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Sustainable Supplier Selection and Evaluation for the Effective Supply Chain Management System

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Abstract: With increased environmental protection awareness, sustainability has been incorporated into supply chain management. Sustainable supplier selection and evaluation have become an acritical part of supply chain management. They can significantly improve the supply chain's operational performance and enhance enterprises' competitiveness. Based on trapezoidal interval type-2 fuzzy numbers (TIT2FNs) and cloud probability dominance relations (PDR), manufacturers can make more tangible and environmentally friendly decisions in the SSSE process. In this paper, a SSSE indicator system is first established using the necessary economic, environmental, and social factors. The importance of the indicators described in linguistic terms is transformed into TIT2FNs, and the weight of each indicator is calculated. In order to prevent candidate suppliers from promoting performance maliciously, different weights are given according to the impact of the enterprise's historical performance on the present. Finally, the cloud PDR method is used to determine the optimal sustainable supplier. A case study and analysis are provided to show the feasibility and superiority of the proposed method.

Keywords: sustainable supplier selection and evaluation (SSSE); TIT2FNs; cloud PDR; supply chain management (SCM); operational performance improvement; sensitivity analysis

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1. Introduction

Due to the high globalization and increased expectations of customers, enterprises should strengthen their supply chain management (SCM) ability to constantly shorten product development time, improve quality, reduce cost, and enhance process efficiency. Supplier selection is the core content of supply chain management because the procurement cost of raw materials accounts for 60% of the total production cost of the enterprise [1–3]. However, traditional supplier selection pursues only economic benefits, and only a few researchers have focused on sustainable social factors or combined them with economic and environmental factors [4–8]. With the increasing attention to environmental and social issues, sustainable supply chain management, that is, introducing attention to environmental and social into SCM, has become an important research direction in operation management [9,10], and some research has already proven that cooperation with suppliers with strong environmental, societal, and economic awareness can significantly improve the sustainability of supply chains [11,12]. Therefore, many organizations are gradually paying more attention to economic-ecological-social aspects in supplier selection. However, there are many difficulties in the SSSE process, such as imperfect indicator systems, inflexible supplier selection, and qualitative methods [13–16]. Scholars in the sustainable supplier domain have applied several research methods, but these methods have limitations with regards to dealing with human judgment and unclearness in data [14,16].

This study aims to develop a novel SSSE method that can help enterprise managers choose more suitable sustainable suppliers. To achieve the objective, the evaluation indicators are first determined by searching the related literature for terms related to economic, environmental, and social indicators, including "lead time required", "environmental competencies", "social health care", and others. Due to the presence of ambiguity and uncertainty in human thinking, decision-making often encounters difficulties. The membership function of TIT2FNs, which has a great advantage in solving problems so that more scientific and robust results can be obtained, is more in line with the actual decision-making situation. In this paper, TIT2FNs are used to determine the weight of each indicator. Finally, the optimal sustainable supplier is determined based on the time weight and the cloud PDR.

In this decision-making process, cloud PDR fully considers the ambiguity, volatility, and randomness of a decision, making the evaluation process and results more objective and comprehensive. Hence, we identify and evaluate a comprehensive SSSE indicator system from the economic, environmental, and social aspects.

The remainder of this paper is organized as follows: Section 2 gives a critical literature review. Section 3 presents the research methodology. Section 4 presented a model. A case study is illustrated in Section 5. Sensitivity analysis is discussed in Section 6. Section 7 describes the managerial implications. Finally, conclusions are drawn in Section 8.

2. Literature Review

With the problems of natural resources shortages, environmental pollution, labor safety, labor rights, and interests becoming increasingly prominent, the public attributes these problems to the lack of corporate social responsibility, forcing enterprises to attach more importance to sustainable development. The sustainable supply chain has been the focus of managers, and the selection of sustainable suppliers is the core content of sustainable supply chain management. This article summarizes commonly used methods for sustainable supplier selection and evaluation.

The first is related studies assessed using a single method. Gören [17] calculated sustainable standard weights using the fuzzy decision-making trial and evaluation laboratory (DEMATEL) method and used the weights as the input of Taguchi loss function to rank calculation results, and finally, the decision-making framework for selecting sustainable supplier is obtained. Thanh and Lan [18] considered the triple bottom line, a fuzzy analytical hierarchical process (FAHP) approach addressing supplier selection in the food processing industry. Park et al. [19] determined the sustainable supply area through multi-attribute utility theory and applied the multi-objective integer linear programming model to find the optimal supplier. Mohammed et al. [20] adopted an approach with four stages: (1) using the fuzzy AHP to allocate the relative weights of the sustainable standards; (2) using the fuzzy TOPSIS to evaluate suppliers; (3) establishing a multi-objective programming model to obtain the optimal quantity allocation, and (4) TOPSIS was used to reveal the final solution of the Pareto solutions set. Govindan et al. [21] assumed the random demand of retailers and proposed a multi-objective hybrid approach to minimize the total cost and environmental impact under the framework of the supply chain network. Moheb-Alizadeh and Handfield [22] built a multi-objective mixed integer nonlinear programming (MINLP) model to achieve sustainable supplier selection. Govindan et al. [23] proposed the ELECTRE-based method to effectively approach the problem of the third-party reverse logistics providers' selection. Yousefi et al. [24] proposed robust dynamic DEA to identify sustainable suppliers. Taking into account business and environmental factors, Yu et al. [25] proposed a transportation distance method considering supplier selection and also proposed an incentive mechanism to urge policy makers to make more environmentally friendly decisions. Su et al. [26] used a hierarchical gray DEMATEL method to analyze criteria in an environment with incomplete information.

Some integrated methods have also been proposed. Sarkis and Dhavale [27] integrated a Bayesian framework and the Monte Carlo Markov chain (MCMC) method to select suppliers. Kumar et al. [28] proposed green DEA (GDEA) with carbon footprint monitoring to select environment friendly suppliers. Azadi et al. [29] combined data envelopment analysis (DEA) with the enhanced Russell measure (ERM) model to select optimal sustainable suppliers. Awasthi et al. [5] combined the fuzzy analytic hierarchy process (AHP) and Vlse Kriterjumska Optimizacija I Kompromisno Resenje (VIKOR) approach to propose a sustainable global supplier selection framework with sustainability risk from subsuppliers. Luthra et al. [16] integrated AHP, VIKOR, and a multi-criteria optimization and compromise solution approach to SSSE. Salimian et al. [30] presented a method combining an extended Vlsekriterijuska Optimizacija I Komoromisno Resenje (E-VIKOR) and measurement alternatives and ranking according to the compromise solution (MARCOS) for the selection of sustainable healthcare equipment suppliers. Shang et al. [31] integrated BWM, fuzzy Shannon entropy, and fuzzy MULTIMOORA methods to select suppliers. Fallahpour et al. [4] determined SSSE standards based on a questionnaire survey and then adopted a systematic method to evaluate sustainable suppliers. Cui et al. [32] proposes a hybrid model that integrates fuzzy set theory, stepwise weight assessment ratio analysis, and a Bayesian network to evaluate the critical SSS criteria in a three-tier supply chain. Izadikhah et al. [33] adopted the Charnes-Cooper-Rhodes (CCR) model to eliminate the inaccuracy of input and output, obtained goals through goal planning (GP) and DEA, and proposed a new method for evaluating supplier sustainability. Hatami-Marbini and Kangi [34] presented fuzzy TOPSIS, which included conventional TOPSIS, adjusted TOPSIS, and modified TOPSIS. Saputro et al. [35] integrated supplier selection with inventory management under supply disruptions. Jauhar and Pant [36] combined the traditional multi-criteria performance evaluation tool with the differential evolution algorithm to overcome the shortcomings of DEA and then developed an effective sustainable supplier selection system.

The literature review shows that the primary methods for SSSE are TOPSIS, AHP, DEMATEL, VIKOR, and others. Few scholars have used goal programming, artificial neural network (ANN), multivariate linear programming (MLP), and Markov chain Monte Carlo (MCMC) methods in their research. To the best of our knowledge, the integration of TIT2FNs and cloud PDR has not been used thus far. TIT2FNs have the advantage of describing uncertainty compared with other fuzzy numbers, which provides a new theoretical basis for handling uncertain problems [37–41]. The cloud PDR method integrates the advantages of cloud model theory with PDR, which fully considers the ambiguity, volatility, and randomness of the decision-making. This method does not strictly require all attributes of schemes to satisfy the dominance relation and only requires a certain proportional relationship. This method is more consistent with actual production and life, which can avoid those schemes and cannot be compared under multiple attributes [42–44]. In SSSE, there are three difficulties. First, it is difficult to construct an evaluation indicator system. Second, when evaluating sustainable suppliers, the evaluation language of the decision subject is vague. Third, it is not possible to compare candidate suppliers because supplier selection is flexible (manufacturers need different services from suppliers according to their development). Therefore, selecting sustainable suppliers based on an integration of TIT2FNs and cloud PDR has more critical theoretical and practical value.

3. Research Methodology

3.1. TIT2FNs

Type-2 fuzzy numbers provide a greater flexibility for formulation uncertainty. However, when using traditional type-2 fuzzy numbers to handle problems, the computation is very complicated and will take considerable time. Based on this, TIT2FNs with obvious advantages are usually adopted in literature. Compared to the type-2 fuzzy numbers, the calculation process of TIT2FNs is relatively effective. Therefore, the TIT2FNs are used in this paper. The relevant basic definitions are described as follows [37–41].

Definition 1. *$\overline{A}$ is a type-2 fuzzy set, and X is the universe of discourse. The membership function of type-2 is $u_{\overline{A}}$; $\overline{A}$ can be represented in two forms, namely:*

$$\overline{A} = \{((x,u), u_{\overline{A}}(x,u)) | \forall x \in X, \forall u \in J_x \subseteq [0,1]\} \tag{1}$$

$$\overline{A} = \int_{x \in X} \int_{u \in J_x} u_{\overline{A}}(x,u)/(x,u) \tag{2}$$

where $u_{\overline{A}}(x,u) \subseteq [0,1]$, $\int\int$ *refers to the union of all available x and u.*

Definition 2. *If the membership functions of the lower bound* $\widetilde{A}^L$ *and upper bound* $\widetilde{A}^U$ *of IT2FNs are all trapezoidal fuzzy numbers, then* $\widetilde{A}$ *is called TIT2FNs, which can be expressed by*

$$\widetilde{A} = (\widetilde{A}^U, \widetilde{A}^L) = ((\widetilde{a}_1^U, \widetilde{a}_2^U, \widetilde{a}_3^U, \widetilde{a}_4^U; H_1(\widetilde{A}^U), H_2(\widetilde{A}^U)), (\widetilde{a}_1^L, \widetilde{a}_2^L, \widetilde{a}_3^L, \widetilde{a}_4^L; H_1(\widetilde{A}^L), H_2(\widetilde{A}^L))) \tag{3}$$

where $H_j(\widetilde{A}^U)$ *and* $H_j(\widetilde{A}^L)$ *represent the upper and lower memberships function of* $\widetilde{a}_{j+1}^U$ *and* $\widetilde{a}_{j+1}^L$*, respectively.* $j+1$ *is the* $(j+1)$*th element of* $\widetilde{A}^U$ and $\widetilde{A}^L$, $1 \leq j \leq 2$.

Definition 3. *Let* $\widetilde{A} = (\widetilde{A}^U, \widetilde{A}^L) = ((\widetilde{a}_1^U, \widetilde{a}_2^U, \widetilde{a}_3^U, \widetilde{a}_4^U; H_1(\widetilde{A}^U), H_2(\widetilde{A}^U)), (\widetilde{a}_1^L, \widetilde{a}_2^L, \widetilde{a}_3^L, \widetilde{a}_4^L; H_1(\widetilde{A}^L), H_2(\widetilde{A}^L)))$ *and* $\widetilde{B} = (\widetilde{B}^U, \widetilde{B}^U) = ((\widetilde{b}_1^U, \widetilde{b}_2^U, \widetilde{b}_3^U, \widetilde{b}_4^U; H_1(\widetilde{B}^U), H_2(\widetilde{B}^U)), (\widetilde{b}_1^L, \widetilde{b}_2^L, \widetilde{b}_3^L, \widetilde{b}_4^L; H_1(\widetilde{B}^L), H_2(\widetilde{B}^L)))$ *be two TIT2FNs. The fundamental operations are given in Table A1 of Appendix A.*

Definition 4. *Let* $A_i (i = 1, 2, \ldots, n)$ *be a set of TIT2FNs, and assume that* $a_{i1}^L, a_{i2}^L, a_{i3}^L$ *and* a_{i4}^L *are greater than zero. The aggregation operator TIT2-WAA (trapezoidal interval type-2 weighted averaging) is also a TIT2FN.*

$$TIT2-WAA(A_i) = \begin{matrix} \left(\left(\sum_{i=1}^n w_i a_{i1}^U, \sum_{i=1}^n w_i a_{i2}^U, \sum_{i=1}^n w_i a_{i3}^U, \sum_{i=1}^n w_i a_{i4}^U; 1-\prod_{i=1}^n \left(1-H_1\left(A_i^U\right)\right)^{w_i}, 1-\prod_{i=1}^n \left(1-H_2\left(A_i^U\right)\right)^{w_i}\right)\right) \\ \left(\left(\sum_{i=1}^n w_i a_{i1}^L, \sum_{i=1}^n w_i a_{i2}^L, \sum_{i=1}^n w_i a_{i3}^L, \sum_{i=1}^n w_i a_{i4}^L; 1-\prod_{i=1}^n \left(1-H_1\left(A_i^L\right)\right)^{w_i}, 1-\prod_{i=1}^n \left(1-H_2\left(A_i^L\right)\right)^{w_i}\right)\right) \end{matrix} \tag{4}$$

where $\sum_{i=1}^n w_i = 1$.

Definition 5. *There are two TIT2FNs that are transformed from fuzzy language.*

$$A_m = (A_m^U, A_m^L) = ((a_{m1}^U, a_{m2}^U, a_{m3}^U, a_{m4}^U; H_1(A_m^U), H_2(A_m^U), (a_{m1}^L, a_{m2}^L, a_{m3}^L, a_{m4}^L; H_1(A_m^L), H_2(A_m^L))$$
$$A_n = (A_n^U, A_n^L) = ((a_{n1}^U, a_{n2}^U, a_{n3}^U, a_{n4}^U; H_1(A_n^U), H_2(A_n^U), (a_{n1}^L, a_{n2}^L, a_{n3}^L, a_{n4}^L; H_1(A_n^L), H_2(A_n^L))$$

The corresponding ranking values of each indicator can be calculated as follows. Calculate R using the below.

$$R = \frac{C + \sum_{k=1}^2 u_k}{\sum_{i=1}^4 w_i + \sum_{k=1}^2 |H_k(A_m^L) - H_k(A_n^L)| + \sum_{k=1}^2 |H_k(A_m^U) - H_k(A_n^U)|} \tag{5}$$

where $C = (a_{m3}^L + a_{m4}^L) - (a_{n1}^L + a_{n2}^L) + (a_{m3}^U + a_{m4}^U) - (a_{n1}^U + a_{n2}^U)$, $u_k = \max(H_k(A_m^L) - H_k(A_n^L), 0)), +\max(H_k(A_m^U) - H_k(A_n^U), 0)$ and

$$w_1 = a_{m4}^L + a_{m3}^L - a_{m1}^L - a_{m2}^L$$
$$w_2 = a_{m4}^U + a_{m3}^U - a_{m1}^U - a_{m2}^U$$
$$w_3 = a_{n4}^L + a_{n3}^L - a_{n1}^L - a_{n2}^L$$
$$w_4 = a_{n4}^U + a_{n3}^U - a_{n1}^U - a_{n2}^U$$

The degree of probability degree of A_m over A_n can be obtained as

$$p(A_m \geq A_n) = \min(\max(R, 0), 1) \tag{6}$$

The weight of each indicator is determined by

$$Rank(A_i) = \frac{\sum\limits_{j=1}^{n} p(A_i \geq A_j)}{\sum\limits_{i=1}^{n}\sum\limits_{j=1}^{n} p(A_i \geq A_j)} \tag{7}$$

3.2. Cloud Model Theory

Cloud model can convert qualitative concepts to quantitative values expressed in linguistic values based on traditional probability, statistics theory, and fuzzy mathematical theory. A cloud droplet y is denoted by $\widetilde{y} = X(E_x, E_n, H_e)$ with three parameters: expectation E_x, entropy E_n, and hyperentropy H_e. Here, E_x represents the center value of the qualitative concept, E_n describes the stochasticity and fuzziness of the qualitative concept, and H_e reflects the degree of dispersion of the cloud droplets and the uncertainty of the membership function.

3.3. PDR

PDR is a method of calculating cloud dominance degree, α-probability dominance class, α-probability dominance degree matrix, and comprehensive dominance degree according to the attribute value of the research object, and then the ranking of the object is determined according to the size of the comprehensive dominance degree [45,46]. This method not only solves the problem that the traditional ranking method is too strict and it is difficult to evaluate sustainable suppliers under the condition of incomplete information, but also enriches the methodology of SSSE.

Cloud dominance degree: Assume that $S = \langle X, A \rangle$ is a decision system, where X represents the set of schemes, and A indicates the attribute set. For any $x_i, x_j \in X, a \in A$, $P_a(x_i, x_j)$ the dominance degree of x_j is relative to x_i under attribute a. There are three cases for cloud dominance degree: If $x_j > x_i$, then the cloud dominance degree of x_j in relation to x_i under attribute a is 1, that is, $x_j \overset{1}{\succ} x_i$. If $x_j < x_i$, then the cloud dominance degree of x_j in relation to x_i under attribute a is 0, that is, $x_j \overset{0}{\succ} x_i$. If $x_j = x_i$, then the cloud dominance degree of x_j in relation to x_i under attribute a is 0.5, that is, $x_j \overset{0.5}{\sim} x_i$. Here, $\succ, \prec$ *and* $\sim$ represent superior, inferior, and similar, respectively.

$$P_A(x_i, x_j) = \frac{num(1) + num(0.5)}{num(1) + num(0.5) + num(0)} \tag{8}$$

where $num(1)$ represents the quantity of attributes for which x_j is superior to x_i, $num(0.5)$ represents the quantity of attributes for which x_j is similar to x_i, and $num(0)$ represents the quantity of attributes for which x_j is inferior to x_i.

α-probability dominance class: In the decision system $S = \langle X, A \rangle$, $R_A^{\geq \alpha}$ is the α-probability dominance relationship for x_i under the attribute set A, where $R_A^{\geq \alpha} = \left\{ (x_i, x_j) \middle| P_A(x_i, x_j) \geq \alpha,\ 0.5 \leq \alpha \leq 1 \right\}$. For any α, $[x_i]_A^{\geq \alpha}$ is the α-probability dominance class of scheme x_i under attribute set A.

α-probability dominance degree matrix**:** This matrix is obtained via a set operation on probability dominance class $[x_i]_A^{\geq \alpha}$, where each element is represented by $M_A^{\geq \alpha}(x_i, x_j)$.

Comprehensive dominance degree: This is calculated by averaging each line element of the probability dominance matrix. We record the comprehensive dominance degree as $C_A^{\geq \alpha}(x_i)$.

3.4. Cloud PDR Method

Cloud PDR is a type of probabilistic dominance relation that is constructed with fault tolerance. We calculate the comprehensive dominance degree according to each scheme's attribute values and determine the ranking of the schemes.

Definition 6. *Assuming that* $\widetilde{y}_1 = X_1(E_{x_1}, E_{n_1}, H_{e_1})$ *and* $\widetilde{y}_2 = X_2(E_{x_2}, E_{n_2}, H_{e_2})$ *are any two clouds in the same domain, the basic operations are shown in Tables A1 and A2 of Appendix A.*

4. Model Formulation

To increase market competitiveness and improve the SCM performance, the selection of sustainable suppliers is crucial, which comprises three components: the first one is to determine the SSSE indicators, the second one is the establishment of the evaluation indicators' weights, and the last one is a comprehensive assessment of candidate sustainable suppliers. The framework of the proposed model is depicted in Figure 1.

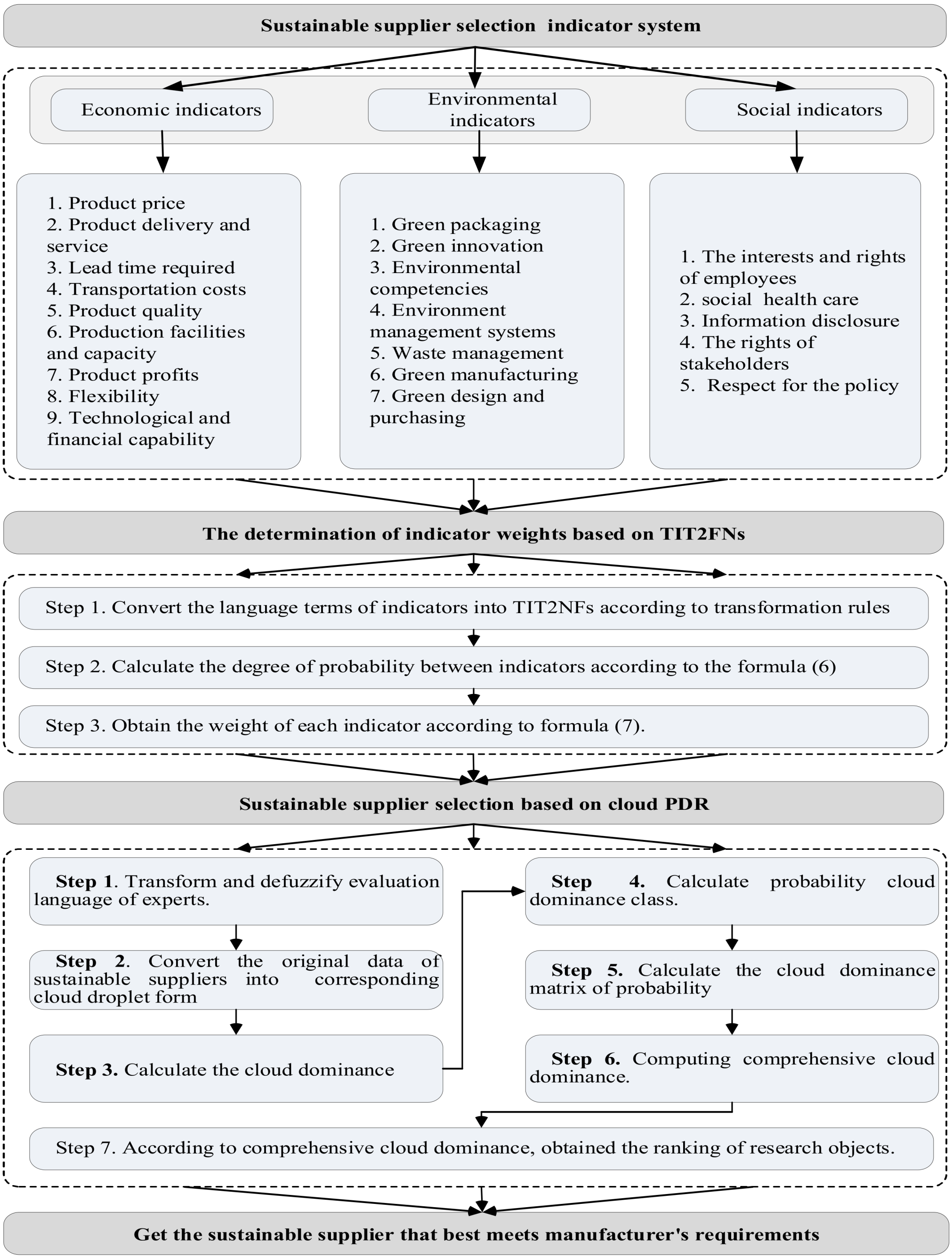

Figure 1. Proposed framework.

4.1. SSSE Indicators

The traditional process of supplier evaluation mainly considers the economic indicators, while the green supplier evaluation primarily considers both the economic indicators and the environmental indicators. Thereby, sustainable suppliers should consider the economic indicators, environmental indicators, and social indicators. We build a tangible indicators system based on literature review. The indicators system lists relatively important indicators. Manufacturers can delete or increase corresponding indicators according to specific circumstances when selecting sustainable suppliers.

The following provides some explanations of economic indicators, environmental indicators, and social indicators:

Economic indicators. For any sustainable supplier, their ultimate goal is to achieve the highest profit at the lowest cost. There are nine economic indicators we have identified: (1) product price [47], (2) product delivery and service, (3) lead time required [48,49], (4) transportation cost, (5) product quality, (6) production facilities and capacity [50], (7) product profit, (8) flexibility [51,52], and (9) technological and financial capability. Product price refers to the ability of sustainable suppliers to provide products with a competitive price; product delivery and service have a great influence on customer satisfaction; lead time required indicates the ability of ensuring delivery on time; transportation costs expresses the costs of transporting the product; product quality represents the rate of qualified products; production facilities and capacity refers to the level of advancement production equipment; product profits indicates the profitability of products; flexibility expresses the sustainable suppliers' ability to respond to market changes; technological and financial capability indicates the ability of sustainable suppliers to handle technical and financial issues.

Environmental indicators. Environmental sustainability has become an important concern for manufacturers. Thus, we not only evaluate the economic performance of suppliers but also understand the environmental awareness of suppliers and consider their corresponding environmental protection measures. There are seven environmental indicators identified: (1) green packaging, (2) green innovation, (3) environmental competencies, (4) environment management systems [53], (5) waste management [54], (6) green manufacturing [55], and (7) green design and purchasing [48,56]. Green packaging refers to the ability of sustainable suppliers to consider the environment in their packaging; green innovation represents the innovation capabilities of sustainable suppliers; environmental competencies indicate the ability and technology of companies to reduce the impact of pollution in the production process; environment management systems expresses the policy structure, planning and implementation of sustainable suppliers in environmental protection; waste management refers to the ability of sustainable suppliers to reduce waste during production; green manufacturing represents sustainable suppliers' ability to reduce raw materials and energy consumption during production; green design and purchasing refer to the environmental capabilities of sustainable suppliers in the design and procurement stage.

Social indicators. Due to the growing society concerns, manufacturers are more willing to cooperate with the suppliers with higher social performance. Very few scholars have incorporated social responsibility into the SSSE process. Five social indicators are identified: (1) the interests and rights of employees [57], (2) social health care, (3) information disclosure, (4) the rights of stakeholders [58], and (5) respect for policy. Here, the interests and rights of employees can increase the overall level of sustainable supplier companies, including staff training input capabilities; social health care represents the health of staff and workplace comfort; information disclosure provides customers with information on the character of materials and substances released during production and use; the rights of stakeholders further indicate social morality and the interests of partners; respect for policy indicates the degree of sustainable suppliers' respect for policy requirements.

4.2. The Determination of Indicator Weights Based on TIT2FNs

The weight of indicators reflects the preference of manufacturers for sustainable supplier indicators, and the solution is the key to SSSE. In real decision-making, due to human ambiguity and uncertainty in data, decision-making information often encounters uncertainties when making decisions. The concept of fuzzy sets is thus introduced to express the evaluation values of the decision makers [59,60]. Attribute values are not expressed in concrete real numbers, but are expressed in the form of fuzzy numbers. In the fuzzy environment decision, it is common to use traditional type-1 fuzzy numbers. In fact, traditional interval-2 fuzzy numbers have more flexibility and accuracy when handling such problems. In other words, describing the evaluation information of decision makers using TIT2NFs is very suitable. There are three steps in the determination of sustainable supplier evaluation indicator weights based on TIT2FNs:

Step 1. Convert the language terms of indicators into TIT2NFs according to the transformation rules. For example, we regard the linguistic term "very unimportant (VU)" as TIT2NFs "((0,0,0,0.1;1,1), (0,0,0,0.05;0.9,0.9))", "less important (LI)" as TIT2NFs "((0.1,0.3,0.3,0.5;1,1), (0.2,0.3,0.3,0.4;0.9,0.9))", and so on.

Step 2. Calculate the possible degree between indicators using Formula (6).

Step 3. Obtain the weight of each indicator using Formula (7).

4.3. SSSE Based on Cloud PDR

The cloud PDR method introduces parameters such as expectation, entropy, and hyper-entropy into the PDR. The method fully considers the ambiguity, volatility, and randomness in decision-making. The traditional dominance relationship has poor fault tolerance. Therefore, it is of great significance to propose PDR that are insensitive to interference data. The PDR do not require that the scheme has a strict dominance relationship among all attribute values, but the number of attributes satisfying the dominance relationship should reach a certain proportion. For example, in the sustainable supplier selection process, it is difficult to determine the strict superiority relationship between two sustainable suppliers. Therefore, adopting the cloud PDR method is more suitable and consistent with the actual decision-making processes.

These are five steps of SSSE using the cloud PDR method, which are elaborated below:

Step 1. Transform and defuzzify the evaluation language of experts.

The TIT2FNs $A = (A^U, A^U) = ((a_1^U, a_2^U, a_3^U, a_4^U; H_1(A^U), H_2(A^U)), (a_1^L, a_2^L, a_3^L, a_4^L; H_1(A^L), H_2(A^L)))$ can be deburred using Formula (9) [61].

$$def(A) = \frac{1}{2}\left(\begin{array}{c} \frac{a_1^U + (1+H_1(A^U))a_2^U + (1+H_2(A^U))a_3^U + a_4^U}{4+H_1(A^U)+H_2(A^U)} \\ + \frac{a_1^L + (1+H_1(A^L))a_2^L + (1+H_2(A^L))a_3^L + a_4^L}{4+H_1(A^L)+H_2(A^L)} \end{array} \right) \tag{9}$$

Step 2. Using the following formulas (10)–(12), the original data of sustainable suppliers are converted into the corresponding cloud droplet form, namely, $\widetilde{y} = X_i(E_{x_i}, E_{n_i}, H_{e_i})$, where

$$E_{x_i} = \frac{1}{T}\sum_{t=1}^{T} f_{iat} \tag{10}$$

$$E_{n_i} = \frac{1}{T}\sum_{t=1}^{T} |f_{iat} - E_{x_i}| \tag{11}$$

$$H_{e_i} = \frac{1}{T-1}\sum_{t=1}^{T} (f_{iat} - E_{x_i})^2 \tag{12}$$

Here, f_{iat} represents the t-th value of sustainable supplier i under attribute a.

Step 3. The calculation of cloud dominance degree.

The cloud attribute value of x_{ia} is $X_{ia}(E_{x_{ia}}, E_{n_{ia}}, H_{e_{ia}})$, and the cloud attribute value of x_{ja} is $X_{ja}(E_{x_{ja}}, E_{n_{ja}}, H_{e_{ja}})$. According to the calculation method of cloud dominance degree, the cloud dominance degree of E_x, E_n and H_e of x_{ia} and x_{ja} are obtained in Table A3:

When comparing x_{ja} with x_{ia}, $p_1(x_{ia}, x_{ja})$, $p_2(x_{ia}, x_{ja})$ and $p_3(x_{ia}, x_{ja})$ represent the cloud dominance degree of expectation E_x, entropy E_n, and hyperentropy H_e, respectively. According to the comparison rules, there are three cases:

If $E_{x_j} > E_{x_i}$, then $p_1(x_{ia}, x_{ja}) = 1$. This means that the expectation E_x of x_j is superior to that of x_i. If $E_{x_j} = E_{x_i}$, then $p_1(x_{ia}, x_{ja}) = 0.5$. This implies that the expectation E_x of x_j is similar to that of x_i. If $E_{x_j} < E_{x_i}$, then $p_1(x_{ia}, x_{ja}) = 0$. This indicates that the expectation E_x of x_j is inferior to that of x_i. The comparison results of entropy E_n and hyperentropy H_e are the opposite. The relationships of $E_{n_{ja}} > E_{n_{ia}}$, $E_{n_{ja}} = E_{n_{ia}}$, $E_{n_{ja}} < E_{n_{ia}}$ and $H_{e_{ja}} > H_{e_{ia}}$, $H_{e_{ja}} = H_{e_{ia}}$, $H_{e_{ja}} < H_{e_{ia}}$ are the opposite.

Comparing x_{ja} and x_{ia}, their cloud dominance degree can be denoted as $P_a(x_{ia}, x_{ja}) = [p_1(x_{ia}, x_{ja}), p_2(x_{ia}, x_{ja}), p_3(x_{ia}, x_{ja})]$. Analogously, the cloud dominance degree of x_j compared to x_i under attribute set A can be denoted by $P_A(x_i, x_j) = [p_{A1}(x_{iA}, x_{jA}), p_{A2}(x_{iA}, x_{jA}),]$ $[p_{A3}(x_{iA}, x_{jA})]$, where

$$p_{A1}(x_{iA}, x_{jA}) = \frac{num|a_1| + 0.5num|b_1|}{num|A|} \tag{13}$$

$$p_{A2}(x_{iA}, x_{jA}) = \frac{num|a_2| + 0.5num|b_2|}{num|A|} \tag{14}$$

$$p_{A3}(x_{iA}, x_{jA}) = \frac{num|a_3| + 0.5num|b_3|}{num|A|} \tag{15}$$

Here, $num|a_1|$, $num|a_2|$, and $num|a_3|$ express the number of attributes whose value is 1 under E_x, E_n, and H_e, respectively. That is, the number of $p_1(x_{ia}, x_{ja})$, $p_2(x_{ia}, x_{ja})$, and $p_3(x_{ia}, x_{ja})$ is equal to 1. $num|b_1|$,$num|b_2|$, and $num|b_3|$ represent the numbers of $p_1(x_{ia}, x_{ja})$, $p_2(x_{ia}, x_{ja})$, and $p_3(x_{ia}, x_{ja})$ equal to 0.5, respectively. $num|A|$ is the number of attributes.

Step 4. Calculate α-probability cloud dominance class.

According to the related concepts and definitions of the α-probability cloud dominance class, α-probability cloud dominance relationship and α-probability cloud dominance class $[x_i]^{\geq\alpha}_{A1}$, $[x_i]^{\geq\alpha}_{A2}$, and $[x_i]^{\geq\alpha}_{A3}$ of x_i under expectation E_x, entropy E_n, and hyperentropy H_e are obtained.

Here,

$$R^{\geq\alpha}_{A1} = \{(x_i, x_j)|p_{A1}(x_i, x_j) \geq \alpha, 0.5 \leq \alpha \leq 1\}, [x_i]^{\geq\alpha}_{A1} = \left\{x_j \middle| (x_i, x_j) \in R^{\geq\alpha}_{A1}\right\} \tag{16}$$

$$R^{\geq\alpha}_{A2} = \{(x_i, x_j)|p_{A2}(x_i, x_j) \geq \alpha, 0.5 \leq \alpha \leq 1\}, [x_i]^{\geq\alpha}_{A2} = \left\{x_j \middle| (x_i, x_j) \in R^{\geq\alpha}_{A2}\right\} \tag{17}$$

$$R^{\geq\alpha}_{A3} = \{(x_i, x_j)|p_{A3}(x_i, x_j) \geq \alpha, 0.5 \leq \alpha \leq 1\}, [x_i]^{\geq\alpha}_{A3} = \left\{x_j \middle| (x_i, x_j) \in R^{\geq\alpha}_{A3}\right\} \tag{18}$$

When α tends to 0.5, $R^{\geq\alpha}_{A1}$ is called an optimistic PDR, and when α approaches 1, $R^{\geq\alpha}_{A1}$ is called a pessimistic PDR.

Obviously, when $\alpha = 0.5$, it means that only half of the attributes are "superior", and this requirement is relatively easy to satisfy. When α= 1, it means that all attributes are "superior". This requirement is relatively strict and difficult to meet. Therefore, 0.5 and 1 are the upper and lower bounds of optimistic and pessimistic decision-making, respectively; and this situation has great significance for decision makers with different risk preferences to choose the credibility parameter.

Step 5. Calculate the cloud dominance matrix of α-probability

Calculate the cloud dominance matrices $M_{A1}^{\geq\alpha}(x_i, x_j)$, $M_{A2}^{\geq\alpha}(x_i, x_j)$, and $M_{A3}^{\geq\alpha}(x_i, x_j)$ according to the expectation E_x, entropy E_n, and hyperentropy H_e, respectively.

$$M_{A1}^{\geq\alpha}(x_i, x_j) = \begin{cases} \frac{\left|[x_j]_{A1}^{\geq\alpha} - [x_i]_{A1}^{\geq\alpha}\right|}{\left|[x_j]_{A1}^{\geq\alpha} - [x_i]_{A1}^{\geq\alpha}\right| + \left|[x_i]_{A1}^{\geq\alpha} - [x_j]_{A1}^{\geq\alpha}\right|}, & [x_i]_{A1}^{\geq\alpha} \neq [x_j]_{A1}^{\geq\alpha} \\ 0.5 & else \end{cases} \tag{19}$$

$$M_{A2}^{\geq\alpha}(x_i, x_j) = \begin{cases} \frac{\left|[x_j]_{A2}^{\geq\alpha} - [x_i]_{A2}^{\geq\alpha}\right|}{\left|[x_j]_{A2}^{\geq\alpha} - [x_i]_{A2}^{\geq\alpha}\right| + \left|[x_i]_{A2}^{\geq\alpha} - [x_j]_{A2}^{\geq\alpha}\right|}, & [x_i]_{A2}^{\geq\alpha} \neq [x_j]_{A2}^{\geq\alpha} \\ 0.5 & else \end{cases} \tag{20}$$

$$M_{A3}^{\geq\alpha}(x_i, x_j) = \begin{cases} \frac{\left|[x_j]_{A3}^{\geq\alpha} - [x_i]_{A3}^{\geq\alpha}\right|}{\left|[x_j]_{A3}^{\geq\alpha} - [x_i]_{A3}^{\geq\alpha}\right| + \left|[x_i]_{A3}^{\geq\alpha} - [x_j]_{A3}^{\geq\alpha}\right|}, & [x_i]_{A3}^{\geq\alpha} \neq [x_j]_{A3}^{\geq\alpha} \\ 0.5 & else \end{cases} \tag{21}$$

In Formulas (19)–(21), $[x_i]_{A1}^{\geq\alpha}$ represents a set of elements that have a better α-probability than the object x_i. $[x_j]_{A2}^{\geq\alpha}$ denotes a set of elements that have a better α-probability than object x_j. In other words, $\left|[x_j]_{A1}^{\geq\alpha} - [x_i]_{A1}^{\geq\alpha}\right|$ measures the difference of the sets. That is, the elements that are better than the α-probability of x_i are removed from the set of elements with better α-probability than x_j to represent the α-probability dominance of object x_i relative to object x_j.

Step 6. Computing comprehensive cloud dominance degree.

According to the cloud dominance matrix of α-probability, calculate the cloud dominance matrices $C_{A1}^{\geq\alpha}$, $C_{A2}^{\geq\alpha}$, and $C_{A3}^{\geq\alpha}$:

$$C_{A1}^{\geq\alpha}(x_i) = \frac{1}{n}\sum_{j=1}^{n} M_{A1}^{\geq\alpha}(x_i, x_j) \tag{22}$$

$$C_{A2}^{\geq\alpha}(x_i) = \frac{1}{n}\sum_{j=1}^{n} M_{A2}^{\geq\alpha}(x_i, x_j) \tag{23}$$

$$C_{A3}^{\geq\alpha}(x_i) = \frac{1}{n}\sum_{j=1}^{n} M_{A3}^{\geq\alpha}(x_i, x_j) \tag{24}$$

Step 7. According to comprehensive cloud dominance degree, the ranking of research objects (suppliers) is obtained.

5. Case Study

Sustainable supplier selection is a very complex process, especially when using TIT2FNs to determine indicator weights and the cloud PDR method to evaluate sustainable suppliers. Therefore, a numerical example is illustrated to prove the effectiveness of the proposed method.

5.1. Problem Definition and Description of Case

With the continuous increase in electronic products, 40–70 million tons of electrical product waste is being generated annually around the worldwide [62]. The electronic products manufacturers of China mainly produce digital products such as mobile phones and computers. These products have a high market share in the world, and there are also many waste electronic products simultaneously. Under the supervision of the government, market, consumers, shareholders, and other factors, the manufacturer must pay attention to sustainable SCM. That is, the manufacturer must consider importance in the selection and evaluation of sustainable suppliers. This section describes the application of the proposed method to this manufacturer. When choosing spare part suppliers, the manufacturer not only considers the economic benefits brought by suppliers, but also uses the concept of sustainable development as an assessment criterion. Based on this, we assume that the manufacturer established a decision-making team composed of three experts from relevant departments (the procurement department, the marketing department, and the logistics department) and two experts from outside the manufacturer to select a more appropriate sustainable supplier of accessories and repairs among the five candidates.

5.2. Selection of Indicators

The determination of the indicator system is the first step in the selection and evaluation of sustainable suppliers. The formulation of indicator standards should meet the requirements and development strategies of the manufacturer. In order to select suitable sustainable suppliers, 15 indicators from 3 dimensions are finally determined through 5 experts' inputs and relevant literature. This study mainly considers three types of indicators: economic, environmental, and social. The economic indicators include product price (PPE), product profits (PPT), product quality (PQ), transportation costs (TC), and lead time required (LTR); the environmental indicators include green design and purchasing (GDP), green manufacturing (GM), green packaging (GP), environmental competencies (EC), and green innovation (GI); the social indicators include social health care (SHC), the interests and rights of employees (IRE), the rights of stakeholders (RS), information disclosure (ID), and respect for policy (RP). Figure 2 shows the SSSE indicators in each dimension.

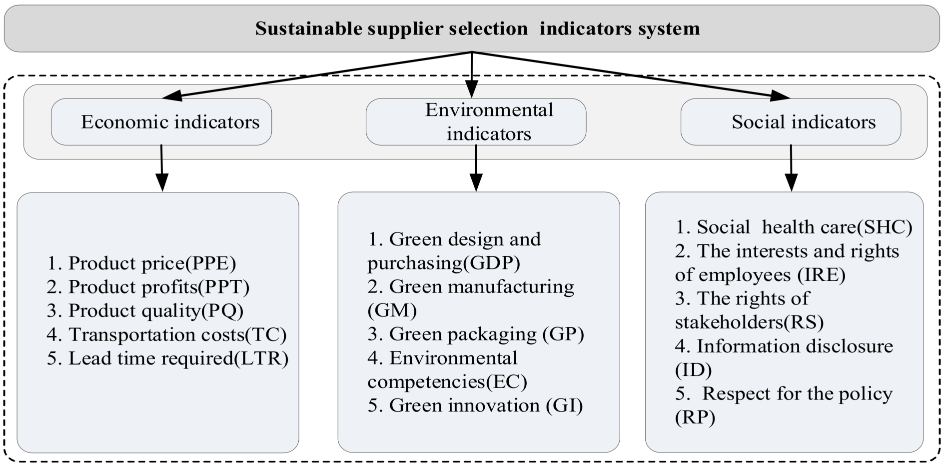

Figure 2. Distribution of the SSSE indicators in each dimension.

5.3. Computing Indicator Weights Using TIT2FNs

The manufacturer evaluated the importance of each indicator according to its own development status, and the evaluation results are presented in Table 1. Then, the manufacturer assigned three experts (they come from the decision-making team, have a good understanding of the measurement methods of each indicator, and are able to make an accurate evaluation of each candidate supplier) to evaluate the performance of the candidate sustainable suppliers. In this part, they assess the importance of each indicator based on the actual development of the manufacturer. When the evaluation results are different, the expert explains the reasons for giving the evaluation results and then repeats the evaluation process until the evaluation results of the three experts are consistent. The final result is shown in Table A4 of Appendix B. To prevent sustainable suppliers from maliciously promoting corporate performance, different time weights (0.2, 0.3, 0.5) are assigned to 2015, 2016, and 2017, respectively, based on the impact of history on the current situation.

Table 1. Indicator importance evaluation form.

Economic Indicators					Environmental Indicators					Social Indicators				
PPE	PPT	PQ	TC	LTR	GDP	GM	GP	EC	GI	SHC	IRE	RS	ID	RP
I	U	VI	GI	MI	VI	LI	LI	VI	I	VI	GI	MI	VI	LI

In this evaluation, decision makers evaluated indicator performance in the past three years using linguistic terms (S1 = (very unimportant (VU), unimportant (U), less important (LI), generally important (GI), more important (MI), important (I), very important (VI))) and (S2 = very very bad (VVB), very bad (VB), bad (B), ordinary (O), medium (M), good (G), very good (VG), very very good (VVG)). The conversion criteria are shown in Table A5 and A6 of Appendix B.

Step 1. To assess the importance of a sustainable supplier indicator, we convert the evaluation language terms (Table A4) of indicator importance into TIT2FNs according to Table A6.

Step 2. Using Formula (4), (5) and the indicator transformation result, the probability matrix is obtained, and the details are in the possibility matrix of Appendix B.

Step 3. Using Equation (7), we obtain the weight of each indicator, shown in Table 2.

Table 2. The weight of each indicator.

Economic Indicators	PPE	PPT	PQ	TC	LTR
	0.0597	0.1111	0.0383	0.0900	0.0711
Environmental indicators	GDP	GM	GP	EC	GI
	0.0425	0.1182	0.0982	0.0271	0.0582
Social indicators	SHC	IRE	RS	ID	RP
	0.0271	0.1025	0.0711	0.0271	0.0578

5.4. Cloud PDR

Step 1. Transformation and defuzzification of the evaluation language is performed. The results are shown in Tables A7–A10.

Step 2. In order to prevent candidate sustainable suppliers from improving performance maliciously, experts assess their performance in the past three years and give different timing weights based on the distance from the current time. The results with timing weights and indicator weights handled are shown in Table 3.

Table 3. Expert evaluation results of candidate sustainable suppliers' indicators based on timing weights and indicator weights.

Sustainable Supplier	**Time**	**Economic Indicators**					**Environmental Indicators**					**Social Indicators**				
		PPE	**PPT**	**PQ**	**TC**	**LTR**	**GDP**	**GM**	**GP**	**EC**	**GI**	**SHC**	**TE**	**RS**	**ID**	**RP**
SS1	2015	0.004	0.022	0.008	0.018	0.011	0.008	0.023	0.015	0.003	0.009	0.007	0.020	0.011	0.005	0.009
	2016	0.018	0.010	0.016	0.036	0.029	0.012	0.035	0.035	0.010	0.024	0.010	0.037	0.025	0.011	0.021
	2017	0.040	0.054	0.019	0.044	0.027	0.029	0.070	0.048	0.013	0.035	0.018	0.069	0.035	0.018	0.022
SS2	2015	0.012	0.022	0.002	0.018	0.014	0.008	0.023	0.010	0.005	0.011	0.005	0.020	0.004	0.005	0.011
	2016	0.021	0.033	0.009	0.020	0.021	0.015	0.027	0.022	0.006	0.017	0.008	0.037	0.016	0.004	0.017
	2017	0.040	0.054	0.019	0.054	0.035	0.029	0.058	0.058	0.016	0.029	0.016	0.061	0.042	0.016	0.034
SS3	2015	0.006	0.007	0.008	0.018	0.011	0.003	0.007	0.019	0.005	0.009	0.000	0.011	0.017	0.005	0.009
	2016	0.018	0.010	0.016	0.036	0.029	0.012	0.035	0.040	0.011	0.024	0.006	0.000	0.029	0.011	0.023
	2017	0.040	0.054	0.019	0.044	0.027	0.029	0.080	0.048	0.013	0.035	0.013	0.069	0.035	0.016	0.022
SS4	2015	0.012	0.022	0.002	0.018	0.014	0.008	0.018	0.006	0.005	0.011	0.005	0.020	0.008	0.005	0.011
	2016	0.021	0.025	0.009	0.020	0.016	0.012	0.042	0.022	0.006	0.021	0.010	0.037	0.016	0.006	0.017
	2017	0.036	0.054	0.014	0.044	0.035	0.029	0.058	0.048	0.016	0.035	0.018	0.050	0.035	0.018	0.034
SS5	2015	0.012	0.022	0.002	0.018	0.011	0.008	0.023	0.010	0.005	0.006	0.005	0.020	0.004	0.005	0.009
	2016	0.021	0.025	0.009	0.020	0.021	0.012	0.019	0.022	0.004	0.017	0.010	0.037	0.016	0.006	0.021
	2017	0.029	0.029	0.019	0.054	0.035	0.029	0.058	0.048	0.016	0.035	0.016	0.050	0.035	0.013	0.028

Step 3. Using Formulas (10)–(12), the expectation, entropy, and hyperentropy of each dimension and indicator were obtained.

Step 4. The cloud dominance degree of sustainable suppliers is calculated using Formulas (13)–(18). The results are shown in Table 4. For example, (x_1, x_2) $[0.600, 0.567, 0.533]$ indicates that the probability that the expectation of SS_2 is higher than that of SS_1 is 0.6, the probability that the entropy of SS_2 is higher than that of SS_1 is 0.567, and the probability that the hyperentropy of SS_2 is higher than that of SS_1 is 0.533.

Table 4. Cloud dominance degree among sustainable suppliers.

Cloud Dominance Degree							
(x_1, x_2)	$[0.600, 0.567, 0.533]$	(x_1, x_3)	$[0.533, 0.533, 0.600]$	(x_1, x_4)	$[0.700, 0.600, 0.633]$	(x_1, x_5)	$[0.833, 0.567, 0.600]$
(x_2, x_1)	$[0.400, 0.433, 0.467]$	(x_2, x_3)	$[0.467, 0.467, 0.467]$	(x_2, x_4)	$[0.667, 0.467, 0.533]$	(x_2, x_5)	$[0.800, 0.400, 0.400]$
(x_3, x_1)	$[0.467, 0.467, 0.400]$	(x_3, x_2)	$[0.533, 0.533, 0.533]$	(x_3, x_4)	$[0.600, 0.567, 0.567]$	(x_3, x_5)	$[0.633, 0.533, 0.533]$
(x_4, x_1)	$[0.300, 0.400, 0.367]$	(x_4, x_2)	$[0.333, 0.533, 0.467]$	(x_4, x_3)	$[0.400, 0.433, 0.433]$	(x_4, x_5)	$[0.667, 0.467, 0.500]$
(x_5, x_1)	$[0.167, 0.433, 0.400]$	(x_5, x_2)	$[0.200, 0.600, 0.600]$	(x_5, x_3)	$[0.367, 0.467, 0.467]$	(x_5, x_4)	$[0.333, 0.533, 0.500]$

Step 5. The probability α is determined according to the actual situation of manufacturers (in this case, $\alpha = 0.5$), and the cloud dominance degree of each sustainable supplier is constructed. The results are shown in Table 5.

Table 5. Cloud dominance degree of sustainable suppliers.

	$\boldsymbol{E_x}$	$\boldsymbol{E_n}$	$\boldsymbol{He}$
$[x_1]_A^{\geq 0.5}$	$\{x_1, x_2, x_3, x_4, x_5\}$	$\{x_1, x_2, x_3, x_4, x_5\}$	$\{x_1, x_2, x_3, x_4, x_5\}$
$[x_2]_A^{\geq 0.5}$	$\{x_2, x_4, x_5\}$	$\{x_2\}$	$\{x_2, x_4\}$
$[x_3]_A^{\geq 0.5}$	$\{x_2, x_3, x_4, x_5\}$	$\{x_2, x_3, x_4, x_5\}$	$\{x_2, x_3, x_4, x_5\}$
$[x_4]_A^{\geq 0.5}$	$\{x_4, x_5\}$	$\{x_2, x_4\}$	$\{x_4, x_5\}$
$[x_5]_A^{\geq 0.5}$	$\{x_5\}$	$\{x_2, x_4, x_5\}$	$\{x_2, x_4, x_5\}$

Step 6. The cloud dominance matrix of α-probability $M_A^{\geq 0.5}$ is calculated using Formulas (19)–(21).

$$M_A^{\geq 0.5} = \begin{bmatrix} (0.5, 0.5, 0.5) & (0.0, 0.0, 0.0) & (0.0, 0.0, 0.0) & (0.0, 0.0, 0.0) & (0.0, 0.0, 0.0) \\ (1.0, 1.0, 1.0) & (0.5, 0.5, 0.5) & (1.0, 1.0, 1.0) & (0.0, 1.0, 0.5) & (0.0, 1.0, 1.0) \\ (1.0, 1.0, 1.0) & (0.0, 0.0, 0.0) & (0.5, 0.5, 0.5) & (0.0, 0.0, 0.0) & (0.0, 0.0, 0.0) \\ (1.0, 1.0, 1.0) & (1.0, 0.0, 0.5) & (1.0, 1.0, 1.0) & (0.5, 0.5, 0.5) & (0.0, 1.0, 1.0) \\ (1.0, 1.0, 1.0) & (1.0, 0.0, 0.0) & (1.0, 1.0, 1.0) & (1.0, 0.0, 0.0) & (0.5, 0.5, 0.5) \end{bmatrix}$$

Step 7. Using the average value of the above comprehensive cloud dominance matrix, the comprehensive dominance degree of sustainable suppliers is obtained. The results are shown in Table 6.

Table 6. The comprehensive cloud dominance degree of sustainable suppliers.

Sustainable Supplier	Comprehensive Cloud Dominance Degree
SS1	$[0.1, 0.1, 0.1]$
SS2	$[0.5, 0.9, 0.8]$
SS3	$[0.3, 0.3, 0.3]$
SS4	$[0.7, 0.7, 0.8]$
SS5	$[0.9, 0.5, 0.5]$

In Table 6, the first numbers of comprehensive cloud dominance degree are compared; 0.1, 0.5, 0.3, 0.7, and 0.9 are compared. A larger value shows that the supplier is better. According to the values of the first numbers, the sequence of sustainable suppliers can be obtained, which is $SS_5 \succ SS_4 \succ SS_2 \succ SS_3 \succ SS_1$.

Through case analysis, we found that SS5 is the most consistent with manufacturers' sustainability requirements.

6. Sensitivity Analysis

To improve the effectiveness of the proposed method, sensitivity analysis is conducted [63,64]. The purpose of sensitivity analysis is to observe the SSSE results when the α-probability changes. From Section 4.3, it can be found that the requirement of one supplier being more appropriate than another increases as the α-probability increases.

When the α-probability increases to 0.6, the calculation results of the cloud dominance class of the sustainable suppliers are as shown in Table 7.

Table 7. Cloud dominance classes of sustainable suppliers when the α-probability is 0.6.

	E_x	E_n	He
$[x_1]_A^{\geq 0.6}$	$\{x_1, x_2, x_4, x_5\}$	$\{x_1, x_4\}$	$\{x_1, x_3, x_4, x_5\}$
$[x_2]_A^{\geq 0.6}$	$\{x_2, x_4, x_5\}$	$\{x_2\}$	$\{x_2\}$
$[x_3]_A^{\geq 0.6}$	$\{x_3, x_4, x_5\}$	$\{x_3\}$	$\{x_3\}$
$[x_4]_A^{\geq 0.6}$	$\{x_4, x_5\}$	$\{x_4\}$	$\{x_4\}$
$[x_5]_A^{\geq 0.6}$	$\{x_5\}$	$\{x_2, x_5\}$	$\{x_2, x_5\}$

Then, we obtain the comprehensive dominance matrix of sustainable suppliers according to cloud dominance classes.

$$M_A^{\geq 0.6} = \begin{bmatrix} (0.5, 0.5, 0.5) & (0.0, 2/3, 0.2) & (1/3, 1/3, 0.0) & (0.0, 0.0, 0.0) & (0.0, 0.5, 0.25) \\ (1.0, 2/3, 0.8) & (0.5, 0.5, 0.5) & (0.5, 0.5, 0.5) & (0.0, 0.5, 0.5) & (0.0, 1.0, 1.0) \\ (2/3, 2/3, 1.0) & (0.5, 0.5, 0.5) & (0.5, 0.5, 0.5) & (0.0, 0.5, 0.5) & (0.0, 2/3, 2/3) \\ (1.0, 1.0, 1.0) & (1.0, 0.5, 0.5) & (1.0, 0.5, 0.5) & (0.5, 0.5, 0.5) & (0.0, 2/3, 2/3) \\ (1.0, 0.5, 0.75) & (1.0, 0.0, 0.0) & (1.0, 1/3, 1/3) & (1.0, 1/3, 1/3) & (0.5, 0.5, 0.5) \end{bmatrix}$$

Using the average value of the above comprehensive dominance matrix, the comprehensive dominance degree of sustainable suppliers is obtained, as shown in Table 8.

Table 8. Comprehensive dominance degree of sustainable suppliers.

Sustainable Supplier	Comprehensive Dominance Degree
SS1	$[0.167, 0.4, 0.19]$
SS2	$[0.4, 0.633, 0.66]$
SS3	$[0.333, 0.567, 0.633]$
SS4	$[0.7, 0.633, 0.633]$
SS5	$[0.9, 0.333, 0.383]$

Therefore, the ranking of sustainable suppliers is $SS_5 \succ SS_4 \succ SS_2 \succ SS_3 \succ SS_1$.

When the α-probability increases to 0.7, the calculation results of the cloud dominance class of the sustainable suppliers are as shown in Table 9.

Table 9. Cloud dominance classes of sustainable suppliers when α-probability is 0.7.

	E_x	E_n	He
$[x_1]_A^{\geq 0.7}$	$\{x_1, x_4, x_5\}$	$\{x_1\}$	$\{x_1\}$
$[x_2]_A^{\geq 0.7}$	$\{x_2, x_5\}$	$\{x_2\}$	$\{x_2\}$
$[x_3]_A^{\geq 0.7}$	$\{x_3\}$	$\{x_3\}$	$\{x_3\}$
$[x_4]_A^{\geq 0.7}$	$\{x_4\}$	$\{x_4\}$	$\{x_4\}$
$[x_5]_A^{\geq 0.7}$	$\{x_5\}$	$\{x_5\}$	$\{x_5\}$

We obtain the comprehensive dominance matrix of sustainable suppliers according to cloud dominance classes.

$$M_{\widetilde{A}}^{\geq 0.7} = \begin{bmatrix} (0.5,0.5,0.5) & (0.25,0.5,0.5) & (0.25,0.5,0.5) & (0.0,0.5,0.5) & (0.0,0.5,0.5) \\ (0.75,0.5,0.5) & (0.5,0.5,0.5) & (0.5,0.5,0.5) & (0.5,0.5,0.5) & (0.5,0.5,0.5) \\ (0.75,0.5,0.5) & (0.5,0.5,0.5) & (0.5,0.5,0.5) & (0.5,0.5,0.5) & (0.5,0.5,0.5) \\ (1.0,0.5,0.5) & (0.5,0.5,0.5) & (0.5,0.5,0.5) & (0.5,0.5,0.5) & (0.5,0.5,0.5) \\ (1.0,0.5,0.5) & (0.5,0.5,0.5) & (0.5,0.5,0.5) & (0.5,0.5,0.5) & (0.5,0.5,0.5) \end{bmatrix}$$

According to the average value of the above comprehensive dominance matrix, the comprehensive dominance degree of sustainable suppliers is obtained, as shown in Table 10.

Table 10. Comprehensive dominance degree of sustainable suppliers.

Sustainable Supplier	Comprehensive Dominance Degree
SS1	$[0.2, 0.5, 0.5]$
SS2	$[0.55, 0.5, 0.5]$
SS3	$[0.55, 0.5, 0.5]$
SS4	$[0.6, 0.5, 0.5]$
SS5	$[0.6, 0.5, 0.5]$

Therefore, when the α-probability is 0.7, the order of sustainable suppliers is $SS_5 \sim SS_4 \succ SS_2 \sim SS_3 \succ SS_1$. From the order, the most appropriate supplier was obtained, which is SS5 or SS4.

The above analysis shows that there are some differences among the ranking results of the sustainable suppliers as the α-probability increases. This change in the results demonstrates the effectiveness of the proposed method. An increase in the α-probability means an improvement in sustainable supplier requirements, further meaning a reduction in the division between sustainable suppliers. For example, if the α-probability is equal to 1, the dominance relationship between sustainable suppliers becomes a strict advantageous relationship. Therefore, the method proposed in this article is more flexible. This flexibility does not affect the robustness of the results. The sensitivity analysis shows that supplier 1 is the optimal choice for the manufacturer.

7. Implications of This Research

This research aims to assist managers in selecting and evaluating their suppliers to improve the operational performance of their sustainable supply chains. This research has the following significant implications.

The study provides a comprehensive indicator system for the selection and evaluation of sustainable suppliers. In the selection of suppliers, decision makers need to understand the problems and objectives of enterprises. The indicator system, proposed in this paper, can guide managers in managing sustainable supplier-related decisions effectively.

The method proposed in this paper has merits in terms of theoretical and practical values and provides robust methodological support for sustainable supplier evaluation decision makers. Practicing managers can make purchasing and production plans based on the findings of this work. The findings of this work further assist managers in improving and evaluating the sustainability of suppliers from a sustainability viewpoint.

8. Conclusions and Future Work

In this paper, an SSSE indicator system was first established considering economic, environmental, and social aspects. An appropriate sustainable supplier is determined using the novel TIT2FNs and cloud PDR methods. Finally, a case study and sensitivity analysis are conducted to show the effectiveness of the proposed methodology. Some concluding remarks can be made on this study: The TIT2FNs not only effectively denote the hesitant characteristics of decision makers, but also evaluate the fuzzy and uncertain characteristics of information. The most appropriate sustainable supplier (SS5) is selected based on comprehensive cloud dominance degree. This means that SS5 better meets the requirements of manufacturers in terms of product profits, green manufacturing, and the interests and rights of employees. These indicators are in line with the sustainable development status of manufacturers.

There are some limitations of this study. The selection of indicators may vary with time and technological advancements. The decision makers and experts must be highly knowledgeable and professionally skilled to better analyze the situation. In the future, we will seek to build a quantitative model to calculate the results based on the relevant data provided by enterprises, which can further reduce the impacts of subjective factors on the selection and evaluation of sustainable suppliers.

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Appendix A

Table A1. The operating rules of TIT2FNs.

Operation	Specific Process
$\widetilde{A}+\widetilde{B}$	$\widetilde{a}_1^U+\widetilde{b}_1^U,\widetilde{a}_2^U+\widetilde{b}_2^U,\widetilde{a}_3^U+\widetilde{b}_3^U,\widetilde{a}_4^U+\widetilde{b}_4^U;min(H_1(\widetilde{A}^U),H_1(\widetilde{B}^U)),min(H_2(\widetilde{A}^U),H_2(\widetilde{B}^U))$ $\widetilde{a}_1^L+\widetilde{b}_1^L,\widetilde{a}_2^L+\widetilde{b}_2^L,\widetilde{a}_3^L+\widetilde{b}_3^L,\widetilde{a}_4^L+\widetilde{b}_4^L;min(H_1(\widetilde{A}^L),H_1(\widetilde{B}^L)),min(H_2(\widetilde{A}^L),H_2(\widetilde{B}^L))$
$A-B$	$\widetilde{a}_1^U-\widetilde{b}_4^U,\widetilde{a}_2^U-\widetilde{b}_3^U,\widetilde{a}_3^U-\widetilde{b}_2^U,\widetilde{a}_4^U-\widetilde{b}_1^U;min(H_1(\widetilde{A}^U),H_1(\widetilde{B}^U)),min(H_2(\widetilde{A}^U),H_2(\widetilde{B}^U))$ $\widetilde{a}_1^L-\widetilde{b}_4^L,\widetilde{a}_2^L-\widetilde{b}_3^L,\widetilde{a}_3^L-\widetilde{b}_2^L,\widetilde{a}_4^L-\widetilde{b}_1^L;min(H_1(\widetilde{A}^L),H_1(\widetilde{B}^L)),min(H_2(\widetilde{A}^L),H_2(\widetilde{B}^L))$
kA	$k\widetilde{A}=((k\widetilde{a}_1^U,k\widetilde{a}_2^U,k\widetilde{a}_3^U,k\widetilde{a}_4^U;H_1(\widetilde{A}^U),H_2(\widetilde{A}^U),(k\widetilde{a}_1^L,k\widetilde{a}_2^L,k\widetilde{a}_3^L,k\widetilde{a}_4^L;H_1(\widetilde{A}^L),H_2(\widetilde{A}^L))$

Table A2. The rules of cloud computing and comparison.

	E_x	E_n	H_e
$\widetilde{y}_1+\widetilde{y}_2$	$E_{x_1}+E_{x_2}$	$\sqrt{{E_{n_1}}^2+{E_{n_2}}^2}$	$\sqrt{{H_{e_1}}^2+{H_{e_2}}^2}$
$\widetilde{y}_1-\widetilde{y}_2$	$E_{x_1}-E_{x_2}$	$\sqrt{{E_{n_1}}^2+{E_{n_2}}^2}$	$\sqrt{{H_{e_1}}^2+{H_{e_2}}^2}$
$\widetilde{y}_1\times\widetilde{y}_2$	$E_{x_1}E_{x_2}$	$\sqrt{(E_{n_1}E_{x_2})^2+(E_{n_2}E_{x_1})^2}$	$\sqrt{(H_{e_1}E_{x_2})^2+(H_{e_2}E_{x_1})^2}$
$\widetilde{y}_1\div\widetilde{y}_2$	E_{x_1}/E_{x_2}	$\left\lvert\frac{Ex_1}{Ex_2}\right\rvert\sqrt{\left(\frac{En_1}{Ex_1}\right)^2+\left(\frac{En_2}{Ex_2}\right)^2}$	$\left\lvert\frac{Ex_1}{Ex_2}\right\rvert\sqrt{\left(\frac{He_1}{Ex_1}\right)^2+\left(\frac{He_2}{Ex_2}\right)^2}$
$E_{x_1}>E_{x_2}$		$\widetilde{y}_1>\widetilde{y}_2$	
$E_{n_1}>E_{n_2}$		$\widetilde{y}_1<\widetilde{y}_2$	
$H_{e_1}>H_{e_2}$		$\widetilde{y}_1<\widetilde{y}_2$	

Table A3. The calculation rules of cloud dominance degree.

	$p_1(x_{ia},x_{ja})$	$p_2(x_{ia},x_{ja})$	$p_3(x_{ia},x_{ja})$
$E_{x_{ja}}>E_{x_{ia}}$	1		
$E_{x_{ja}}=E_{x_{ia}}$	0.5		
$E_{x_{ja}}<E_{x_{ia}}$	0		
$E_{n_{ja}}>E_{n_{ia}}$		0	
$E_{n_{ja}}=E_{n_{ia}}$		0.5	
$E_{n_{ja}}<E_{n_{ia}}$		1	
$H_{e_{ja}}>H_{e_{ia}}$			0
$H_{e_{ja}}=H_{e_{ia}}$			0.5
$H_{e_{ja}}<H_{e_{ia}}$			1

Appendix B

Table A4. Evaluation results of indicators for sustainable suppliers in the past three years.

Sustainable Suppliers	Time	Economic Indicators					Environmental Indicators					Social Indicators				
		PPE	**PPT**	**PQ**	**TC**	**LTR**	**GDP**	**GM**	**GP**	**EC**	**GI**	**SHC**	**IRE**	**RS**	**ID**	**RP**
SS1	2015	B	G	G	G	M	G	G	M	O	M	VVG	G	M	G	M
	2016	G	B	VVG	VVG	VVG	G	G	VG	VG	VVG	VG	VG	VG	VVG	VG
	2017	VVG	G	G	G	M	VVG	VG	G	G	VG	VVG	VVG	G	VVG	M
SS2	2015	G	G	B	G	G	G	G	O	G	G	G	G	B	G	G
	2016	VG	G	M	M	G	VG	M	M	M	G	G	VG	M	O	G
	2017	VVG	G	G	VG	G	VVG	G	VG	VG	G	VG	VG	VG	VG	VG
SS3	2015	O	B	G	G	M	B	B	G	G	M	VVB	O	VG	G	M
	2016	G	B	VVG	VVG	VVG	G	G	VVG	VVG	VVG	M	VVB	VVG	VVG	VVG
	2017	VVG	G	G	G	M	VVG	VVG	G	G	VG	G	VVG	G	VG	M
SS4	2015	G	G	B	G	G	G	M	B	G	G	G	G	O	G	G
	2016	VG	M	M	M	M	G	VG	M	M	VG	VG	VG	M	M	G
	2017	VG	G	M	G	G	VVG	G	G	VG	VG	VVG	G	G	VVG	VG
SS5	2015	G	G	B	G	M	G	G	O	G	O	G	G	B	G	M
	2016	VG	M	M	M	G	G	O	M	O	G	VG	VG	M	M	VG
	2017	G	O	G	VG	G	VVG	G	G	VG	VG	VG	G	G	G	G

Table A5. Transformation rules between language terms and trapezoid interval type-2 fuzzy numbers.

Linguistic Terms	Trapezoidal Interval Type-2 Fuzzy Number
Very unimportant (VU)	((0,0,0,0.1;1,1), (0,0,0,0.05;0.9,0.9))
Unimportant (U)	((0,0.1,0.1,0.3;1,1), (0.05,0.1,0.1,0.2;0.9,0.9))
Less important (LI)	((0.1,0.3,0.3,0.5;1,1), (0.2,0.3,0.3,0.4;0.9,0.9))
General important (GI)	((0.3,0.5,0.5,0.7;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
More important (MI)	((0.5,0.7,0.7,0.9;1,1), (0.6,0.7,0.7,0.8;0.9,0.9))
Important(I)	((0.7,0.9,0.9,1;1,1), (0.8,0.9,0.9,0.95;0.9,0.9))
Very important (VI)	((0.9,1,1,1;1,1), (0.95,1,1,1;0.9,0.9))

Table A6. Transformation rules between language terms and trapezoid interval type-2 fuzzy numbers.

Linguistic Variables	TIT2FSs
Very very bad (VVB)	((0,0,0,0;1,1), (0,0,0,0;0.9,0.9))
Very bad (VB)	((0,0.1,0.1,0.2;1,1), (0.05,0.1,0.1,0.15;0.9,0.9))
Bad (B)	((0.1,0.2,0.2,0.35;1,1), (0.15,0.2,0.2,0.3;0.9,0.9))
Ordinary (O)	((0.2,0.35,0.35,0.5;1,1), (0.25,0.35,0.35,0.45;0.9,0.9))
Medium (M)	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
Good (G)	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
Very good (VG)	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))
Very very good (VVG)	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))

$$\textit{possibility matrix} = \begin{bmatrix}
0.5000 & 1.0000 & 0.1250 & 1.0000 & 1.0000 & 0.2222 & 1.0000 & 1.0000 & 0.0000 & 0.4375 & 0.0000 & 1.0000 & 1.0000 & 0.0000 & 0.0000 \\
0.0000 & 0.5000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 1.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 1.0000 \\
0.8750 & 1.0000 & 0.5000 & 1.0000 & 1.0000 & 0.5625 & 1.0000 & 1.0000 & 0.3000 & 0.8571 & 0.3000 & 1.0000 & 1.0000 & 0.3000 & 0.0000 \\
0.0000 & 1.0000 & 0.0000 & 0.5000 & 0.0000 & 0.0000 & 1.0000 & 0.8333 & 0.0000 & 0.0000 & 0.0000 & 0.5455 & 0.0000 & 0.0000 & 1.0000 \\
0.0000 & 1.0000 & 0.0000 & 1.0000 & 0.5000 & 0.0000 & 1.0000 & 1.0000 & 0.0000 & 0.0000 & 0.0000 & 1.0000 & 0.5000 & 0.0000 & 1.0000 \\
0.7778 & 1.0000 & 0.4375 & 1.0000 & 1.0000 & 0.5000 & 1.0000 & 1.0000 & 0.2500 & 0.7500 & 0.2500 & 1.0000 & 1.0000 & 0.2500 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.5000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.2000 & 0.0000 & 0.0000 & 1.0000 \\
0.0000 & 1.0000 & 0.0000 & 0.1667 & 0.0000 & 0.0000 & 1.0000 & 0.5000 & 0.0000 & 0.0000 & 0.0000 & 0.2857 & 0.0000 & 0.0000 & 1.0000 \\
1.0000 & 1.0000 & 0.7000 & 1.0000 & 1.0000 & 0.7500 & 1.0000 & 1.0000 & 0.5000 & 1.0000 & 0.5000 & 1.0000 & 1.0000 & 0.5000 & 0.0000 \\
0.5625 & 1.0000 & 0.1429 & 1.0000 & 1.0000 & 0.2500 & 1.0000 & 1.0000 & 0.0000 & 0.5000 & 0.0000 & 1.0000 & 1.0000 & 0.0000 & 0.0000 \\
1.0000 & 1.0000 & 0.7000 & 1.0000 & 1.0000 & 0.7500 & 1.0000 & 1.0000 & 0.5000 & 1.0000 & 0.5000 & 1.0000 & 1.0000 & 0.5000 & 0.0000 \\
0.0000 & 1.0000 & 0.0000 & 0.4545 & 0.0000 & 0.0000 & 0.8000 & 0.7143 & 0.0000 & 0.0000 & 0.0000 & 0.5000 & 0.0000 & 0.0000 & 0.0000 \\
0.0000 & 1.0000 & 0.0000 & 1.0000 & 0.5000 & 0.0000 & 1.0000 & 1.0000 & 0.0000 & 0.0000 & 0.0000 & 1.0000 & 0.5000 & 0.0000 & 1.0000 \\
1.0000 & 1.0000 & 0.7000 & 1.0000 & 1.0000 & 0.7500 & 1.0000 & 1.0000 & 0.5000 & 1.0000 & 0.5000 & 1.0000 & 1.0000 & 0.5000 & 0.0000 \\
1.0000 & 0.0000 & 1.0000 & 0.0000 & 0.0000 & 1.0000 & 0.0000 & 0.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 0.0000 & 1.0000 & 0.5000
\end{bmatrix}$$

Table A7. Trapezoidal interval type-2 fuzzy numbers represent the economic indicators of sustainable suppliers.

Sustainable Suppliers	Time	Economic Indicators				
		PPE	PPT	PQ	TC	LTR
SS1	2015	((0.1,0.2,0.2,0.35;1,1), (0.15,0.2,0.2,0.3;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
	2016	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.1,0.2,0.2,0.35;1,1), (0.15,0.2,0.2,0.3;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))
	2017	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
SS2	2015	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.1,0.2,0.2,0.35;1,1), (0.15,0.2,0.2,0.3;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
	2016	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
	2017	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
SS3	2015	((0.2,0.35,0.35,0.5;1,1), (0.25,0.35,0.35,0.45;0.9,0.9))	((0.1,0.2,0.2,0.35;1,1), (0.15,0.2,0.2,0.3;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
	2016	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.1,0.2,0.2,0.35;1,1), (0.15,0.2,0.2,0.3;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))
	2017	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
SS4	2015	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.1,0.2,0.2,0.35;1,1), (0.15,0.2,0.2,0.3;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
	2016	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
	2017	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
SS5	2015	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.1,0.2,0.2,0.35;1,1), (0.15,0.2,0.2,0.3;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
	2016	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
	2017	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.2,0.35,0.35,0.5;1,1), (0.25,0.35,0.35,0.45;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))

Table A8. Trapezoidal interval type-2 fuzzy numbers represent the environmental indicators of sustainable suppliers.

Sustainable Suppliers	Time	Environmental Indicators				
		GDP	GM	GP	EC	GI
SS1	2015	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.2,0.35,0.35,0.5;1,1), (0.25,0.35,0.35,0.45;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
	2016	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))
	2017	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))
SS2	2015	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.2,0.35,0.35,0.5;1,1), (0.25,0.35,0.35,0.45;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
	2016	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
	2017	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
SS3	2015	((0.1,0.2,0.2,0.35;1,1), (0.15,0.2,0.2,0.3;0.9,0.9))	((0.1,0.2,0.2,0.35;1,1), (0.15,0.2,0.2,0.3;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
	2016	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))
	2017	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))
SS4	2015	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.1,0.2,0.2,0.35;1,1), (0.15,0.2,0.2,0.3;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
	2016	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))
	2017	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))
SS5	2015	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.2,0.35,0.35,0.5;1,1), (0.25,0.35,0.35,0.45;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.2,0.35,0.35,0.5;1,1), (0.25,0.35,0.35,0.45;0.9,0.9))
	2016	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.2,0.35,0.35,0.5;1,1), (0.25,0.35,0.35,0.45;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.2,0.35,0.35,0.5;1,1), (0.25,0.35,0.35,0.45;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
	2017	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))

Table A9. Trapezoidal interval type-2 fuzzy numbers represent the social indicators of sustainable suppliers.

Sustainable Suppliers	Time	Social Indicators				
		SHC	TE	RS	ID	RP
SS1	2015	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
	2016	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))
	2017	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
SS2	2015	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.1,0.2,0.2,0.35;1,1), (0.15,0.2,0.2,0.3;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
	2016	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.2,0.35,0.35,0.5;1,1), (0.25,0.35,0.35,0.45;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
	2017	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))
SS3	2015	((0,0,0,0;1,1), (0,0,0,0;0.9,0.9))	((0.2,0.35,0.35,0.5;1,1), (0.25,0.35,0.35,0.45;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
	2016	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0,0,0,0;1,1), (0,0,0,0;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))
	2017	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
SS4	2015	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.2,0.35,0.35,0.5;1,1), (0.25,0.35,0.35,0.45;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
	2016	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))
	2017	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.8,0.9,0.9,1;1,1), (0.85,0.9,0.9,0.95;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))
SS5	2015	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.1,0.2,0.2,0.35;1,1), (0.15,0.2,0.2,0.3;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))
	2016	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.35,0.5,0.5,0.65;1,1), (0.4,0.5,0.5,0.6;0.9,0.9))	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))
	2017	((0.65,0.8,0.8,0.9;1,1), (0.7,0.8,0.8,0.85;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))	((0.5,0.65,0.65,0.8;1,1), (0.55,0.65,0.65,0.75;0.9,0.9))

Table A10. Expert evaluation of candidate sustainable suppliers.

Sustainable Supplier	Time	Economic Indicators				Environmental Indicators						Social Indicators				
		PPE	PPT	PQ	TC	LTR	GDP	GM	GP	EC	GI	SHC	IRE	RS	ID	RP
SS1	2015	0.31	0.98	0.98	0.98	0.75	0.98	0.98	0.75	0.53	0.75	1.35	0.98	0.75	0.98	0.75
	2016	0.98	0.31	1.35	1.35	1.35	0.98	0.98	1.19	1.19	1.35	1.19	1.19	1.19	1.35	1.19
	2017	1.35	0.98	0.98	0.98	0.75	1.35	1.19	0.98	0.98	1.19	1.35	1.35	0.98	1.35	0.75
SS2	2015	0.98	0.98	0.31	0.98	0.98	0.98	0.98	0.53	0.98	0.98	0.98	0.98	0.31	0.98	0.98
	2016	1.19	0.98	0.75	0.75	0.98	1.19	0.75	0.75	0.75	0.98	0.98	1.19	0.75	0.53	0.98
	2017	1.35	0.98	0.98	1.19	0.98	1.35	0.98	1.19	1.19	0.98	1.19	1.19	1.19	1.19	1.19
SS3	2015	0.53	0.31	0.98	0.98	0.75	0.31	0.31	0.98	0.98	0.75	0.00	0.53	1.19	0.98	0.75
	2016	0.98	0.31	1.35	1.35	1.35	0.98	0.98	1.35	1.35	1.35	0.75	0.00	1.35	1.35	1.35
	2017	1.35	0.98	0.98	0.98	0.75	1.35	1.35	0.98	0.98	1.19	0.98	1.35	0.98	1.19	0.75
SS4	2015	0.98	0.98	0.31	0.98	0.98	0.98	0.75	0.31	0.98	0.98	0.98	0.98	0.53	0.98	0.98
	2016	1.19	0.75	0.75	0.75	0.75	0.98	1.19	0.75	0.75	1.19	1.19	1.19	0.75	0.75	0.98
	2017	1.19	0.98	0.75	0.98	0.98	1.35	0.98	0.98	1.19	1.19	1.35	0.98	0.98	1.35	1.19
SS5	2015	0.98	0.98	0.31	0.98	0.75	0.98	0.98	0.53	0.98	0.53	0.98	0.98	0.31	0.98	0.75
	2016	1.19	0.75	0.75	0.75	0.98	0.98	0.53	0.75	0.53	0.98	1.19	1.19	0.75	0.75	1.19
	2017	0.98	0.53	0.98	1.19	0.98	1.35	0.98	0.98	1.19	1.19	1.19	0.98	0.98	0.98	0.98

References

1. Rentizelas, A.; de Sousa Jabbour, A.B.L.; Al Balushi, A.D.; Tuni, A. Social sustainability in the oil and gas industry: Institutional pressure and the management of sustainable supply chains. *Ann. Oper. Res.* **2018**, *290*, 279–300. [CrossRef]
2. 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.* **2019**, *141*, 347–361. [CrossRef]
3. Kaluarachchi, Y. Potential advantages in combining smart and green infrastructure over silo approaches for future cities. *Front. Eng. Manag.* **2021**, *8*, 98–108. [CrossRef]
4. Fallahpour, A.; Olugu, E.U.; Musa, S.N. A hybrid model for supplier selection: Integration of AHP and multi expression programming (MEP). *Neural Comput. Appl.* **2017**, *28*, 499–504. [CrossRef]
5. Awasthi, A.; Govindan, K.; Gold, S. Multi-tier sustainable global supplier selection using a fuzzy AHP-VIKOR based approach. *Int. J. Prod. Econ.* **2018**, *195*, 106–117. [CrossRef]
6. Bakeshlou, E.A.; Khamseh, A.A.; Asl, M.A.G.; Sadeghi, J.; Abbaszadeh, M. Evaluating a Green Supplier Selection Problem Using a Hybrid MODM Algorithm. *J. Intell. Manuf.* **2017**, *28*, 913–927. [CrossRef]
7. Grimm, J.H.; Hofstetter, J.S.; Sarkis, J. Critical factors for sub-supplier management: A sustainable food supply chains perspective. *Int. J. Prod. Econ.* **2014**, *152*, 159–173. [CrossRef]
8. Liu, A.; Xiao, Y.; Lu, H.; Tsai, S.; Song, W. A fuzzy three-stage multi-attribute decision-making approach based on customer needs for sustainable supplier selection. *J. Clean. Prod.* **2019**, *239*, 118043. [CrossRef]
9. Soon, A.; Heidari, A.; Khalilzadeh, M.; Antucheviciene, J.; Zavadskas, E.K.; Zahedi, F. Multi-Objective Sustainable Closed-Loop Supply Chain Network Design Considering Multiple Products with Different Quality Levels. *Systems* **2022**, *10*, 94. [CrossRef]
10. De Soete, W. Towards a multidisciplinary approach on creating value: Sustainability through the supply chain and ERP systems. *Systems* **2016**, *4*, 16. [CrossRef]
11. Gebauer, H.; Fleisch, E. Managing sustainable service improvements in manufacturing companies. *Kybernetes* **2007**, *36*, 583–595. [CrossRef]
12. Jakhar, S.K.; Rathore, H.; Mangla, S.K. Is lean synergistic with sustainable supply chain? An empirical investigation from emerging economy. *Resour. Conserv. Recycl.* **2018**, *139*, 262–269. [CrossRef]
13. Goebel, P.; Reuter, C.; Pibernik, R. The influence of ethical culture on supplier selection in the context of sustainable sourcing. *Int. J. Prod. Econ.* **2012**, *140*, 7–17. [CrossRef]
14. Zimmer, K.; Fröhling, M.; Schultmann, F. Sustainable supplier management—A review of models supporting sustainable supplier selection, monitoring and development. *Int. J. Prod. Res.* **2015**, *54*, 1412–1442. [CrossRef]
15. Kumar, A.; Jain, V.; Kumar, S. A comprehensive environment friendly approach for supplier selection. *Omega* **2014**, *42*, 109–123. [CrossRef]
16. 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]
17. Gören, H.G. A decision framework for sustainable supplier selection and order allocation with lost sales. *J. Clean. Prod.* **2018**, *183*, 1156–1169. [CrossRef]
18. Thanh, N.V.; Lan, N.T.K. A new hybrid triple bottom line metrics and fuzzy MCDM model: Sustainable supplier selection in the food-processing industry. *Axioms* **2022**, *11*, 57. [CrossRef]
19. Park, K.; Kremer, G.E.O.; Ma, J. A regional information-based multi-attribute and multi-objective decision-making approach for sustainable supplier selection and order allocation. *J. Clean. Prod.* **2018**, *187*, 590–604. [CrossRef]
20. Mohammed, A.; Setchi, R.; Filip, M. An integrated methodology for a sustainable two-stage supplier selection and order allocation problem. *J. Clean. Prod.* **2018**, *192*, 99–114. [CrossRef]

21. Govindan, K.; Jafarian, A.; Nourbakhsh, V. Bi-objective integrating sustainable order allocation and sustainable supply chain network strategic design with stochastic demand using a novel robust hybrid multi-objective metaheuristic. *Comput. Oper. Res.* **2015**, *62*, 112–130. [CrossRef]
22. Moheb-Alizadeh, H.; Handfield, R. An integrated chance-constrained stochastic model for efficient and sustainable supplier selection and order allocation. *Int. J. Prod. Res.* **2017**, *56*, 6890–6916. [CrossRef]
23. Govindan, K.; Kadziński, M.; Ehling, R.; Miebs, G. Selection of a sustainable third-party reverse logistics provider based on the robustness analysis of an outranking graph kernel conducted with ELECTRE I and SMAA. *Omega* **2019**, *85*, 1–15. [CrossRef]
24. Yousefi, S.; Shabanpour, H.; Fisher, R. Evaluating and ranking sustainable suppliers by robust dynamic data envelopment analysis. *Measurement* **2016**, *83*, 72–85. [CrossRef]
25. Yu, F.; Xue, L.; Sun, C. Product transportation distance-based supplier selection in sustainable supply chain network. *J. Clean. Prod.* **2016**, *137*, 29–39. [CrossRef]
26. Su, C.M.; Horng, D.J.; Tseng, M.L. Improving sustainable supply chain management using a novel hierarchical grey-DEMATEL approach. *J. Clean. Prod.* **2016**, *134*, 469–481. [CrossRef]
27. Sarkis, J.; Dhavale, D.G. Supplier selection for sustainable operations, A triple-bottom-line approach using a Bayesian framework. *Int. J. Prod. Econ.* **2015**, *166*, 177–191. [CrossRef]
28. Kumar, D.T.; Palaniappan, M.; Kannan, D. Analyzing the CSR issues behind the supplier selection process using ISM approach. *Resour. Conserv. Recycl.* **2014**, *92*, 268–278. [CrossRef]
29. Azadi, M.; Jafarian, M.; Saen, R.F. A new fuzzy DEA model for evaluation of efficiency and effectiveness of suppliers in sustainable supply chain management context. *Comput. Oper. Res.* **2015**, *54*, 274–285. [CrossRef]
30. Salimian, S.; Mousavi, S.M.; Antucheviciene, J. An Interval-Valued Intuitionistic Fuzzy Model Based on Extended VIKOR and MARCOS for Sustainable Supplier Selection in Organ Transplantation Networks for Healthcare Devices. *Sustainability* **2022**, *14*, 3795. [CrossRef]
31. Shang, Z.; Yang, X.; Barnes, D.; Wu, C. Supplier selection in sustainable supply chains: Using the integrated BWM, fuzzy Shannon entropy, and fuzzy MULTIMOORA methods. *Expert Syst. Appl.* **2022**, *195*, 116567. [CrossRef]
32. Cui, L.; Wu, H.; Dai, J. Modelling flexible decisions about sustainable supplier selection in multitier sustainable supply chain management. *Int. J. Prod. Res.* **2021**, 1–22. [CrossRef]
33. Izadikhah, M.; Saen, R.F.; Roostaee, R. How to assess sustainability of suppliers in the presence of volume discount and negative data in data envelopment analysis? *Ann. Oper. Res.* **2018**, *269*, 241–267. [CrossRef]
34. Hatami-Marbini, A.; Kangi, F. An Extension of Fuzzy TOPSIS for a Group Decision Making with an Application to Tehran Stock Exchange. *Appl. Soft. Comput.* **2016**, *52*, 1084–1097. [CrossRef]
35. Saputro, T.E.; Figueira, G.; Almada-Lobo, B. Integrating supplier selection with inventory management under supply disruptions. *Int. J. Prod. Res.* **2020**, *59*, 3304–3322. [CrossRef]
36. Jauhar, S.K.; Pant, M. Integrating DEA with DE and MODE for sustainable supplier selection. *J. Comput. Sci.* **2017**, *21*, 299–306. [CrossRef]
37. Chen, T.Y.; Chang, C.H.; Lu, J.R. The extended QUALIFLEX method for multiple criteria decision analysis based on interval type-2 fuzzy sets and applications to medical decision making. *Eur. J. Oper. Res.* **2013**, *226*, 615–625. [CrossRef]
38. Hu, J.; Zhang, Y.; Chen, X. Multi-criteria decision making method based on possibility degree of interval type-2 fuzzy number. *Knowl.-Based Syst.* **2013**, *43*, 21–29. [CrossRef]
39. Zhang, Z.; Zhang, S. A novel approach to multi attribute group decision making based on trapezoidal interval type-2 fuzzy soft sets. *Appl. Math. Model.* **2013**, *37*, 4948–4971. [CrossRef]
40. Qin, J.; Liu, X.; Pedrycz, W. An extended TODIM multi-criteria group decision making method for green supplier selection in interval type-2 fuzzy environment. *Eur. J. Oper. Res.* **2017**, *258*, 626–638. [CrossRef]
41. Zhong, L.; Yao, L. An ELECTRE I-based multi-criteria group decision making method with interval type-2 fuzzy numbers and its application to supplier selection. *Appl. Soft Comput.* **2017**, *57*, 556–576. [CrossRef]
42. Wang, K.Q.; Liu, H.C.; Liu, L.; Huang, J. Green supplier evaluation and selection using cloud model theory and the QUALIFLEX method. *Sustainability* **2017**, *9*, 688–705. [CrossRef]
43. Wang, G.; Xu, C.; Li, D. Generic normal cloud model. *Inform. Sci.* **2017**, *280*, 1–15. [CrossRef]
44. Jiang, J.; Han, G.; Shu, L. A trust model based on cloud theory in underwater acoustic sensor networks. *IEEE Trans. Ind. Inform.* **2017**, *13*, 342–350. [CrossRef]
45. Yuan, Y.; Xu, H.; Wang, B.A. new dominance relation-based evolutionary algorithm for many-objective optimization. *IEEE Trans. Evolut. Comput.* **2016**, *20*, 16–37. [CrossRef]
46. Giagkiozis, I.; Fleming, P.J. Methods for multi-objective optimization, An analysis. *Inform. Sci.* **2015**, *293*, 338–350. [CrossRef]
47. Kokangul, A.; Susuz, Z. Integrated analytical hierarch process and mathematical programming to supplier selection problem with quantity discount. *Appl. Math. Model.* **2009**, *33*, 1417–1429. [CrossRef]
48. Kuo, R.J.; Lin, Y.J. Supplier selection using analytic network process and data envelopment analysis. *Int. J. Prod. Res.* **2012**, *50*, 2852–2863. [CrossRef]
49. Genovese, A.; Lenny Koh, S.C.; Bruno, G.; Esposito, E. Greener supplier selection: State of the art and some empirical evidence. *Int. J. Prod. Res.* **2013**, *51*, 2868–2886. [CrossRef]

50. Tan, T.; Alp, O. Optimal sourcing from alternative capacitated suppliers with general cost structures. *Omega* **2016**, *58*, 26–32. [CrossRef]
51. Bai, C.; Sarkis, J. Integrating sustainability into supplier selection with grey system and rough set methodologies. *Int. J. Prod. Econ.* **2010**, *124*, 252–264. [CrossRef]
52. Lin, C.T.; Chen, C.B.; Ting, Y.C. A green purchasing model by using ANP and LP methods. *J. Test. Eval.* **2012**, *40*, 203–210. [CrossRef]
53. 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]
54. Fahimnia, B.; Sarkis, J.; Eshragh, A. A Tradeoff Model for Green Supply Chain Planning, A Leanness-versus-Greenness Analysis. *Omega* **2015**, *54*, 173–190. [CrossRef]
55. Kou, G.; Akdeniz, Ö.O.; Dinçer, H.; Yüksel, S. Fintech investments in European banks: A hybrid IT2 fuzzy multidimensional decision-making approach. *Financ. Innov.* **2021**, *7*, 39. [CrossRef]
56. Govindan, K.; Kadziński, M.; Sivakumar, R. Application of a novel PROMETHEE-based method for construction of a group compromise ranking to prioritization of green suppliers in food supply chain. *Omega* **2017**, *71*, 129–145. [CrossRef]
57. Varsei, M.; Soosay, C.; Fahimnia, B.; Sarkis, J. Framing sustainability performance of supply chains with multidimensional indicators. *Supply Chain. Manag.* **2014**, *19*, 242–257. [CrossRef]
58. Kuo, R.J.; Wang, Y.C.; Tien, F.C. Integration of artificial neural network and MADA methods for green supplier selection. *J. Clean. Prod.* **2010**, *18*, 1161–1170. [CrossRef]
59. Zadeh, L.A. Fuzzy sets. *Inf. Control* **1965**, *8*, 338–353. [CrossRef]
60. Meng, Y.; Wu, H.; Zhao, W.; Chen, W.; Dinçer, H.; Yüksel, S. A hybrid heterogeneous Pythagorean fuzzy group decision modelling for crowdfunding development process pathways of fintech-based clean energy investment projects. *Financ. Innov.* **2021**, *7*, 33. [CrossRef]
61. Ghorabaee, M.K.; Amiri, M.; Sadaghiani, J.S.; Zavadskas, E.K. Multi-criteria project selection using an extended VIKOR method with interval type-2 fuzzy sets. *Int. J. Inf. Technol. Decis. Mak.* **2015**, *14*, 993–1016. [CrossRef]
62. Vats, M.; Singh, S. Assessment of gold and silver in assorted mobile phone printed circuit boards (PCBs). *Waste Manag.* **2015**, *45*, 280–288. [CrossRef]
63. Peng, H.G.; Wang, J.Q. A Multicriteria Group Decision-Making Method Based on the Normal Cloud Model with Zadeh's Z-Numbers. *IEEE Trans. Fuzzy Syst.* **2018**, *26*, 3246–3260. [CrossRef]
64. Wang, D.; Liu, D.; Ding, H.; Singh, V.P.; Wang, Y.; Zeng, X.; Wang, L. A cloud model-based approach for water quality assessment. *Environ. Res.* **2016**, *148*, 24–35. [CrossRef]