An Integrated Spherical Fuzzy Approach for Global Supplier Selection

Abedallah Z. Abualkishik*, Rasha Almajed, Amer Ibrahim

American University in the Emirates, Dubai, UAE
Emails: abedallah.abualkishik@aue.ae, rasha.almajed@aue.ae, amer.ibrahim@aue.ae

Abstract

Political-economic liberalization, modern communication technologies, and low-cost transportation have prompted companies to outsource an increasing amount of commercial activities to other countries. This exporting has often resulted in complex supply chain configurations. Considering that human and ecological regulation in these countries is often insufficient or poorly enforced, stakeholders place the responsibility of ensuring socially and environmentally sustainable product specifications across their supply chains on firms with particular emphasis. This research presents a combined fuzzy spherical AHP-WASPAS method basis for environmental global procurement planning that takes subsupplier sustainability considerations into account. From the present study, standards (containing risk considerations) were devised and then improved with the assistance of experts in the field and case decision-makers in order to avoid literature bias. Next, providers and semi were evaluated collectively using the agreed sustainability criteria. In previous studies, this methodology proved unsatisfactory. The problem is rectified in two stages, as shown below. In the first phase, fuzzy AHP is used to define parameter weights for inclusive sustainable supplier evaluation, so in the second phase, fuzzy WASPAS is employed to assess supplier performance in relation to evaluation criteria. Economic factors held the highest weight among some of the five ecological sustainability (financial, health, environment, and social), whereas worldwide risk assessments carried the least. This research suggests that global threats are not yet important selection factors for suppliers. Moreover, the proposed framework may help pave the way for the creation of managerial decision-making tools to aid firms in tackling sustainability risks that occur farther downstream in their supply chains. When major organizations are under intense scrutiny from their stakeholders, these vital tools are extremely important.

Keywords: AHP; WASPAS; Spherical fuzzy sets; Supplier Selection.

1. Introduction

Corporations in the developed world have been forced by globalization to outsource their workforce and export their products to low-cost economies. These strategies allow businesses to take advantage of the lower costs of the goods and materials they get and so increase their position in the market.[1]. Specialization at certain phases of production and on indigenous production resource endowments, such as low-cost labor and raw materials, provide profits. [2]. Constant outsourcing provides a number of benefits, but it also has certain drawbacks. There may be unanticipated consequences of outsourcing to developing and transitional nations, such as additional layers of work processes and a fragmented supply chain that might lead to poor quality.[1] and hazards from unsustainable manufacturing in the upstream channel [3].

Globalization is among the growing ideas in the industrial sector. Due to low-cost labor, improved product quality, and innovation strategy, many businesses rely on global suppliers to reduce procurement-related expenses. However, the choice of global suppliers is particularly susceptible to

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

transportation hazards, such as a rise in the price of the product, terrorism or crime rate, uncertain diplomacy, strikes, etc. To completely analyze the performance of global suppliers and optimize the supply chain, it is necessary, in addition to the use of standard criteria, to use the risks criterion.

Consequently, rising synchronization and provided to the customers need a decrease in the supply base, a tightening of integration, and a strengthening of cooperation with selected partners [4]. Global supplier selection poses a strategic and intricate managerial decision dilemma[5].

Due to the close relationship between supplier selection and corporate performance and competitive posture, the decision is typically made by companies with a dominant supply chain location and trademark ownership[6]. Any accurate comparison of prospective suppliers encompasses various levels and reflects a multi-attribute managerial decision problem; hence, supplier selection on a worldwide scale extends these evaluation dimensions. Additional risk considerations, including geographical region, social-financial processes which help, and terrorism risks, must be taken into account [7].

Most current techniques disregard the reality that focuses firms are held responsible for the negative effects and complaints of their entire supplier chain. In reality, existing supplier selection methods do not extend beyond the immediate (first-tier) suppliers of the focus firm. The omission of upstream suppliers in supply chain modeling techniques does not account for the reality that firms are held responsible for social and environmental repercussions along the whole supply chain, including the extraction of raw materials. Noncompliance with social norms puts corporations in danger of losing their brand's image and legitimacy and may expose companies to unfavorable government measures. Recent instances demonstrate how (multinational) firms may be blamed for the immoral or unsustainable business practices of their suppliers.

One instance scenario involves European and North American supermarkets (Wal-Mart, Carrefour, and Tesco) who were accused of selling shrimp harvested under cruel circumstances. Charoen Pokphand Products (CPF), a Thai enterprise and the biggest prawn farming company in the world, provided the shrimp. CPF was accused of purchasing fishmeal for its shrimp farms from fishing vessels using slave labor [8]. Campaigns launched by NGOs and amplified by the media tarnished the brand reputation of the targeted supermarkets (with financial ramifications) and compelled them to remove the specific shrimp items from their shelves[9].

As part of our investigation into implementing sustainable supplier evaluation, we looked at the risks presented by the sub-suppliers of a firm. The vast majority of existing research focuses on a variety of sustainability factors (market, ecology, and society). The selection process will be more effective if global hazards are included in sustainable supplier selection procedures. Five study areas were developed and presented in earlier sections due to a lack of papers published and background. To achieve the study's goal, these questionnaires may be divided into two categories: assessments of sustainability and hazards, which are then combined via an examination of both suppliers and sub-suppliers. As a result, case manufacturing managers and subject matter experts helped us extract and evaluate common sustainability criteria, such as risk issues. Environmental and hazard factors were employed at 2 levels of supplier evaluation. First-tier suppliers are the emphasis of the evaluation, while the sub-suppliers of those first-tier suppliers are the subject of the second stage. The core corporation, which is concerned about maintaining its brand's image across the supply chain, carried out both analyses.

A case study is used to develop and validate a model framework. Using AHP and WASPAS, the provider and sub-suppliers are evaluated based on sustainability criteria. In the absence of quantitative assessments, fuzzy set theory is used to handle uncertainties. In the next sections, the approach and its applications are described in depth.

The requirements for handling uncertainty and vagueness in linguistic phrases may also be realized using spherical fuzzy sets (SFS). SFS provides a fresh perspective on making decisions in ambiguous situations. The decision maker's degree of indeterminacy is specified independently of the elements' levels of membership and nonmembership in these sets. To generalize to additional fuzzy sets, decision-makers use SFS to build membership functions on spherical surfaces. These membership functions are thus applied to a bigger set of variables. Fuzzy Pythagorean sets are combined with neutrosophic fuzzy sets to form SFS.

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

The AHP technique, which relies on human judgments to solve decision-making issues, has seen a recent uptick in popularity in the scientific community. Fuzzy AHP is being used more and more in conjunction with other decision-making methodologies.

For multi-criteria decision-making, WASPAS is widely used and well-known. Multicriteria decision-making strategies, such as WASPAS, combine the weighted total and weighted multiplying procedures.

As part of this study, we explore the issue of selecting a worldwide sustainable supplier, taking into account the risks posed by the company's subsuppliers. According to current research, sustainability may be defined as a combination of the three pillars of the economy, the environment, and society. Sustainable supplier evaluation actions can be made more efficient by incorporating global risks into the process. In this way, general guidelines including risk concerns were gathered from the research and examined further with the support of example industrial managers and specialists in the area. Two levels of supplier assessment made use of the sustainability and risk criteria. To begin with, suppliers and sub-suppliers are considered in the first step of the assessment. To protect its brand's image across the supply chain, the company conducted these two analyses. We're particularly interested in finding out how to include sustainability risks from suppliers into the sustainable environment supplier evaluation methodology. A case study is used to test a model framework. Evaluation of suppliers and sub-suppliers is done using AHP and VIKOR methodologies, which are based on sustainability criteria. Uncertainties originating from a lack of quantitative assessments are addressed using spherical fuzzy set theory. The approach and its applications will be explained in-depth in the following sections.

The remaining structure of the manuscript: In the second part, we discuss the relevant research and research gaps. In Section 3, we present a technique for selecting global sustainable suppliers based on spherical fuzzy AHP and fuzzy WASPAS. In section 4, a statistical application is then illustrated. In parts 5 and 6, the article concludes with management implications and recommendations.

2. Related Work

Buying achieved strategic significance in the 1990s [10]–[13] as a result of its significant influence on company core performance goals, which was facilitated by a market direction toward core competencies [14]–[16]. These core skills increase the amount of outsourced non-core operations, which has resulted in buying expenses being the majority of product costs in various sectors[7]–[9]. The strategic significance of buying places a premium on the supplier selection process. The objective of the selection procedure is to find suppliers who can consistently and cost-effectively meet the needs of the purchasing organization [17], [17], [18]. Supplier selection substantially influences subsequent efforts to form buyer-supplier alliances and enhance supplier skills via supplier development programs [19], [20], [20].

[21] Identify four steps in the supplier selection process: (1) problem description, (2) creation of eligibility criteria, (3) candidate preselection, and (4) final selection. Phases two through four of the selection procedure will benefit the most from quantitative management decision-support technologies[21]. The majority of the techniques addressed in the present literature pertain to step 4, the ultimate supplier selection, and include numerous supplier qualities as opposed to solely the cost factor[22], [23]. There are a variety of mathematical programming models that are commonly used for supplier selection, such as linear, goal, and multi-objective programming, as also AHP/ANP, FS, SMART, and ANN networks.[24].

Supplier choice is one of the most challenging decisions for any performance decision to make due to the substantial cash involved. Consequently, various writers have proposed numerous strategies to effectively address this problem during the last few decades. [25]have recently suggested the fluid decision support system, which integrates economic, social, and ecological criteria for the thorough evaluation of reliable vendors in the petrochemical sector. [26]utilized a multi-stage hybrid strategy to segment and choose providers in Industries 4.0, taking into consideration supply chain disruptions and hazards. The authors evaluated the suggested methodology in the automobile sector. However, their suggested research does not evaluate suppliers based on economic and environmental factors. To solve the sustainable SS&OA issue, [27] suggested a multiitem, multiperiod, and multiobjective fuzzy programming approach. Under conditions of uncertainty, inflation, and hazards, the writers chose their providers. [28]proposed a decision-making basis for analyzing oil and gas providers by selecting the 16 most important factors using the grey-Delphi method. The authors then estimated the criterion weights and alternative rankings using grey-EDAS and grey-Shannon entropy

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

techniques. [29]used a combination of rough set theory and the ELECTRE technique, which does not need a great deal of previous knowledge during the assessment of providers to control the ambiguity in data. Their proposed technique only aids decision-makers in assessing providers, not in finding the best amount of order distribution among them.

Just used the TOPSIS and ELECTRE techniques, [30]chose sustainable suppliers. Their proposed strategy seeks to maximize economic benefits while fulfilling environmental standards.[31], created the fuzzy multi-objective framework for addressing the fuzzy restrictions and fuzzy factors difficulties during SS&OA.

Their proposed methodology is intended to lower total costs, the number of defective units, and the number of late deliveries. [32]introduced two mixed-integer non-linear programming methods to assess the optimal network of vendors, order quantity, retail price, and several goods per order cycle for a variety of lot-sizing techniques. [33]created a two-stage circular supplier evaluation and order allocation approach to analyze the apparel manufacturing sector's suppliers. Their proposed multi-objective strategy minimizes total network costs, lost sales, and unfavorable environmental consequences while expanding opportunities for sustainable supplier procurement and employment. [34]used the interval type 2 FAHP and COPRAS-G approaches to evaluate the important criteria and supplier performance in Industry 4.0 for supplier selection. Baki[35], in the year 2021, designed an integrated approach for assessing Turkish automotive suppliers primarily on socioeconomic, social, environmental, and competence aspects. The writer used the best-worst and fuzzy TODIM techniques to determine the priority level of each stated criteria and the final supplier rating.

3. Mathematical equations for the MCDM Model

This article presents an effective integrated assessment technique for assessing and choosing the best sustainable supplier case study in China. The suggested framework consists of two phases, as shown in the figure. 1. In the first step, the Fuzzy AHP model is used to predict the fuzzy weight and crisp weight of each criterion. The spherical fuzzy set, denoted by languages number, is included in the AHP model to handle ambiguity and uncertainty based on the opinion of experts. To validate the model, the consistency of the similarity matrix is evaluated. In the second step, the WASPAS model is used to rank the wind power sites.

A. Spherical Fuzzy AHP

Kutlu Gündoudu and Kahraman[36] created spherical fuzzy sets (SFS) to manage uncertainty during the quantification of expert opinions. Figure 2 illustrates the distinctions between the intuitionistic fuzzy set, the Pythagorean fuzzy set, the neutrosophic set, and the spherical fuzzy set[37]. Three dimensions comprise the SFS: membership, non-membership, and hesitation levels.

Step 1: A analysis and decision tree have three levels: the study objective (level 1), the list of criteria $GSC = GSC_1, GSC_2, \dots GSC_e$ (level 2), and the location options $GSA = GSA_1, GSA_2, \dots GSA_f$.
Step 2: Similarity matrices are computed for linguistic concepts in Step 2. Score indices (SCI) are calculated.

$$SCI = \sqrt{|100 * [(x-z)^2 - (y-z)^2]|} \quad (1)$$

Step 3: Requires a consistency check on pairwise comparison matrices using the consistency ratio (CR), which must be less than 10%.
Step 4: Calculate the criteria and option spherical fuzzy weights in the fourth step. The SWAM operator is used to measure the weight of each option.

$$SWAM_w(GSA_1, \dots\dots, GSA_e) = w_1 GSA_1 + w_2 GSA_2 + \dots + w_e GSA_e$$
$$= < \left[1 - \prod_{a=1}^{e} \left(1 - x_{GSA_i}^2\right)^{w_a}\right]^{0.5},$$
$$\prod_{a=1}^{e} \left(y_{GSA_i}^{w_a}\right),$$

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

$$\left[\prod_{a=1}^{e}\left(1-x_{GSA_a}^2\right)^{w_a}-\prod_{a=1}^{e}\left(1-x_{GSA_a}^2-z_{GSA_a}^2\right)^{w_a}\right]^{0.5}> \tag{2}$$

Where $w = 1/e$

Step 5: Using the defuzzification global weights, the final rating orders for the option are calculated in the fifth step.

$$S(w_b) = \sqrt{\left|100 * \left[(3 * x - \frac{z}{2})^2 - (\frac{y}{2} - z)^2\right]\right|} \tag{3}$$

Step 6: Normalize the weights of the criterion and perform the spherical fuzzy multiplication.

$$w_b = \frac{S(w_b)}{\sum_{b=1}^{e} S(w_b)} \tag{4}$$

$$GSA_{ab} = w_b GSA_a = <\left(1-\left(1-x_{GSA_a}^2\right)^{w_b}\right)^{0.5}, y_{GSA_a}^{w_b}, \left(\left(1-x_{GSA_a}^2\right)^{w_b}-\left(1-x_{GSA_a}^2-z_{GSA_a}^2\right)^{w_b}\right)^{1/2}> \tag{5}$$

B. Spherical Fuzzy WASPAS

Evaluation of a product based on a weighted tally of the total value (WASPAS). The WASPAS approach was introduced in 2012 [38]; it is a mix of the weighted product model (WPM) and the weighted sum model (WSM); the steps of the proposed model are shown in figure 1. the process is described below.

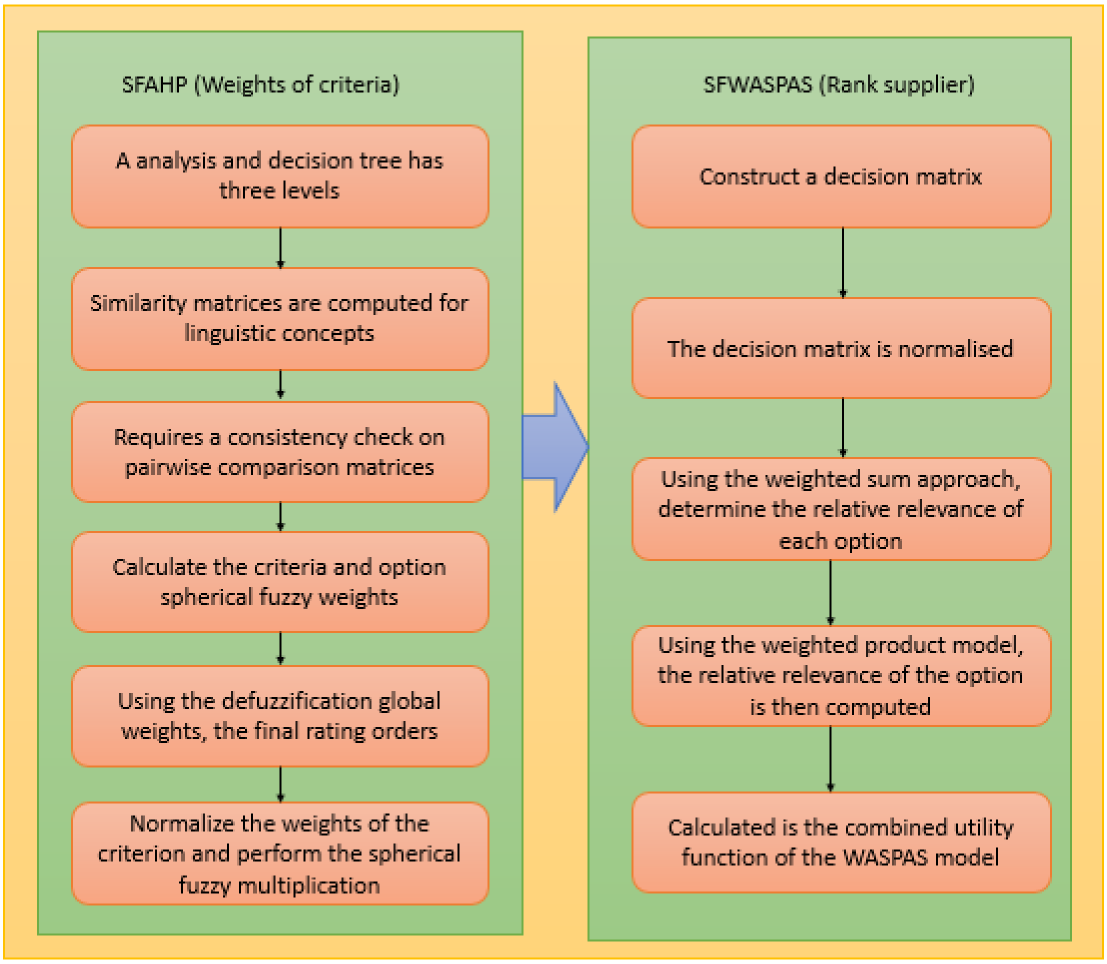

Figure 1: The framework of the paper.

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

Step 1: Construct a decision matrix $O = [o_{ab}]_{ef}$, where o_{ab} represents the performance of the ath option to the bth criterion, f represents the number of choices, and e represents the number of criteria.

Step 2: The decision matrix is normalized for benefit and cost criteria as:

$$O_{ab} = \frac{o_{ab}}{\max_{a} o_{ab}} \tag{6}$$

$$O_{ab} = \frac{o_{ab}}{\min_{a} o_{ab}} \tag{7}$$

Where $a = 1,2,3, \ldots . f; b = 1,2,3, \ldots \ldots e$

Step 3: Using the weighted sum approach, determine the relative relevance of each option

$$R_a^{(1)} = \sum_{b=1}^{e} o_{ab} w_b \tag{8}$$

Step 4: Using the weighted product model, the relative relevance of the option is then computed.

$$R_a^{(2)} = \prod_{b=1}^{e} (o_{ab})^{w_b} \tag{10}$$

Step 5: Calculated is the combined utility function of the WASPAS model.

$$R_a = \lambda R_a^{(1)} + (1 - \lambda) R_a^{(2)} \tag{11}$$

$$\lambda = \frac{\sum_{a=1}^{f} R_a^{(1)}}{\sum_{a=1}^{f} R_a^{(1)} + \sum_{a=1}^{f} R_a^{(2)}} \tag{12}$$

4. Application

In this part, we illustrate the numerical application of the suggested technique for a manufacturer of electronic products interested in assessing its worldwide suppliers from a holistic sustainability standpoint.

To determine their priorities, the decision-making committee undertakes pairwise assessments of criteria. Using the average method technique aggregate pairwise scores are calculated for the different criteria and sub-criteria. The aggregate pairwise judgment matrix of the decision committee members for the stage I criterion is shown in Table 1. The C.R is less than 0.1; hence, the assessments are consistent.

After running pairwise comparison matrices and verifying consistencies, the priority of sub-criteria linked with stage I are also displayed. The local and global weights of the different sub-criteria connected with stage I are shown in Table 2. The global weights are calculated by multiplying the local weights by the weight associated with each criterion. For example, the local weight of sub-criteria is 0.5, while the local weight of criterion is 0.3; consequently, the global weight of sub-criteria is 0.5*0.3 = 0.15. Figure 2 shows the weights of the main criteria. The main, sub-criteria and alternatives in below

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

Main criteria	Sub criteria	Alternatives
Economic GSC1	Cost GSC1.1	GSA1 GSA2 GSA3 GSA4 GSA5 GSA6 GSA7 GSA8 GSA9 GSA10
	Quality GSC1.2	
	Flexibility GSC1.3	
	Speed GSC1.4	
	Dependability GSC1.5	
	Innovativeness GSC1.6	
Quality of relationship GSC2	Trust GSC2.1	
	Effectiveness of communication GSC2.2	
	EDI GSC2.3	
Environmental GSC3	Materials GSC3.1	
	Energy GSC3.2	
	Water GSC3.3	
	Biodiversity GSC3.4	
	Emissions GSC3.5	
	Effluents and waste GSC3.6	
	Supplier environmental selection procedure GSC3.7	
Social GSC4	Labor practices and decent work GSC4.1	
	Human rights GSC4.2	
	Society GSC4.3	
	Product responsibility GSC4.4	
	Supplier social selection procedure GSC4.5	
Global risks GSC5	Currency risks GSC5.1	
	Disruption risks through political instability GSC5.2	
	Disruption risks through terrorism GSC5.3	
	Cultural compatibility GSC5.4	

Table 1: The aggregated pairwise matrix for the main criteria.

	GSC_1	GSC_2	GSC_3	GSC_4	GSC_5
GSC_1	1.00	4.65	10.65	16.66	11.49
GSC_2	0.06	1.00	13.16	6.33	10.32
GSC_3	0.19	0.11	1.00	16.66	10.65
GSC_4	0.14	0.16	0.14	1.00	6.32
GSC_5	0.17	0.17	0.19	0.20	1.00

Table 2: The local and global weights of criteria.

Local	Weights	Global weights
$GSC_{1.1}$	0.506191	0.255736
$GSC_{1.2}$	0.154128	0.077868
$GSC_{1.3}$	0.180551	0.091217
$GSC_{1.4}$	0.087896	0.044406
$GSC_{1.5}$	0.049321	0.024918
$GSC_{1.6}$	0.021913	0.011071
$GSC_{2.1}$	0.713449	0.162824

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

$GSC_{2.2}$	0.23045	0.052594
$GSC_{2.3}$	0.056101	0.012803
$GSC_{3.1}$	0.341957	0.058352
$GSC_{3.2}$	0.213156	0.036373
$GSC_{3.3}$	0.201354	0.034359
$GSC_{3.4}$	0.109233	0.01864
$GSC_{3.5}$	0.076044	0.012976
$GSC_{3.6}$	0.041723	0.00712
$GSC_{3.7}$	0.016532	0.002821
$GSC_{4.1}$	0.469055	0.02872
$GSC_{4.2}$	0.245406	0.015026
$GSC_{4.3}$	0.162903	0.009975
$GSC_{4.4}$	0.081545	0.004993
$GSC_{4.5}$	0.041091	0.002516
$GSC_{5.1}$	0.570643	0.019798
$GSC_{5.2}$	0.24964	0.008661
$GSC_{5.3}$	0.142066	0.004929
$GSC_{5.4}$	0.037651	0.001306

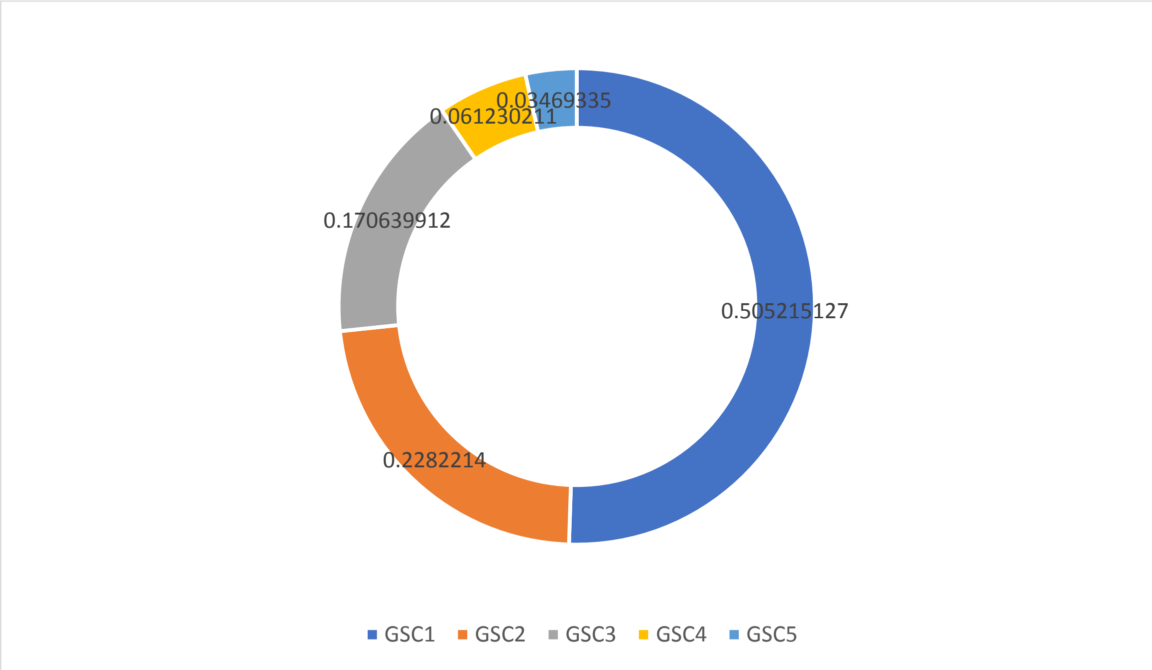

Figure 2: The weights of the main criteria.

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

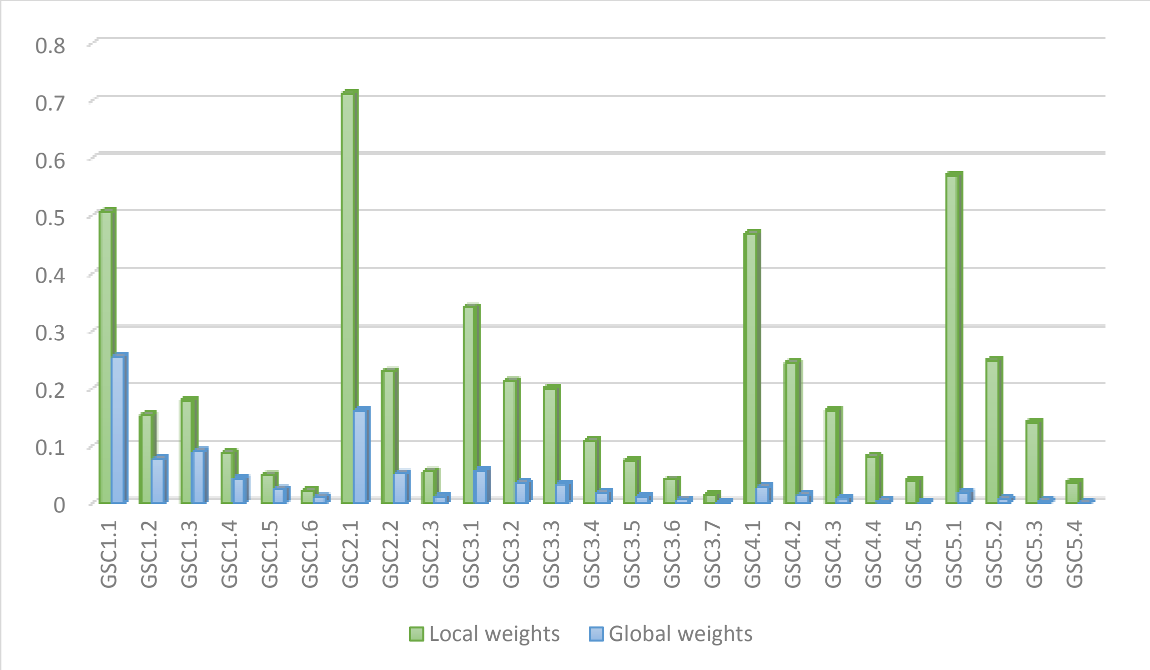

Figure 3: The local and global weights of criteria.

Fuzzy WASPAS is used to choose the sustainable supplier and sub-supplier(s) based on the weighted criteria derived by fuzzy AHP (stages I and II). A committee of three decision-makers is created to assess the alternatives (ten suppliers) using qualitative (linguistic) evaluations based on the stated criteria in tables 3.1-3.3. The aggregated acquired ratings are shown in Table 3.

In the second phase, the SF-AHP weights were combined with the WASPAS model to rank the probable suppliers. Table 4 shows the normalized decision matrix. Tables 5 and 6 exhibit, respectively, the weighted normalized matrix for the WSM and the weighted normalized matrix for the WPM. Using an integrated simple additive weighting and exponentially weighted product model, the WASPAS model ranks the alternatives to provide a compromise solution. The integrated utility function R_a of the WASPAS model is derived from the weighted sum model $R_a{}^{(1)}$ (WSM) and the weighted product model $R_a{}^{(1)}$ (WSM). The findings indicate that the top three suppliers GSC_5, GSC_4, GSC_1, ranked first, second, and third, respectively, with scores of 0.734, 0.6837, and 0.6365. Figure 4 depicts the WASPAS model's final supplier ranking.

Table 3.1: The decision matrix by the first expert.

	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC	GSC
GSC	5.491812	23.5	23.5	23.5	2.966058	19.99994	19.99994	23.5	19.99994	23.5	7.998594	7.998594	19.99994	7.998594	19.99994	23.5	7.998594	19.99994	23.5	5.491812	23.5	23.5	23.5	5.491812	7.998594
GSC	23.5	10.5	7.998594	19.99994	2.966058	19.99994	23.5	7.998594	23.5	7.998594	2.966058	7.998594	23.5	19.99994	23.5	7.998594	23.5	19.99994	7.998594	23.5	5.491812	5.491812	23.5	23.5	23.5
GSC	7.998594	2.966058	23.5	23.5	2.966058	23.5	19.99994	23.5	23.5	23.5	19.99994	7.998594	19.99994	23.5	7.998594	23.5	19.99994	5.491812	23.5	7.998594	23.5	5.491812	23.5	7.998594	23.5

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

GSC	GSC	GSC	GSC	GSC	GSC	GSC
7.998594	7.998594	7.998594	7.998594	7.998594	7.998594	23.5
2.966058	23.5	26.99995	7.998594	7.998594	7.998594	23.5
7.998594	7.998594	7.998594	23.5	7.998594	23.5	
23.5	26.99995	7.998594	23.5	7.998594	23.5	7.998594
7.998594	2.966058	7.998594	23.5	19.99994	23.5	2.966058
23.5	2.966058	7.998594	23.5	19.99994	23.5	19.99994
2.966058	7.998594	23.5	7.998594	23.5	7.998594	23.5
7.998594	7.998594	23.5	7.998594	23.5	26.99995	7.998594
2.966058	2.966058	23.5	26.99995	7.998594	23.5	7.998594
7.998594	2.966058	2.966058	2.966058	23.5	26.99995	7.998594
7.998594	7.998594	23.5	7.998594	23.5	2.966058	2.966058
2.966058	2.966058	23.5	19.99994	23.5	23.5	23.5
2.966058	7.998594	23.5	7.998594	2.966058	7.998594	23.5
7.998594	2.966058	23.5	26.99995	7.998594	23.5	7.998594
2.966058	7.998594	2.966058	23.5	26.99995	7.998594	23.5
7.998594	2.966058	2.966058	2.966058	23.5	26.99995	7.998594
2.966058	19.99994	23.5	2.966058	2.966058	7.998594	23.5
2.966058	23.5	26.99995	7.998594	23.5	7.998594	23.5
7.998594	5.491812	5.491812	5.491812	5.491812	7.998594	7.998594
2.966058	2.966058	2.966058	23.5	26.99995	7.998594	23.5
2.966058	2.966058	23.5	26.99995	7.998594	23.5	7.998594
2.966058	5.491812	7.998594	7.998594	23.5	7.998594	23.5
7.998594	2.966058	23.5	26.99995	7.998594	23.5	7.998594
5.491812	5.491812	5.491812	23.5	26.99995	7.998594	23.5
7.998594	2.966058	7.998594	7.998594	23.5	7.998594	23.5

Table 3.2: The decision matrix by the second expert.

GSC	GSC	GSC	
7.998594	7.998594	7.998594	GSC
7.998594	26.99995	2.966058	GSC
7.998594	7.998594	7.998594	GSC
7.998594	7.998594	23.5	GSC
19.99994	7.998594	7.998594	GSC
19.99994	7.998594	23.5	GSC
23.5	23.5	2.966058	GSC
23.5	23.5	7.998594	GSC
7.998594	23.5	2.966058	GSC
23.5	2.966058	7.998594	GSC
23.5	23.5	7.998594	GSC
23.5	23.5	2.966058	GSC
2.966058	23.5	2.966058	GSC
7.998594	23.5	7.998594	GSC
26.99995	2.966058	2.966058	GSC
23.5	2.966058	7.998594	GSC
2.966058	23.5	2.966058	GSC
23.5	26.99995	2.966058	GSC
5.491812	5.491812	7.998594	GSC
26.99995	2.966058	2.966058	GSC
7.998594	23.5	2.966058	GSC
23.5	7.998594	2.966058	GSC
7.998594	23.5	7.998594	GSC
26.99995	5.491812	5.491812	GSC
23.5	7.998594	7.998594	GSC

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

GSC	GSC	GSC	GSC	GSC	GSC	GSC
23.5	7.998594	7.998594	23.5	7.998594	7.998594	23.5
23.5	23.5	26.99995	23.5	7.998594	26.99995	23.5
	7.998594	7.998594		7.998594	7.998594	
7.998594	26.99995	7.998594	7.998594	7.998594	7.998594	7.998594
2.966058	2.966058	7.998594	2.966058	19.99994	7.998594	2.966058
19.99994	2.966058	7.998594	19.99994	19.99994	7.998594	19.99994
23.5	7.998594	23.5	23.5	23.5	23.5	23.5
7.998594	7.998594	23.5	7.998594	23.5	23.5	7.998594
7.998594	2.966058	23.5	7.998594	7.998594	23.5	7.998594
7.998594	2.966058	2.966058	7.998594	23.5	2.966058	7.998594
2.966058	7.998594	23.5	2.966058	23.5	23.5	2.966058
23.5	2.966058	23.5	23.5	23.5	23.5	23.5
23.5	7.998594	23.5	23.5	2.966058	23.5	23.5
7.998594	2.966058	23.5	7.998594	7.998594	23.5	7.998594
23.5	7.998594	2.966058	23.5	26.99995	2.966058	23.5
7.998594	2.966058	2.966058	7.998594	23.5	2.966058	7.998594
23.5	19.99994	23.5	23.5	2.966058	23.5	23.5
23.5	23.5	26.99995	23.5	23.5	26.99995	23.5
7.998594	5.491812	5.491812	7.998594	5.491812	5.491812	7.998594
23.5	2.966058	2.966058	23.5	26.99995	2.966058	23.5
7.998594	2.966058	23.5	7.998594	7.998594	23.5	7.998594
23.5	5.491812	7.998594	23.5	23.5	7.998594	23.5
7.998594	2.966058	23.5	7.998594	7.998594	23.5	7.998594
23.5	5.491812	5.491812	23.5	26.99995	5.491812	23.5
23.5	2.966058	7.998594	23.5	23.5	7.998594	23.5

Table 3.3: The decision matrix by a third expert.

GSC	GSC	GSC	
23.5	23.5	5.491812	GSC
23.5	10.5	23.5	GSC
	7.998594	23.5	GSC
7.998594	19.99994	23.5	GSC
2.966058	2.966058	2.966058	GSC
19.99994	19.99994	19.99994	GSC
23.5	23.5	19.99994	GSC
7.998594	7.998594	23.5	GSC
7.998594	23.5	19.99994	GSC
7.998594	7.998594	23.5	GSC
2.966058	2.966058	7.998594	GSC
23.5	7.998594	7.998594	GSC
23.5	23.5	19.99994	GSC
7.998594	19.99994	7.998594	GSC
23.5	23.5	19.99994	GSC
7.998594	7.998594	23.5	GSC
23.5	23.5	7.998594	GSC
23.5	19.99994	19.99994	GSC
7.998594	7.998594	23.5	GSC
23.5	23.5	5.491812	GSC
7.998594	5.491812	23.5	GSC
23.5	5.491812	23.5	GSC
7.998594	23.5	23.5	GSC
23.5	23.5	5.491812	GSC
23.5	23.5	7.998594	GSC

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

GSC	GSC	GSC	GSC	GSC	GSC	GSC
7.998 594	5.491 812	23.5	7.998 594	7.998 594	5.491 812	23.5
2.966 058	23.5	23.5	7.998 594	7.998 594	23.5	23.5
23.5	23.5		23.5	7.998 594	23.5	
23.5	23.5	7.998 594	23.5	7.998 594	23.5	7.998 594
2.966 058	2.966 058	2.966 058	23.5	19.99 994	2.966 058	2.966 058
23.5	19.99 994	19.99 994	23.5	19.99 994	19.99 994	19.99 994
19.99 994	19.99 994	23.5	7.998 594	23.5	19.99 994	23.5
23.5	23.5	7.998 594	7.998 594	23.5	23.5	7.998 594
23.5	19.99 994	7.998 594	26.99 995	7.998 594	19.99 994	7.998 594
23.5	23.5	7.998 594	2.966 058	23.5	23.5	7.998 594
19.99 994	7.998 594	2.966 058	7.998 594	23.5	7.998 594	2.966 058
7.998 594	7.998 594	23.5	19.99 994	23.5	7.998 594	23.5
19.99 994	19.99 994	23.5	7.998 594	2.966 058	19.99 994	23.5
23.5	7.998 594	7.998 594	26.99 995	7.998 594	7.998 594	7.998 594
7.998 594	19.99 994	23.5	23.5	26.99 995	19.99 994	23.5
23.5	23.5	7.998 594	2.966 058	23.5	23.5	7.998 594
19.99 994	7.998 594	23.5	2.966 058	2.966 058	7.998 594	23.5
5.491 812	19.99 994	23.5	7.998 594	23.5	19.99 994	23.5
23.5	23.5	7.998 594	5.491 812	5.491 812	23.5	7.998 594
7.998 594	5.491 812	23.5	23.5	26.99 995	5.491 812	23.5
23.5	23.5	7.998 594	26.99 995	7.998 594	23.5	7.998 594
5.491 812	23.5	23.5	7.998 594	23.5	23.5	23.5
23.5	23.5	7.998 594	26.99 995	7.998 594	23.5	7.998 594
7.998 594	5.491 812	23.5	23.5	26.99 995	5.491 812	23.5
23.5	7.998 594	23.5	7.998 594	23.5	7.998 594	23.5

Table 3: The aggregated decision matrix.

GSC	GSC	GSC	
573	286	406	GSC
822	998	535	GSC
953	594	286	GSC
573	949	23.5	GSC
018	57	57	GSC
663	949	663	GSC
331	23.5	198	GSC
286	573	286	GSC
573	23.5	198	GSC
286	082	286	GSC
867	705	594	GSC
286	573	082	GSC
867	23.5	198	GSC
573	663	594	GSC
952	535	198	GSC
286	082	286	GSC
867	23.5	082	GSC
727	328	198	GSC
014	7.163	286	GSC
952	535	894	GSC
573	454	535	GSC
727	406	535	GSC
573	23.5	286	GSC
952	727	812	GSC
23.5	286	594	GSC

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

GSC	GSC	GSC	GSC	GSC	GSC	GSC
573	7.163	573	573	594	7.163	23.5
705	23.5	33	573	594	952	23.5
953	573	396	667	594	286	0
286	33	594	286	594	286	594
57	058	082	535	994	822	058
331	018	904	331	994	618	994
867	904	23.5	573	23.5	618	23.5
573	573	286	594	23.5	665	594
822	018	286	617	594	331	594
573	705	57	57	23.5	2	594
153	594	535	082	23.5	822	058
822	57	23.5	663	23.5	286	23.5
867	904	23.5	573	058	618	23.5
573	57	286	617	594	286	594
822	904	705	23.5	995	153	23.5
573	705	57	57	23.5	2	594
867	949	23.5	705	058	573	23.5
262	331	33	573	23.5	283	23.5
573	454	406	406	812	014	594
822	976	705	23.5	995	488	23.5
822	705	286	617	594	23.5	594
262	454	573	573	23.5	573	23.5
573	705	286	617	594	23.5	594
014	812	454	23.5	995	406	23.5
286	57	573	573	23.5	594	23.5

Table 4: The normalized aggregated decision matrix.

GSC	GSC	GSC	
0.544064	0.390719	1.132059	GSC
0.444706	0.619355	0.644724	GSC
0.572716	0.436298	1	GSC
0.509642	0.619336	0.909679	GSC
0.432202	0.232179	0.232179	GSC
0.94776	0.716396	0.94776	GSC
0.950354	1	0.609446	GSC
0.743225	0.533746	0.743225	GSC
0.560244	1	0.609446	GSC
0.780122	0.268982	0.780122	GSC
0.659092	0.417477	0.340366	GSC
0.780122	0.560244	0.268982	GSC
0.659092	1	0.609446	GSC
0.622004	1	0.377887	GSC
0.722206	0.616866	0.530445	GSC
0.780122	0.268982	0.780122	GSC
0.659092	1	0.268982	GSC
0.677315	0.864515	0.5544	GSC
0.67257	0.390719	1	GSC
0.722206	0.616866	0.172219	GSC
0.560244	0.489129	0.708738	GSC
0.744565	0.269251	0.708738	GSC
0.560244	1	0.780122	GSC
0.722206	0.648048	0.203401	GSC
1	0.780122	0.340366	GSC

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

GSC	GSC	GSC	GSC	GSC	GSC	GSC
0.544064	1	0.544064	0.544064	0.895532	1	0.304809
0.37977	0.909679	1	0.509642	0.309623	0.754821	0.909679
0.572716	0.718149	0.290865	0.854567	0.436298	1	0
0.70966	1	0.309623	0.70966	0.309623	0.70966	0.309623
0.232179	0.148303	0.316055	0.83277	1	0.574413	0.148303
1	0.387046	0.537271	1	0.89552	0.768636	0.89552
0.659092	0.510598	1	0.560244	1	0.730476	1
0.533746	0.533746	0.743225	0.324268	0.952703	1	0.324268
0.48886	0.367831	0.780122	0.879411	0.340366	0.950354	0.340366
0.560244	0.417477	0.197599	0.197599	1	0.758383	0.340366
0.439214	0.340366	0.708738	0.268982	1	0.48886	0.126215
0.48886	0.197599	1	0.900707	1	0.780122	1
0.659092	0.510598	1	0.560244	0.126215	0.730476	1
0.622004	0.219382	0.866121	0.976356	0.377887	0.866121	0.377887
0.42549	0.44441	0.36336	0.870372	1	0.38228	0.870372
0.560244	0.417477	0.197599	0.197599	1	0.758383	0.340366
0.659092	0.680829	1	0.417477	0.126215	0.560244	1
0.41236	0.864516	1	0.509642	0.909679	0.709659	0.909679
0.718149	0.626991	0.34514	0.34514	0.299561	0.67257	0.436298
0.42549	0.141036	0.36336	0.870372	1	0.203167	0.870372
0.48886	0.417477	0.780122	0.879411	0.340366	1	0.340366
0.453303	0.489129	0.560244	0.560244	1	0.560244	1
0.560244	0.417477	0.780122	0.879411	0.340366	1	0.340366
0.456672	0.203401	0.425724	0.870372	1	0.234349	0.870372
0.780122	0.197599	0.560244	0.560244	1	0.340366	1

Table 5: The WSM values.

GSC	GSC	GSC	
0.139136	0.099921	0.289508	GSC
0.034628	0.048228	0.050203	GSC
0.052241	0.039798	0.091217	GSC
0.022631	0.027502	0.040396	GSC
0.010769	0.005785	0.005785	GSC
0.010493	0.007931	0.010493	GSC
0.154741	0.162824	0.099233	GSC
0.039089	0.028072	0.039089	GSC
0.007173	0.012803	0.007803	GSC
0.045521	0.015696	0.045521	GSC
0.023973	0.015185	0.01238	GSC
0.026804	0.019249	0.009242	GSC
0.012285	0.01864	0.01136	GSC
0.008071	0.012976	0.004904	GSC
0.005142	0.004392	0.003777	GSC
0.002201	0.000759	0.002201	GSC
0.018929	0.02872	0.007725	GSC
0.010178	0.01299	0.008331	GSC
0.006709	0.003897	0.009975	GSC
0.003606	0.00308	0.00086	GSC
0.00141	0.001231	0.001783	GSC
0.014741	0.005331	0.014031	GSC
0.004852	0.008661	0.006757	GSC
0.00356	0.003194	0.001003	GSC
0.001306	0.001019	0.000445	GSC

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

GSC	GSC	GSC	GSC	GSC	GSC	GSC
0.139136	0.255736	0.139136	0.139136	0.229019	0.255736	0.07795
0.029572	0.070835	0.077868	0.039685	0.02411	0.058776	0.070835
0.052241	0.065507	0.026532	0.077951	0.039798	0.091217	0
0.031513	0.044406	0.013749	0.031513	0.013749	0.031513	0.013749
0.005785	0.003695	0.007875	0.020751	0.024918	0.014313	0.003695
0.011071	0.004285	0.005948	0.011071	0.009914	0.00851	0.009914
0.107316	0.083138	0.162824	0.091221	0.162824	0.118939	0.162824
0.028072	0.028072	0.039089	0.017054	0.050106	0.052594	0.017054
0.006259	0.004709	0.009988	0.011259	0.004358	0.012168	0.004358
0.032691	0.02436	0.01153	0.01153	0.058352	0.044253	0.019861
0.015976	0.01238	0.025779	0.009784	0.036373	0.017781	0.004591
0.016797	0.006789	0.034359	0.030947	0.034359	0.026804	0.034359
0.012285	0.009517	0.01864	0.010443	0.002353	0.013616	0.01864
0.008071	0.002847	0.011239	0.012669	0.004904	0.011239	0.004904
0.003029	0.003164	0.002587	0.006197	0.00712	0.002722	0.006197
0.001581	0.001178	0.000557	0.000557	0.002821	0.002139	0.00096
0.018929	0.019554	0.02872	0.01199	0.003625	0.01609	0.02872
0.006196	0.01299	0.015026	0.007658	0.013669	0.010664	0.013669
0.007163	0.006254	0.003443	0.003443	0.002988	0.006709	0.004352
0.002124	0.000704	0.001814	0.004346	0.004993	0.001014	0.004346
0.00123	0.00105	0.001963	0.002213	0.000856	0.002516	0.000856
0.008974	0.009684	0.011091	0.011091	0.019798	0.011091	0.019798
0.004852	0.003616	0.006757	0.007616	0.002948	0.008661	0.002948
0.002251	0.001003	0.002098	0.00429	0.004929	0.001155	0.00429
0.001019	0.000258	0.000732	0.000732	0.001306	0.000445	0.001306

Table 6: The WPM values.

GSC	GSC	GSC	
0.855847	0.786367	1.03223	GSC
0.93885	0.963383	0.966399	GSC
0.95043	0.927133	1	GSC
0.970512	0.978949	0.995805	GSC
0.979315	0.964268	0.964268	GSC
0.999406	0.996314	0.999406	GSC
0.991743	1	0.922534	GSC
0.984514	0.967519	0.984514	GSC
0.992609	1	0.99368	GSC
0.985615	0.92624	0.985615	GSC
0.984951	0.968727	0.961558	GSC
0.991505	0.98029	0.955885	GSC
0.992259	1	0.990812	GSC
0.993858	1	0.987452	GSC
0.997686	0.996566	0.995496	GSC
0.9993	0.996302	0.9993	GSC
0.988098	1	0.962989	GSC
0.994163	0.997815	0.991176	GSC
0.996051	0.99067	1	GSC
0.998376	0.997591	0.991256	GSC
0.998543	0.998202	0.999134	GSC
0.994178	0.974358	0.993208	GSC
0.994995	1	0.997852	GSC
0.998397	0.997864	0.992181	GSC
1	0.999676	0.998593	GSC

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

GSC	GSC	GSC	GSC	GSC	GSC	GSC
0.855847	1	0.855847	0.855847	0.972177	1	0.737985
0.927381	0.992656	1	0.948867	0.912751	0.978336	0.992656
0.95043	0.970252	0.893469	0.985767	0.927133	1	0
0.984885	1	0.94927	0.984885	0.94927	0.984885	0.94927
0.964268	0.953558	0.971707	0.995451	1	0.98628	0.953558
1	0.989546	0.993146	1	0.998779	0.997091	0.998779
0.934372	0.89633	1	0.909975	1	0.950149	1
0.967519	0.967519	0.984514	0.94249	0.997455	1	0.94249
0.990879	0.987277	0.996826	0.998356	0.986296	0.999348	0.986296
0.966757	0.950306	0.90972	0.90972	1	0.983991	0.939049
0.970517	0.961558	0.987556	0.953361	1	0.974305	0.92748
0.97571	0.94581	1	0.996413	1	0.991505	1
0.992259	0.987549	1	0.989259	0.962155	0.994163	1
0.993858	0.980508	0.998137	0.99969	0.987452	0.998137	0.987452
0.993935	0.994243	0.992818	0.999012	1	0.993177	0.999012
0.998367	0.997539	0.995436	0.995436	1	0.99922	0.996964
0.988098	0.989019	1	0.975224	0.942288	0.983498	1
0.986777	0.997815	1	0.989923	0.998579	0.99486	0.998579
0.996703	0.995354	0.989445	0.989445	0.988048	0.996051	0.991761
0.995742	0.990268	0.994958	0.999307	1	0.992074	0.999307
0.998201	0.997805	0.999375	0.999677	0.997292	1	0.997292
0.984458	0.985942	0.988595	0.988595	1	0.988595	1
0.994995	0.992463	0.997852	0.998888	0.990709	1	0.990709
0.996144	0.992181	0.9958	0.999316	1	0.992874	0.999316
0.999676	0.997884	0.999243	0.999243	1	0.998593	1

According to the availability and trustworthiness of data, an evaluation committee of specialists may be the best option for reviewing suppliers; these committees may harness their extensive knowledge and therefore manage elevated amounts of absent or ambiguous information. It is possible to evaluate options qualitatively (linguistically) using the fuzzy numbers generated in this research. To save time and money, companies might choose to undertake a second round of supplier evaluation on a smaller set of pre-selected vendors who have already been screened out in the first round.

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

Figure 4: The rank of alternatives.

5. Managerial Implication

Managers, society, and academics all stand to benefit from this study. The sustainability of the supply chain is not taken into consideration in current management decision-making approaches for supplier selection. If civil society campaigns and conventional and social networking sites encourage supply chain breaches of international social and environmental norms, this is a critical omission that might result in monetary losses for focused enterprises across Europe, Japan, North America, and elsewhere. Methodology for managers to choose suppliers based on full selection criteria, which incorporates key sustainable development risks is presented in this paper. To address the risks that transnational corporations (MNCs) confront when they acquire their pre-products abroad, particularly if they are exposed to public scrutiny, which often holds the focal enterprises responsible for their whole supply chains, this management tool has been developed. Managers may use this tool to help them identify suppliers and sub-suppliers that pose a high risk or poor performance focused on company sustainability standards.

6. Conclusion

Deregulation of the political-economic system, internet-connected devices, and low-cost mass transit have tried to push business owners to increasingly outsource business activities to distant countries; these decisions frequently result in more effective supply chain setups covering multiple stages from the harvesting of raw materials to the finished consumer. Supply chains have expanded into low-income countries because of the cheap cost of labor and the ease with which environmental assets may be processed. Civil society has entrusted target companies with implementing basic sustainability-related production criteria in these countries, where social and environmental regulations are generally weak or badly enforced. Most supplier selection models do not take into account how NGOs, student groups, unions, and other forms of civil society might have an adverse effect on the economic and policy policies of big corporations.

There are several possibilities for further development based on this work. In the beginning, real data might be used to assess the proposed model. It is feasible to compare the model's results to those of other MCDM techniques. Thirdly, the model's results may be compared to other uncertainty modeling methods. A final test of the proposed framework might include situation analysis, emergency preparation, and uncertainty evaluation.

Funding: “This research received no external funding”

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

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021

References

[1] A. B. Steven, Y. Dong, and T. Corsi, "Global sourcing and quality recalls: An empirical study of outsourcing-supplier concentration-product recalls linkages," *Journal of Operations Management*, vol. 32, no. 5, pp. 241–253, 2014.

[2] F. A. G. Den Butter, "The transaction management perspective on procurement in the era of globalisation," *International Journal of Procurement Management*, vol. 5, no. 2, pp. 123–139, 2012.

[3] B. Fahimnia, C. S. Tang, H. Davarzani, and J. Sarkis, "Quantitative models for managing supply chain risks: A review," *European journal of operational research*, vol. 247, no. 1, pp. 1–15, 2015.

[4] I. J. Chen and A. Paulraj, "Towards a theory of supply chain management: the constructs and measurements," *Journal of operations management*, vol. 22, no. 2, pp. 119–150, 2004.

[5] F. T. S. Chan, N. Kumar, M. K. Tiwari, H. C. W. Lau, and K. Choy, "Global supplier selection: a fuzzy-AHP approach," *International Journal of production research*, vol. 46, no. 14, pp. 3825–3857, 2008.

[6] M. Andersen and T. Skjoett-Larsen, "Corporate social responsibility in global supply chains," *Supply chain management: an international journal*, 2009.

[7] F. T. S. Chan and N. Kumar, "Global supplier development considering risk factors using fuzzy extended AHP-based approach," *Omega*, vol. 35, no. 4, pp. 417–431, 2007.

[8] K. Hodal, C. Kelly, and F. Lawrence, "Revealed: Asian slave labour producing prawns for supermarkets in US, UK," *The Guardian*, vol. 10, 2014.

[9] S. Gold, A. Trautrims, and Z. Trodd, "Modern slavery challenges to supply chain management," *Supply chain management: an international journal*, 2015.

[10] D. R. Krause, S. Vachon, and R. D. Klassen, "Special topic forum on sustainable supply chain management: introduction and reflections on the role of purchasing management," *Journal of Supply Chain Management*, vol. 45, no. 4, pp. 18–25, 2009.

[11] P. Kraljic, "Purchasing must become supply management," *Harvard business review*, vol. 61, no. 5, pp. 109–117, 1983.

[12] H. Schiele, "Supply-management maturity, cost savings and purchasing absorptive capacity: Testing the procurement–performance link," *Journal of purchasing and supply management*, vol. 13, no. 4, pp. 274–293, 2007.

[13] K. Foerstl, M. C. Schleper, and M. Henke, "Purchasing and supply management: From efficiency to effectiveness in an integrated supply chain," *Journal of Purchasing and Supply Management*, vol. 23, no. 4, 2017.

[14] K. Hafeez, Y. Zhang, and N. Malak, "Core competence for sustainable competitive advantage: a structured methodology for identifying core competence," *IEEE transactions on engineering management*, vol. 49, no. 1, pp. 28–35, 2002.

[15] A. Kak and H. Sushil, "Sustainable competitive advantage with core competence: a review," *Global Journal of flexible systems management*, vol. 3, no. 4, pp. 23–38, 2002.

[16] Y.-H. Cheng and C.-Y. Yeh, "Core competencies and sustainable competitive advantage in air-cargo forwarding: evidence from Taiwan," *Transportation journal*, vol. 46, no. 3, pp. 5–21, 2007.

[17] R. Dulmin and V. Mininno, "Supplier selection using a multi-criteria decision aid method," *Journal of purchasing and supply management*, vol. 9, no. 4, pp. 177–187, 2003.

[18] C. Kahraman, U. Cebeci, and Z. Ulukan, "Multi-criteria supplier selection using fuzzy AHP," *Logistics information management*, 2003.

[19] S. A. Yawar and S. Seuring, "Management of social issues in supply chains: a literature review exploring social issues, actions and performance outcomes," *Journal of Business Ethics*, vol. 141, no. 3, pp. 621–643, 2017.

[20] A. J. Hillman and G. D. Keim, "Shareholder value, stakeholder management, and social issues: what's the bottom line?," *Strategic management journal*, vol. 22, no. 2, pp. 125–139, 2001.

[21] L. De Boer, E. Labro, and P. Morlacchi, "A review of methods supporting supplier selection," *European journal of purchasing & supply management*, vol. 7, no. 2, pp. 75–89, 2001.

[22] K. Govindan, S. Rajendran, J. Sarkis, and P. Murugesan, "Multi criteria decision making approaches for green supplier evaluation and selection: a literature review," *Journal of Cleaner Production*, vol. 98, pp. 66–83, 2015.

[23] W. Ho, X. Xu, and P. K. Dey, "Multi-criteria decision making approaches for supplier evaluation and selection: A literature review," *European Journal of operational research*, vol. 202, no. 1, pp. 16–24, 2010.

[24] P. Agarwal, M. Sahai, V. Mishra, M. Bag, and V. Singh, "A review of multi-criteria decision making techniques for supplier evaluation and selection," *International journal of industrial engineering computations*, vol. 2, no. 4, pp. 801–810, 2011.

Doi : https://doi.org/10.54216/FPA.060105

Received: May 17, 2021 Accepted: July 26, 2021

[25] B. Alavi, M. Tavana, and H. Mina, "A dynamic decision support system for sustainable supplier selection in circular economy," *Sustainable Production and Consumption*, vol. 27, pp. 905–920, 2021.
[26] H. Kaur and S. P. Singh, "Multi-stage hybrid model for supplier selection and order allocation considering disruption risks and disruptive technologies," *International Journal of Production Economics*, vol. 231, p. 107830, 2021.
[27] S. Khoshfetrat, M. Rahiminezhad Galankashi, and M. Almasi, "Sustainable supplier selection and order allocation: a fuzzy approach," *Engineering Optimization*, vol. 52, no. 9, pp. 1494–1507, 2020.
[28] M. A. Kaviani, A. K. Yazdi, L. Ocampo, and S. Kusi-Sarpong, "An integrated grey-based multi-criteria decision-making approach for supplier evaluation and selection in the oil and gas industry," *Kybernetes*, 2019.
[29] H. Lu, S. Jiang, W. Song, and X. Ming, "A rough multi-criteria decision-making approach for sustainable supplier selection under vague environment," *Sustainability*, vol. 10, no. 8, p. 2622, 2018.
[30] C. Yu, W. Zhao, and M. Li, "An integrated sustainable supplier selection approach using compensatory and non-compensatory decision methods," *Kybernetes*, vol. 48, no. 8, pp. 1782–1805, 2018.
[31] F. Firouzi and O. Jadidi, "Multi-objective model for supplier selection and order allocation problem with fuzzy parameters," *Expert Systems with Applications*, vol. 180, p. 115129, 2021.
[32] J. A. Ventura, K. A. Bunn, B. B. Venegas, and L. Duan, "A coordination mechanism for supplier selection and order quantity allocation with price-sensitive demand and finite production rates," *International Journal of Production Economics*, vol. 233, p. 108007, 2021.
[33] A. K. Nasr, M. Tavana, B. Alavi, and H. Mina, "A novel fuzzy multi-objective circular supplier selection and order allocation model for sustainable closed-loop supply chains," *Journal of Cleaner production*, vol. 287, p. 124994, 2021.
[34] S. Kayapinar Kaya and E. Aycin, "An integrated interval type 2 fuzzy AHP and COPRAS-G methodologies for supplier selection in the era of Industry 4.0," *Neural Computing and Applications*, vol. 33, no. 16, pp. 10515–10535, 2021.
[35] R. Baki, "An integrated, multi-criteria approach based on environmental, economic, social, and competency criteria for supplier selection," *RAIRO: Recherche Opérationnelle*, vol. 55, p. 1487, 2021.
[36] F. Kutlu Gündoğdu and C. Kahraman, "A novel spherical fuzzy analytic hierarchy process and its renewable energy application," *Soft Computing*, vol. 24, no. 6, pp. 4607–4621, 2020.
[37] M. Mathew, R. K. Chakrabortty, and M. J. Ryan, "A novel approach integrating AHP and TOPSIS under spherical fuzzy sets for advanced manufacturing system selection," *Engineering Applications of Artificial Intelligence*, vol. 96, p. 103988, 2020.
[38] E. K. Zavadskas, Z. Turskis, J. Antucheviciene, and A. Zakarevicius, "Optimization of weighted aggregated sum product assessment," *Elektronika ir elektrotechnika*, vol. 122, no. 6, pp. 3–6, 2012.

Doi : https://doi.org/10.54216/FPA.060105
Received: May 17, 2021 Accepted: July 26, 2021