected, as they indicate that two complementary sets of criteria are follow, efficiency and innovation. Nevertheless, a weak point emerges since environmental criteria, even being one of the goals of the firm, are hardly considered. Managers should pay more attention to environmental issues and look for sustainability through the entire supply chain. This fact seems to be an important aspect for improvement in future decision-making processes. Despite the advantages of PROMETHEE-GAIA, this approach has some limitations. The application of this methodology requires the simplification of some PROMETHEE functions. Assigning weights to the criteria and set preferences functions for supplier selection criteria is difficult because all the criteria are important and it is not always simple to choose the best preference function for a given criterion.

Finally, future research may consider the use of other ranking techniques, such as the Best-Worst Method (BWM), in which decision-makers choose the best (most significant) criterion and the worst (least significant) criterion and then provide two preference vectors by comparing criteria best to other (BO) and other to worst (OW) [76,77], the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [14,78] under fuzzy environment, namely fuzzy-TOPSIS [12,79,80], Analytic Hierarchy Process (AHP) [10,11], Elimination and Choice Expressing Reality (ELECTRE) [23,81], Stepwise Weight Assessment Ratio Analysis (SWARA) [82,83] and similar techniques can be applied to elicit the position of each alternative. In addition, the proposed approach can be implemented in other fields, such as, Logistics, Financial Applications, Industrial Location, Manpower Planning, Water Resources, Investments, Medicine, Chemistry, Health Care, Tourism, Management, among others.

Author Contributions: Conceptualization, A.P.L. and N.R.-L.; methodology, A.P.L. and N.R.-L.; software, A.P.L. and N.R.-L.; validation, A.P.L. and N.R.-L.; formal analysis, A.P.L. and N.R.-L.; investigation, A.P.L. and N.R.-L.; resources, A.P.L. and N.R.-L.; data curation, A.P.L. and N.R.-L.; writing—original draft preparation, A.P.L. and N.R.-L.; writing—review and editing, A.P.L. and N.R.-L.; visualization, A.P.L. and N.R.-L.; supervision, A.P.L. and N.R.-L.; project administration, A.P.L. and N.R.-L.; funding acquisition, A.P.L. and N.R.-L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was partially supported by the IACOBUS Programme. This work was financed by Portuguese national funds through FCT—Fundação para a Ciência e Tecnologia, under the project UIDB/05422/2020.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. O'Regan, N.; Sims, M.; Ghobadian, A. High performance: Ownership and decision-making in SMEs. *Manag. Decis.* **2005**, *43*, 382–396. [CrossRef]
2. Govindan, K.; Rajendran, S.; Sarkis, J.; Murugesan, P. Multi criteria decision making approaches for green supplier evaluation and selection: A literature review. *J. Clean. Prod.* **2013**, *98*, 66–83. [CrossRef]
3. Banaeian, N.; Mobli, H.; Fahimnia, B.; Nielsen, I.E.; Omid, M. Green supplier selection using fuzzy group decision making methods: A case study from the agri-food industry. *Comput. Oper. Res.* **2018**, *89*, 337–347. [CrossRef]
4. Guarnieri, P. Síntese dos Principais Critérios, Métodos e Subproblemas da Seleção de Fornecedores Multicritério. *Synth. Main Criteria Methods Issues Multicriteria Supplier Sel.* **2015**, *19*, 1–25. [CrossRef]
5. Gupta, H.; Barua, M.K. Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS. *J. Clean. Prod.* **2017**, *152*, 242–258. [CrossRef]
6. Vetschera, R.; de Almeida, A.T. A promethee-based approach to portfolio selection problems. *Comput. Oper. Res.* **2012**, *39*, 1010–1020. [CrossRef]
7. Kizielewicz, B.; Więckowski, J.; Shekhovtsov, A.; Wątróbski, J.; Depczyński, R.; Sałabun, W. Study towards the time-based mcda ranking analysis—A supplier selection case study. *Facta Univ. Ser. Mech. Eng.* **2021**, *19*, 381–399.
8. Biswas, T.K.; Das, M.C. Selection of the barriers of supply chain management in Indian manufacturing sectors due to Covid-19 impacts. *Oper. Res. Eng. Sci. Theory Appl.* **2020**, *3*, 1–12. [CrossRef]
9. Schramm, V.B.; Cabral, L.P.B.; Schramm, F. Approaches for supporting sustainable supplier selection—A literature review. *J. Clean. Prod.* **2020**, *273*, 123089. [CrossRef]
10. Astanti, R.D.; Mbolla, S.E.; Ai, T.J. Raw material supplier selection in a glove manufacturing: Application of AHP and fuzzy AHP. *Decis. Sci. Lett.* **2020**, *9*, 291–312. [CrossRef]
11. Fagundes, M.V.C.; Keler, A.C.; Teles, E.O.; de Melo, S.A.B.V.; Freires, F.G.M. Multicriteria Decision-Making System for Supplier Selection Considering Risk: A Computational Fuzzy AHP-Based Approach. *IEEE Lat. Am. Trans.* **2021**, *19*, 1564–1572. [CrossRef]
12. Solanki, R.; Gulati, G.; Tiwari, A.; Lohani, Q.D. A correlation based Intuitionistic fuzzy TOPSIS method on supplier selection problem. In Proceedings of the 2016 IEEE International Conference on Fuzzy Systems, FUZZ-IEEE, Vancouver, BC, Canada, 24–29 July 2016; pp. 2106–2112.
13. Jain, V.; Sangaiah, A.K.; Sakhuja, S.; Thoduka, N.; Aggarwal, R. Supplier selection using fuzzy AHP and TOPSIS: A case study in the Indian automotive industry. *Neural Comput. Appl.* **2016**, *29*, 555–564. [CrossRef]
14. Jadidi, O.; Firouzi, F.; Bagliery, E. TOPSIS method for supplier selection problem. *World Acad. Sci. Eng. Technol.* **2010**, *47*, 956–958.
15. Utama, D.M.; Maharani, B.; Amallynda, I. Integration Dematel and ANP for the Supplier Selection in the Textile Industry: A Case Study. *J. Ilm. Tek. Ind.* **2021**, *20*, 119–130.
16. Önder, E.; Kabadayi, N. Supplier Selection in Hospitality Industry Using ANP. *Int. J. Acad. Res. Bus. Soc. Sci.* **2015**, *1*, 166–185.
17. Zaied, A.N.H.; Ismail, M.; Gamal, A. *An Integrated of Neutrosophic-ANP Technique for Supplier Selection*; Infinite Study: West Conshohocken, PA, USA, 2019; Volume 72, pp. 237–244.
18. Kilaparthi, S.; Sambana, N. Fuzzy kano—Vikor integrated approach for supplier selection—A case study. *Int. J. Mech. Prod. Eng. Res. Dev.* **2018**, *8*, 337–348.
19. Parkouhi, S.V.; Ghadikolaei, A.S. A resilience approach for supplier selection: Using Fuzzy Analytic Network Process and grey VIKOR techniques. *J. Clean. Prod.* **2017**, *161*, 431–451. [CrossRef]
20. Szmelter-Jarosz, A. DEMATEL Method in Supplier Evaluation and Selection. *Transp. Econ. Logist.* **2019**, *82*, 129–142. [CrossRef]
21. Kumar, M.; Garg, D.; Agarwal, A. Fuzzy DEMATEL approach for agile supplier selections performance criteria. *J. Phys. Conf. Ser.* **2019**, *1240*, 012157. [CrossRef]
22. Fahmi, A.; Kahraman, C.; Bilen, Ü. ELECTRE I Method Using Hesitant Linguistic Term Sets: An Application to Supplier Selection. *Int. J. Comput. Intell. Syst.* **2016**, *9*, 153–167. [CrossRef]
23. Tham, T.T.; Le, D.T.H. An integrated approach of fuzzy ELECTRE I for supplier selection. *Int. J. Appl. Manag. Sci.* **2021**, *13*, 240–274. [CrossRef]
24. Wan, S.-P.; Xu, G.-L.; Dong, J.-Y. Supplier selection using ANP and ELECTRE II in interval 2-tuple linguistic environment. *Inf. Sci.* **2017**, *385–386*, 19–38. [CrossRef]
25. Peide, L. Research on the supplier selection of supply chain based on the improved ELECTRE-II method. In Proceedings of the Workshop on Intelligent Information Technology Application, IITA, Zhangjiajie, China, 2–3 December 2007.
26. Liu, P.; Zhang, X. Research on the supplier selection of a supply chain based on entropy weight and improved ELECTRE-III method. *Int. J. Prod. Res.* **2011**, *49*, 637–646. [CrossRef]
27. Guarnieri, P.; Trojan, F. Decision making on supplier selection based on social, ethical, and environmental criteria: A study in the textile industry. *Resour. Conserv. Recycl.* **2018**, *141*, 347–361. [CrossRef]
28. Agrawal, N. Multi-criteria decision-making toward supplier selection: Exploration of PROMETHEE II method. *Benchmarking Int. J.* **2021**, ahead-of-print. [CrossRef]
29. Isa, M.A.M.; Saharudin, N.S.; Anuar, N.B.; Mahad, N.F. The application of AHP-PROMETHEE II for supplier selection. *J. Phys. Conf. Ser.* **2021**, *1988*, 012062. [CrossRef]
30. Abdullah, L.; Chan, W.; Afshari, A. Application of PROMETHEE method for green supplier selection: A comparative result based on preference functions. *J. Ind. Eng. Int.* **2018**, *15*, 271–285. [CrossRef]

31. Madić, M.; Marković, D.; Petrović, G.; Radovanović, M. Application of COPRAS method for supplier selection. In Proceedings of the Fifth International Conference Transport and Logistics-TIL, Niš, Serbia, 5–6 June 2014.
32. Sałabun, W.; Watróbski, J.; Shekhovtsov, A. Are MCDA methods benchmarkable? A comparative study of TOPSIS, VIKOR, COPRAS, and PROMETHEE II methods. *Symmetry* **2020**, *12*, 1549. [CrossRef]
33. Chai, J.; Liu, J.N.; Ngai, E.W. Application of decision-making techniques in supplier selection: A systematic review of literature. *Expert Syst. Appl.* **2013**, *40*, 3872–3885. [CrossRef]
34. Chai, J.; Ngai, E.W. Decision-making techniques in supplier selection: Recent accomplishments and what lies ahead. *Expert Syst. Appl.* **2019**, *140*, 112903. [CrossRef]
35. Wątróbski, J.; Jankowski, J.; Ziemba, P.; Karczmarczyk, A.; Zioło, M. Generalised framework for multi-criteria method selection. *Omega* **2018**, *86*, 107–124. [CrossRef]
36. Wątróbski, J.; Jankowski, J.; Ziemba, P.; Karczmarczyk, A.; Zioło, M. Generalised framework for multi-criteria method selection: Rule set database and exemplary decision support system implementation blueprints. *Data Brief* **2018**, *22*, 639–642. [CrossRef] [PubMed]
37. Agarwal, G.; Vijayvargy, L. Modeling of Intangibles: An Application in Supplier Selection in Supply Chain—A Case Study of Multinational Food Industry. *Int. J. Manag. Innov.* **2013**, *5*, 61–80. [CrossRef]
38. Voss, M.D.; Closs, D.J.; Calantone, R.J.; Helferich, O.K.; Speier, C. The role of security in the food supplier selection decision. *J. Bus. Logist.* **2009**, *30*, 127–155. [CrossRef]
39. Azadfallah, M. Supplier Selection using MADM Method under Uncertainty. *J. Supply Chain Manag. Syst.* **2016**, *5*, 1–8. [CrossRef]
40. de Santis, R.B.; Golliat, L.; de Aguiar, E.P. Multi-Criteria Supplier Selection Using Fuzzy Analytic Hierarchy Process: Case Study from a Brazilian Railway Operator. *Braz. J. Oper. Prod. Manag.* **2017**, *14*, 428–437. [CrossRef]
41. Lima-Junior, F.R.; Carpinetti, L.C.R. A multicriteria approach based on fuzzy QFD for choosing criteria for supplier selection. *Comput. Ind. Eng.* **2016**, *101*, 269–285. [CrossRef]
42. Ortiz-Barrios, M.A.; Kucukaltan, B.; Carvajal-Tinoco, D.; Neira-Rodado, D.; Jiménez, G. Strategic hybrid approach for selecting suppliers of high-density polyethylene. *J. Multi-Criteria Decis. Anal.* **2017**, *24*, 296–316. [CrossRef]
43. Hamdan, S.; Cheaitou, A. Supplier selection and order allocation with green criteria: An MCDM and multi-objective optimization approach. *Comput. Oper. Res.* **2017**, *81*, 282–304. [CrossRef]
44. Sarkar, S.; Pratihar, D.K.; Sarkar, B. An integrated fuzzy multiple criteria supplier selection approach and its application in a welding company. *J. Manuf. Syst.* **2018**, *46*, 163–178. [CrossRef]
45. Wetzstein, A.; Hartmann, E.; Benton, W.C., Jr.; Hohenstein, N.-O. A systematic assessment of supplier selection literature–State-of-the-art and future scope. *Int. J. Prod. Econ.* **2016**, *182*, 304–323. [CrossRef]
46. Weber, C.A.; Current, J.R.; Benton, W. Vendor selection criteria and methods. *Eur. J. Oper. Res.* **1991**, *50*, 2–18. [CrossRef]
47. Yazdani, M.; Chatterjee, P.; Zavadskas, E.K.; Zolfani, S.H. Integrated QFD-MCDM framework for green supplier selection. *J. Clean. Prod.* **2017**, *142*, 3728–3740. [CrossRef]
48. Asadabadi, M.R. A customer based supplier selection process that combines quality function deployment, the analytic network process and a Markov chain. *Eur. J. Oper. Res.* **2017**, *263*, 1049–1062. [CrossRef]
49. Luthra, S.; Govindan, K.; Kannan, D.; Mangla, S.K.; Garg, C.P. An integrated framework for sustainable supplier selection and evaluation in supply chains. *J. Clean. Prod.* **2017**, *140*, 1686–1698. [CrossRef]
50. de Boer, L.; Labro, E.; Morlacchi, P. A review of methods supporting supplier selection. *Eur. J. Purch. Supply Manag.* **2001**, *7*, 75–89. [CrossRef]
51. de Boer, L. Procedural rationality in supplier selection. *Manag. Decis.* **2017**, *55*, 32–56. [CrossRef]
52. Chen, Y.-J. Structured methodology for supplier selection and evaluation in a supply chain. *Inf. Sci.* **2011**, *181*, 1651–1670. [CrossRef]
53. Ho, W.; Xu, X.; Dey, P. Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *Eur. J. Oper. Res.* **2010**, *202*, 16–24. [CrossRef]
54. Karsak, E.E.; Dursun, M. Taxonomy and review of non-deterministic analytical methods for supplier selection. *Int. J. Comput. Integr. Manuf.* **2015**, *29*, 263–286. [CrossRef]
55. Izadikhah, M.; Saen, R.F.; Ahmadi, K. How to Assess Sustainability of Suppliers in the Presence of Dual-Role Factor and Volume Discounts? A Data Envelopment Analysis Approach. *Asia-Pac. J. Oper. Res.* **2017**, *34*, 1740016. [CrossRef]
56. Ranjan, R.; Chatterjee, P.; Chakraborty, S. Performance evaluation of Indian states in tourism using an integrated PROMETHEE-GAIA approach. *OPSEARCH* **2015**, *53*, 63–84. [CrossRef]
57. Amorim, P.; Curcio, E.; Almada-Lobo, B.; Barbosa-Póvoa, A.P.; Grossmann, I.E. Supplier selection in the processed food industry under uncertainty. *Eur. J. Oper. Res.* **2016**, *252*, 801–814. [CrossRef]
58. Sahraei, L. Providing a Structured Method for Supplier Evaluation and Ranking under Agility Approach and based on MODM Techniques. *Int. J. Sci. Manag. Dev.* **2017**, *5*, 266–273.
59. Degraeve, Z.; Labro, E.; Roodhooft, F. An evaluation of vendor selection models from a total cost of ownership perspective. *Eur. J. Oper. Res.* **2000**, *125*, 34–58. [CrossRef]
60. Brans, J.P. *L'ingénierie de la Décision: Élaboration D'instruments D'aide à la Décision. La Méthode PROMETHEE*; Presses de l'Université Laval: Québec, QC, Canada, 1982.

61. Brans, J.; Vincke, P. A preference ranking organization method: The PROMETHEE method for MCDM. *Manag. Sci.* **1985**, *31*, 647–656. [CrossRef]
62. Brans, B.; Mareschal, J.P. *Promethee Methods: Multiple Criteria Decision Analysis: State of the Art Surveys*; Springer: New York, NY, USA, 2005; Volume 78, pp. 163–186.
63. Behzadian, M.; Kazemzadeh, R.; Albadvi, A.; Aghdasi, M. PROMETHEE: A comprehensive literature review on methodologies and applications. *Eur. J. Oper. Res.* **2010**, *200*, 198–215. [CrossRef]
64. Anahas, A.M.P.; Muralitharan, G. Characterization of heterocystous cyanobacterial strains for biodiesel production based on fatty acid content analysis and hydrocarbon production. *Energy Convers. Manag.* **2018**, *157*, 423–437. [CrossRef]
65. de Almeida-Filho, A.T.; Monte, M.; Morais, D.C. A Voting Approach Applied to Preventive Maintenance Management of a Water Supply System. *Group Decis. Negot.* **2016**, *26*, 523–546. [CrossRef]
66. Andreopoulou, Z.; Koliouska, C.; Galariotis, E.; Zopounidis, C. Renewable energy sources: Using PROMETHEE II for ranking websites to support market opportunities. *Technol. Forecast. Soc. Chang.* **2018**, *131*, 31–37. [CrossRef]
67. Kilic, H.S.; Zaim, S.; Delen, D. Selecting 'the best' ERP system for SMEs using a combination of ANP and PROMETHEE methods. *Expert Syst. Appl.* **2015**, *42*, 2343–2352. [CrossRef]
68. Yilmaz, B.; Dağdeviren, M. A combined approach for equipment selection: F-PROMETHEE method and zero-one goal programming. *Expert Syst. Appl.* **2011**, *38*, 11641–11650. [CrossRef]
69. Albadvi, A.; Chaharsooghi, S.K.; Esfahanipour, A. Decision making in stock trading: An application of PROMETHEE. *Eur. J. Oper. Res.* **2007**, *177*, 673–683. [CrossRef]
70. Lolli, F.; Ishizaka, A.; Gamberini, R.; Rimini, B.; Ferrari, A.M.; Marinelli, S.; Savazza, R. Waste treatment: An environmental, economic and social analysis with a new group fuzzy PROMETHEE approach. *Clean Technol. Environ. Policy* **2016**, *18*, 1317–1332. [CrossRef]
71. Peng, A.-H.; Xiao, X.-M. Material selection using PROMETHEE combined with analytic network process under hybrid environment. *Mater. Des.* **2013**, *47*, 643–652. [CrossRef]
72. Nemery, P.; Ishizaka, A.; Camargo, M.; Morel, L. Enriching descriptive information in ranking and sorting problems with visualizations techniques. *J. Model. Manag.* **2012**, *7*, 130–147. [CrossRef]
73. Alencar, L.H.; de Almeida, A.T. A model for selecting project team members using multicriteria group decision making. *Pesqui. Oper.* **2010**, *30*, 221–236. [CrossRef]
74. Brans, J.-P.; Mareschal, B. The PROMCALC & GAIA decision support system for multicriteria decision aid. *Decis. Support Syst.* **1994**, *12*, 297–310.
75. .Lopes, A.P.F.; Muñoz, M.M.; Alarcón-Urbistondo, P. Regional tourism competitiveness using the PROMETHEE approach. *Ann. Tour. Res.* **2018**, *73*, 1–13. [CrossRef]
76. Faizi, S.; Sałabun, W.; Nawaz, S.; Rehman, A.U.; Wątróbski, J. Best-Worst method and Hamacher aggregation operations for intuitionistic 2-tuple linguistic sets. *Expert Syst. Appl.* **2021**, *181*, 115088. [CrossRef]
77. Tian, Z.-P.; Zhang, H.-Y.; Wang, J.-Q.; Wang, T.-L. Green Supplier Selection Using Improved TOPSIS and Best-Worst Method Under Intuitionistic Fuzzy Environment. *Informatica* **2018**, *29*, 773–800. [CrossRef]
78. Shahroudi, K.; Tonekaboni, S.S. Application of topsis method to supplier selection in iran auto supply chain. *J. Glob. Strat. Manag.* **2012**, *2*, 123. [CrossRef]
79. Rouyendegh, B.D.; Yildizbasi, A.; Üstünyer, P. Intuitionistic Fuzzy TOPSIS method for green supplier selection problem. *Soft Comput.* **2020**, *24*, 2215–2228. [CrossRef]
80. Pınar, A.; Erdebilli, B.; Özdemir, Y. q-Rung Orthopair Fuzzy TOPSIS Method for Green Supplier Selection Problem. *Sustainability* **2021**, *13*, 985. [CrossRef]
81. Taqi, H.M.M.; Ahmed, S. Fuzzy TOPSIS and Fuzzy ELECTRE-I Approach for Selecting the Best Suppliers by Multiple Criteria. *Int. J. Appl. Fuzzy Sets Artif. Intell.* **2018**, *8*, 155–173.
82. Rani, P.; Mishra, A.R.; Krishan Kumar, R.; Mardani, A.; Cavallaro, F.; Ravichandran, K.S.; Balasubramanian, K. Hesitant Fuzzy SWARA-Complex Proportional Assessment Approach for Sustainable Supplier Selection (HF-SWARA-COPRAS). *Symmetry* **2020**, *12*, 1152. [CrossRef]
83. Rajesh, G.; Malliga, P. Selection of suppliers using Swara and Copras-G. *Int. J. Enterp. Netw. Manag.* **2018**, *9*, 169–185. [CrossRef]