International Journal of Multiphysics
Volume 18, No. 2, 2024
ISSN: 1750-9548

Decision-making Methods in Green Vendor Selection with Blockchain Willingness under FL/AHP/FAHP

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Abstract

With the worldwide recognition of environmental conservation, green production has emerged as a pivotal concern for nearly every manufacturer, and it will be determined for a long time to determine the sustainability of the manufacturer. Therefore, the performance evaluation system must be performed for green suppliers to determine the applicability of the supplier and the company. In a complex transaction and operating environment, suppliers choose to face information asymmetry usually. Fortunately, with the development of computer technology, blockchain technology enhances not only traceability and decentralization in supply chain management, but also boosts the flexibility of the supply chain. Since it is unclear whether the FAHP (Fuzzy Analytic Hierarchy Process) is better than the AHP (Analytic Hierarchy Process) in terms of the quality of decision solution, the method of a mathematical model is first adopted to determine the difference between AHP and FAHP. Then, taking H company's green supplier selection decision as the research object, determine five evaluation criteria, such as quality, delivery, blockchain willingness, costs, and environment protection by literature combing method. Based on FL (Fuzzy logic analysis method), AHP, and FAHP three methods to study the green supplier selection of H company. The result shows that different evaluation methods of FL, AHP, and FAHP have no significant effect on the comprehensive ranking of vendors, and AHP is particularly suitable for a company to select its alternative vendors.

Keywords: Green vendor selection, fuzzy logic, analytic hierarchy process, fuzzy analytic hierarchy process, blockchain willingness

1. Introduction

As consumer awareness of environmental protection grows and government initiatives to regulate environmental conservation intensify, enterprises are increasingly inclined to improve the reliability and sustainability of their supply chain to meet the diverse needs of customers and environmental requirements. One of the main ways for enhancing the reliability and sustainability of the supply chain involves choosing appropriate suppliers. In intricate transactions and operational landscapes, suppliers often confront information asymmetry. Fortunately, the advancement of computer technology has enabled blockchain to offer not only traceability and decentralized authority in supply chain management but also enhanced flexibility within the supply chain. Within sustainable supply chain operations, blockchain technology can integrate features like distribution, information sharing, and environmental stewardship [1]. Blockchain offers a plethora of benefits. For instance, it enhances transparency and traceability within supply chains [2], while bolstering the security of digital platforms [3]. Moreover, its transparency can address sustainability challenges [4]. Additionally, it aids in cost reduction and more efficient inventory management within supply chains [5]. Therefore, the scientific construction of Supplier Selection (SS) evaluation system is the key to the success of enterprises. Potential SS has been recognized as one of the key issues for enterprises to maintain their strategic competitive position [6]. The traditional sense of SS has only one main purpose, that is, to decrease the enterprise's expenses, thereby improving the economic efficiency of the enterprise. In the 1990s, Wal-Mart mainly relied on factors such as the brand and price of suppliers when selecting suppliers. Suppliers only need to focus on operational issues such as reducing production costs and improving product quality. With the increasingly serious environmental and resource problems, a low-carbon economy, centered on low energy consumption, minimal pollution, and sustainable development principles, is increasingly garnering global attention. Wal-Mart regards the green production of vendors and the green performance of products as the main basis for its selection of suppliers. Huawei requires its suppliers to obtain and update environmental permits (such as carbon emission monitoring) and the products produced must meet certain environmental protection requirements. Green supply chain selection refers to the amalgamation of environmental concerns with supply chain management. Choosing green suppliers emphasizes environmental science considerations alongside factors (such as energy use and pollutant emissions) aimed at maximizing economic gains. Traditional supply chain management focuses more on the management of the final product, often neglecting its environmental footprint during manufacturing and delivery, while in green supply chain management, environmental protection requirements are regarded as key criteria for manufacturing and final products.

Meantime, the SS issue is often a decision analysis employing multiple criteria (MCDA) involving multiple levels, multiple criteria and multiple alternatives, which is affected by multiple conflicting factors. The criteria for enterprises to select suppliers not only focus on pricing, but also on the quality of products provided by suppliers, the punctuality of delivery and environmental protection. To some extent, the selection of suppliers is another interpretation of procurement. The primary role of procurement in enterprises is to facilitate operational and production activities by ensuring a consistent flow of materials and blockchain-enabled transactional flow. A standard manufacturing company allocates 60% of its sales towards procuring materials, goods, and blockchain services from external suppliers. The quality, cost and other aspects of the final products are all affected by the supplier's performance. Therefore, with the increasing dependence of enterprises on suppliers, the consequences of purchasing decision-making errors are becoming more and more serious [7]. How to establish a set of systematic and scientific SS and evaluation system is a key scientific problem that needs to be solved urgently in the academic and business circles. In view of the subjectivity and uncertainty of decision makers involved in SS process, it is difficult to quantify the evaluation index with exact numbers. Zadeh [8] proposed a Fuzzy logic analysis method (FL) which can describe the uncertainty of decision makers' thinking. Fuzzy logic can use mathematical formulas to express people's logical thinking and judgment mode, which is helpful for decision makers to score and rank multi-factor decision-making problems. Subsequently, FL has been well developed and applied in both academia and business circles. Aksoy et al. [9] used the FL analysis method to study the multi-stage dynamic decision problem of strategic supplier selection under stochastic demand. Labib [10] believes that although FL can describe the fuzziness of human thinking mode, this analysis method can’t determine how different factors affect the final score of the target layer. At the same time, FL doesn’t have the function of identifying the coherence of the decision-maker's judgment matrix. To address solve this problem, Satty [11] introduced an Analytic Hierarchy Process (AHP) that integrates both qualitative and quantitative analyses. Because AHP is easy to use and flexible, it has been widely used. Ishizaka and Labib [12] used the expert analysis software (Expert Choice) to systematically simulate the specific process of AHP, and explained the advantages and limitations of AHP. Dweiri et al. [13] selected the key indicators of quality, cost, blockchain willingness and delivery, and used AHP to analyze the supplier selection of automotive industry in developing countries. At the same time, AHP has also been questioned by some scholars, who believe that AHP transforms the linguistic logic of decision makers into definite quantitative data, ignoring the randomness of decision makers' judgments. Laarhoven and Pedrycz [14] proved Fuzzy Analytic Hierarchy Process (FAHP) on the basis of reference, and considered that this method combines the advantages of FL and AHP analysis methods. However, the originator of AHP analysis method Satty [15] thinks that the value of judgment in AHP is already fuzzy, and the introduction of fuzzy sets into FAHP to make the value of fuzzy judgment more fuzzy frequently leads to poor evaluation results.

Chai and Ngai [16] systematically reviewed the literature on SS from 2013 to 2019, and gave the current achievements and future development directions of SS decision-making technology. Based on the above literature, it can be found that most of the literature used mixed evaluation methods in the study of SS, such as FAHP and TOPSIS [17]. This paper focuses on the literature related to FL, AHP and FAHP. Ishizaka [18] first introduced FL, AHP, FAHP and hybrid fuzzy analytic hierarchy process into the SS evaluation system, and found that the hybrid fuzzy analytic hierarchy process could influence the ranking outcomes of supplier selection. It is worth noting that Ishizaka ignores the consistency influence of the relative importance gap of evaluation index on the judgment matrix of FAHP when converting the semantic evaluation grade into fuzzy value. Chan et al. [19] extracted and analyzed the impact of social media data on consumer decision-making behavior based on AHP, FAHP and TOPSIS, and found that different analysis methods had no significant impact on the ranking of indicators affecting consumer behavior. Chan et al. [20] made a comprehensive analysis of the conditions for the differences between FAHP and AHP, and found that when the matrix size is large, the consistency verification of FAHP will be challenged. Deepika M [21] analyzes and compares the selected criteria by determining priority weights through AHP, FAHP, and IF-AHP methodologies, respectively, with a focus on using IF-AHP for efficient supplier selection in electronic procurement for the first time. Bas [22] made a novel hybrid methodology of the Interval Type-2 Fuzzy (IT2F) Analytical Hierarchy Process (AHP) and IT2F Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is presented for the GSS model to deal with uncertainty. Liang et al. [23] improves supplier performance evaluation criteria by integrating the influence of blockchain technology, providing decision-making assistance for supply chain management enabled by blockchain. On the domestic side, there are few literatures that use FL, AHP and FAHP to analyze the selection and evaluation of suppliers.

Throughout the above literature, it can be found that the methods involved in SS analysis and evaluation are becoming more and more diversified and complex, but there is little literature to explain which method is better. Different from the existing literature, this paper will adopts FL, AHP and FAHP methods to explore which method can be better used for green SS evaluation. It is found that the three evaluation methods of FL, AHP and FAHP have no significant effect on the comprehensive ranking of SS of H company, and the AHP method is more suitable for H company to screen its potential suppliers.

2. Supplier Selection

The potential SS process mainly involves two main aspects: (I) identifying the decision criteria for SS evaluation; and (II) selecting the evaluation method for comprehensive ranking of alternative suppliers. Selecting suitable suppliers is a MCDA problem, which needs to measure and compare suppliers from multiple perspectives, reflect the situation of suppliers scientifically and objectively, and comprehensively reflect the potential development ability of suppliers. To address determine a collection of widely accepted SS standards, the relevant literature of SS is sorted out on the basis of the existing SS standards, and five first-level indicators are determined: quality, delivery, blockchain willingness, cost and environmental protection. Ten secondary indicators: quality qualification rate, customer return rate, delivery lead time, delivery flexibility, reliability, empathy, purchase price, logistics cost, environmental protection management system and pollution control. Simultaneously, to address validate the scientific character of the chosen evaluation index, the paper will compare and analyze the relevant literature on SS assessment, as illustrated in Table 1.

Table 1 provides a clear overview of the literature on SS assessment. The supplier assessment index method developed in this paper can be judged to be rather scientific. At the same time, Table 1 clearly illustrates the contrasts between this paper and the existing literature. Of course, the indicators evaluated in green SS should be established in accordance with the real demands of enterprises, and each enterprise needs to formulate selection criteria that match its own requirements when examining alternative suppliers.

International Journal of Multiphysics
Volume 18, No. 2, 2024
ISSN: 1750-9548

Table 1 Comparison of the related SS literatures

	Evaluation index					Analysis method		
	Quality	Delivery	Blockchain willingness	Cost	Environmental	FL	AHP	FAHP
Korpela et al. [1]			✓					
Tian [4]			✓					
Labib [12]	✓	✓		✓			✓	
Dweiri et al. [13]	✓	✓		✓			✓	
Ishizaka[18]	✓	✓		✓		✓	✓	✓
Ordoobadi [24]	✓	✓		✓		✓		
Gupta et al. [25]	✓			✓	✓			✓
This paper	✓	✓	✓	✓	✓	✓	✓	✓

3. Green Supplier Evaluation Method

Due to the vendor selection process involves the fuzziness of decision-makers' thinking, it is difficult to quantify the evaluation index with exact numerical value. This paper firstly adopts FL to solve this problem. Then the semantic evaluation level of each index in FL is transformed into the importance degree that can be compared in pairs. Finally, AHP and FAHP are utilized for assessing the selection of environmentally friendly suppliers.

3.1 Green supplier selection evaluation based on FL

FL was initially introduced by Zadeh [8], who regarded the fuzziness of a decision-maker's mindset, characterized by continuous grades of membership. The fuzzy set F denotes a subset within the universe U, described by the membership function F, and the domain of the membership function is $F(x)\in[0,1]$, of which, $x\in U$, $F(x)$ represents the degree of membership that X belongs to the fuzzy set F: $F(x): U\rightarrow[0,1]$. Among, $F(x)$ represents the membership function. $F(x)=0$ indicates that the element does not belong to the set F, $F(x)=1$ indicates that the element belongs to set F completely, $F(U)$ represents all fuzzy sets. The fuzzy set can transform the knowledge or experience of the decision maker into a precise numerical interval that can be processed.

Membership functions can usually be represented by different functions, such as linear, S-curve, triangular or trapezoidal functions. Trapezoidal function is the most commonly used membership function (as shown in the figure 1), which can be defined as $R=(l,m_l,m_u,u)$, of which, $l<m_l<m_u<u$. l 、 m_l 、 m_u and u represent semantic evaluation scale low boundary, medium low boundary, medium high boundary and high boundary respectively. Ordoobadi uses the trapezoidal membership function to describe the fuzziness of the evaluator in the evaluation process, and the following will use a similar method to describe the subjectivity of the decision-maker's thinking. The trapezoidal ambiguity function is:

$$U_R(x)=\begin{cases}\dfrac{x-l}{m_l-l}, & l<x<m_l\\ 1, & m_l<x<m_u\\ \dfrac{u-x}{u-m_u}, & m_u<x<u\\ 0, & \text{else}\end{cases} \tag{1}$$

International Journal of Multiphysics
Volume 18, No. 2, 2024
ISSN: 1750-9548

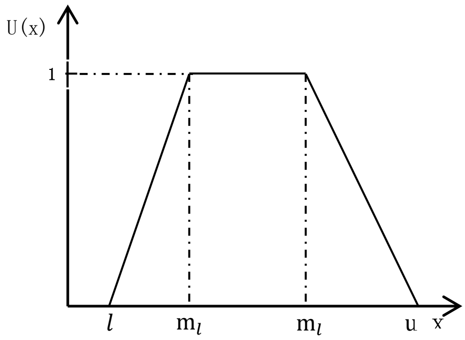

Figure 1 Trapezoidal membership function

The relative importance of evaluation indicators is characterized by four semantic scales: low importance (L), medium importance (M), high importance (H) and very high importance (VH). The upper and lower limits refer to the points where the membership degree reaches 0 ($x=l$) or 1 $(x=u)$. The membership function establishes the intermediate degrees of membership between the two extremes. Similarly, suppliers' semantic evaluation grades for each index are also described by similar methods: poor (P), good (G), good (VG), and very good (EX). For the convenience of expression, the semantic evaluation grades are summarized, as illustrated in Table 2.

Table 2 Linguistic importance scale and fuzzy performance

Criteria linguistic importance scale	Criteria fuzzy scores	Supplier linguistic importance scale	Supplier fuzzy scores
Low importance(L)	(0,0,0.2,0.4)	Poor(P)	(0,0,2,4)
Moderate importance(M)	(0.2,0.4,0.4,0.6)	Good(G)	(2,4,4,6)
High importance(H)	(0.4,0.6,0.6,0.8)	Very good(VG)	(4,6,6,8)
Very high importance(VH)	(0.6, 0.8, 1.0, 1.0)	Excellent(EX)	(6,8,10,10)

Having completed the characterization of SS metrics and supplier performance ratings, the specific stages of the proposed approach are outlined below:

Step 1: Build a hierarchical arrangement. Decision-makers are divided into target layer, criterion layer and scheme layer according to the nature and subordinate relationship of supplier evaluation related indicators, and establish a hierarchical structure.

Step 2: Determine the evaluation index and semantic evaluation level. First, the decision maker receives a collection of SS indicator evaluation criteria and is tasked with selecting the most pertinent indicator for the current assessment. Then, the relevant evaluation indicators are selected according to the questionnaire, and the decision-makers are asked to evaluate the importance of the indicators, such as L, M, H or VH.

Step 3: Establish the count of alternative suppliers and the semantic assessment level. The decision maker selects and evaluates alternative suppliers such as P, G, VG or EX based on the actual needs of the company.

Step 4: Conversion of semantic evaluation level. Based on the trapezoidal fuzzy membership function, the semantic evaluation level is converted into fuzzy numbers. Set w_i represents the importance weight of index i in fuzzy terms, a_{ij} represents the performance rating of supplier J in fuzzy terms relative to indicator i, where i = 1, 2, n is the number of evaluation indexes, J = 1, 2, … , K is the number of suppliers. $A_1 = (a_{ij})_{nxn}$ represents the judgment matrix:

$$A_1 = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{k1} & a_{k2} & \dots & a_{kn} \end{bmatrix} \tag{2}$$

Step 5: Determine the total fuzzy number of each supplier. $S_j = \sum a_{ji} w_i$, of which, S_j represents the comprehensive fuzzy score of supplier J with respect to all relevant evaluation indicators.

$$S = \begin{bmatrix} S_1 \\ S_2 \\ \dots \\ S_K \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{k1} & a_{k2} & \dots & a_{kn} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \dots \\ w_K \end{bmatrix} \tag{3}$$

Step 6: The midpoint of gravity technique is employed for defuzzifying the fuzzy number associated with each index, and the fuzzy comprehensive score is transformed into the exact score. The corresponding defuzzification formula is:

$$F^* = \frac{l + m_l + m_u + u}{4} \tag{4}$$

Step 7: Organize the overall scores of suppliers, and the supplier with the highest score emerges as the optimal selection.

3.2 Selection and evaluation of green suppliers based on AHP

AHP is a qualitative and quantitative system analysis method proposed by Satty, which is mainly used to solve MCDA problems. AHP, like other evaluation methods, divides the decision issue into three parts: objectives, criteria, and alternatives. The specific analysis steps of AHP are as follows: setting up a hierarchical structure, defining scales, and constructing comparison judgment matrices, hierarchical ranking and consistency test. Since the selection of supplier evaluation indicators and the construction of hierarchical structure have been completed in FL, the following will mainly show other key steps of AHP:

Step 1: Conversion of semantic evaluation level. In order to convert the semantic evaluation level in FL into an exact value, the conversion method proposed by Ordoobadi [24] is adopted below, and the specific conversion scale is indicated in Table 3.

Table 3 Pairwise comparison of the linguistic importance scale of criteria and supplier performance

Linguistic importance scale ratio		AHP scale
Criteria	Supplier	
VH/H	EX/VG	2
VH/M	EX/G	4
VH/L	EX/P	6
H/M	VG/G	2
H/L	VG/P	4
M/L	G/P	2

Step 2: Define scales and build judgment matrices. The weighting of each criterion in the criterion layer concerning the target, as well as the weighting of each alternative concerning each criterion, is established through pairwise comparison methodology.

Step 3: Layered single form and consistency check. Compared with the indicators of the previous level, the layered single -level indicator is the ranking of the comparative significance of each indicator in this level. Since the comparative significance of indicators is obtained through personal subjective judgment, the judgment matrix may be inconsistent to some extent. To maintain the consistency of the judgment matrix, it's essential to calculate the consistency ratio (*CR*) that can measure the level of consistency in the pairwise comparison of indices. First, the consistency index is calculated $CI = (\lambda_{\max} - n)/(n-1)$. Then, the random consistency index (*RI*) of the corresponding judgment matrix is obtained by looking up the table. Finally, the consistency ratio is calculated, where $CR = CI / RI$. When *CR*<0.1, the judgment matrix passes the consistency check.

Step 4: Total classification and consistency inspection of layered. The total ranking of the hierarchical structure indicates the ranking of the relative importance of the target level at this level. Similar to step 3 and is not described here.

3.3 Selection and evaluation of green suppliers based on FAHP

The basic idea and steps of FAHP are the same as that of AHP, and their differences are mainly embodied in two aspects: First, the construction of the judgment matrix is different. Although the essence of the comparative significance of FAHP and AHP indicators is the comparison between two indicators, AHP constructs an exact consistent judgment matrix, while FAHP constructs a fuzzy consistent judgment matrix. Secondly, the weight determination methods between FAHP and AHP are different. Some of the analytical processes of FAHP are similar to those of AHP and FL, and only the other key steps of FAHP are shown here:

Step 1: Specify the ambiguous judgment matrix. To depict the uncertainty and variability of decision makers' thoughts, the semantic evaluation scale is converted into a fuzzy number.

Let $F_1 = (l_1, m_{l1}, m_{u1}, u_1)$ and $F_1 = (l_2, m_{l2}, m_{u2}, u_2)$ represent trapezoidal fuzzy numbers of indexes 1 and 2 respectively. F_1 and F_2 fuzzy ratios are defined as:

$$\frac{F_1}{F_2} = \frac{(l_1, m_{l1}, m_{u1}, u_1)}{(l_2, m_{l2}, m_{u2}, u_2)} = \{min(\frac{l_1}{u_2}, \frac{u_1}{l_2}), min(\frac{m_{l1}}{m_{u2}}, \frac{m_{u1}}{m_{l2}}), max(\frac{m_{l1}}{m_{u2}}, \frac{m_{u1}}{m_{l2}}), min(\frac{l_1}{u_2}, \frac{u_1}{l_2})\} \quad (5)$$

The indicators obtained according to formula (4) and the supplier evaluation grade conversion table is shown in Table 4. It should be noted that, in order to be consistent with the AHP scale developed by Saaty [11], the value divided by 0 to represent infinity will be replaced by 9, and the evaluation value less than 1 will be replaced by 1.

Table 4 Comparing the linguistic importance scale of criteria and supplier performance in pairs

Evaluation grade ratio		FAHP scale
Criteria	Supplier	
VH/H	EX/VG	(1,1.33,1.67,2.5)
VH/M	EX/G	(1,2,2.5,5)
VH/L	EX/P	(1.5,5,9,9)
H/M	VG/G	(1,1.5,1.5,4)
H/L	VG/P	(1,3,9,9)
M/L	G/P	(1,2,9,9)

Step 2: Create a vague judgment matrix. Then, in terms of the comparative significance of the index, form a vague judgment matrix, and scaling the values in the fuzzy judgment matrix as per the definition approach in the step 1. The fuzzy judgment matrix A_2 is:

$$A_2 = \begin{bmatrix} (1,1,1,1) & \cdots & (l_{1n}, m_{l1n}, m_{u1n}, u_{1n}) \\ \cdots & \cdots & \cdots \\ (l_{k1}, m_{lk1}, m_{uk1}, u_{k1}) & \cdots & (l_{kn}, m_{lkn}, m_{ukn}, u_{kn}) \end{bmatrix} \quad (6)$$

Step 3: Hierarchical singular sorting and consistency verification. The calculation process is similar to AHP, which is omitted here.

Step 4: Hierarchical overall ranking and consistency assessment. The calculation process is similar to AHP, which is omitted here.

4. Contrast between the Triangular FAHP and Classical AHP

To better understand the differences and applicable conditions between AHP and FAHP, in this section, a function is established to represent the classic AHP and triangular FAHP function corresponding to the same pair of comparisons and corresponding blur. Essentially, this function encapsulates the weight disparity of all criteria between the two methodologies, and experiments are carried out on this basis.

If these two methods can be proved, there is absolutely no need to choose a complex method in a simpler way. Next, this paper examines the difference between the two methods by establishing a function, and analyze the consistency level of the two methods through numerical experiments.

4.1 Weights estimated by the classical AHP and the triangular FAHP

Saaty [26] initially introduced the technique of a pair of comparative matrix A as the estimated proportional scale. The measurement table is based on the 9-point system of Saaty [27].

$$A = \begin{bmatrix} 1 & a_{12} & a_{13} & & a_{1n} \\ a_{21} & 1 & a_{23} & \dots & a_{2n} \\ a_{31} & a_{32} & 1 & \dots & a_{3n} \\ \vdots & \vdots & \vdots & \dots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & & 1 \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & a_{13} & & a_{1n} \\ 1/a_{12} & 1 & a_{23} & \dots & a_{2n} \\ 1/a_{13} & 1/a_{23} & 1 & \dots & a_{3n} \\ \vdots & \vdots & \vdots & \dots & \vdots \\ 1/a_{1n} & 1/a_{2n} & 1/a_{3n} & & 1 \end{bmatrix} \tag{7}$$

The matrix $A = (\alpha_{ij})$, where $\alpha_{ij} = \frac{w_i}{w_j}$, i, j = 1, 2, …n. n is the matrix size, which indicates the quantity of criteria or alternatives to be taken into account. The calculated ratio scale $w = \left[w_1 w_2 \cdots w_n\right]^T$ arises from resolving the eigenvalue problem. $A\mathrm{w} = \lambda_{\max} w$. $\lambda_{\max}$ is the principal eigenvalue of A. The final weights of the criteria (alternatives) w^N are obtained by normalizing w.

Based on the original matrix A, its corresponding symmetric triangular fuzzy version $\overline{A} = \left(l_{ij}, m_{ij}, u_{ij}\right)$ is

$$\begin{bmatrix} (1,1,1) & (1/\alpha_{12}+\beta, 1/\alpha_{12}, 1/\alpha_{12}-\beta) & (1/\alpha_{13}+\beta, 1/\alpha_{13}, 1/\alpha_{13}-\beta) & \vdots & (\alpha_{13}-\beta, \alpha_{13}, \alpha_{13}+\beta) & & (\alpha_{1n}-\beta, \alpha_{1n}, \alpha_{1n}+\beta) \\ & (\alpha_{12}-\beta, \alpha_{12}, \alpha_{12}+\beta) & & & (\alpha_{23}-\beta, \alpha_{23}, \alpha_{23}+\beta) & \cdots & (\alpha_{2n}-\beta, \alpha_{2n}, \alpha_{2n}+\beta) \\ & (1,1,1) & & & (1,1,1) & \cdots & (\alpha_{3n}-\beta, \alpha_{3n}, \alpha_{3n}+\beta) \\ (1/\alpha_{1n}+\beta, 1/\alpha_{1n}-\beta) & & (1/\alpha_{23}+\beta, 1/\alpha_{23}, 1/\alpha_{23}-\beta) & & \vdots & \cdots & \vdots \\ & \vdots & & & (1/\alpha_{3n}+\beta, 1/\alpha_{3n}, 1/\alpha_{3n}-\beta) & \cdots & (1,1,1) \\ & (1/\alpha_{2n}+\beta, 1/\alpha_{2n}, 1/\alpha_{2n}-\beta) & & & & & \end{bmatrix} \tag{8}$$

The fuzzy weights $\overline{w} = \left[\overline{w_1}\,\overline{w_2} \cdots \overline{w_n}\right]^T$. The weight $\overline{w_i} = \left(\frac{l_i}{u}, \frac{m_i}{m}, \frac{u_i}{l}\right)$ $(i = 1, 2, \ldots, n)$, where $l_i = \left(\prod_{j=1}^{n} l_{ij}\right)^{\frac{1}{n}}$, $m_i = \left(\prod_{j=1}^{n} m_{ij}\right)^{\frac{1}{n}}$, $u_i = \left(\prod_{j=1}^{n} u_{ij}\right)^{\frac{1}{n}}$, $l = \sum_{i=1}^{n} l_i$, $m = \sum_{i=1}^{n} m_i$, and $u = \sum_{i=1}^{n} u_i$. In the matrix, β

denotes the width of the side of the triangular component function. When $\beta=0$, $\overline{w}$ will degenerate into the weight determined by the minimum number of two multiplications.

$$l_i=\left(\prod_{j=1}^{n} l_{ij}\right)^{\frac{1}{n}}=\left(\prod_{j>1} l_{ij}\prod_{j<1} l_{ij}\right)^{\frac{1}{n}}=\left(\prod_{j<i}\frac{1}{\alpha_{ji}+\beta}\prod_{j>i}\left(\alpha_{ij}-\beta\right)\right)^{\frac{1}{n}} \tag{9}$$

$$u_i=\left(\prod_{j=1}^{n} u_{ij}\right)^{\frac{1}{n}}=\left(\prod_{j<1} u_{ij}\prod_{j>1} u_{ij}\right)^{\frac{1}{n}}=\left(\prod_{j<i}\frac{1}{\alpha_{ji}-\beta}\prod_{j>i}\left(\alpha_{ij}+\beta\right)\right)^{\frac{1}{n}} \tag{10}$$

$$m_i=\left(\prod_{j=1}^{n} m_{ij}\right)^{\frac{1}{n}}=\left(\prod_{j<1} m_{ij}\prod_{j>1} m_{ij}\right)^{\frac{1}{n}}=\left(\prod_{j<i}\frac{1}{\alpha_{ji}+\beta}\prod_{j>i}\alpha_{ij}\right)^{\frac{1}{n}} \tag{11}$$

$$l=\sum_{i=1}^{n} l_i=\sum_{i=1}^{n}\left(\prod_{j<i}\frac{1}{\alpha_{ji}+\beta}\prod_{j>i}\left(\alpha_{ij}-\beta\right)\right)^{\frac{1}{n}} \tag{12}$$

$$u=\sum_{i=1}^{n} u_i=\sum_{i=1}^{n}\left(\prod_{j<i}\frac{1}{\alpha_{ji}-\beta}\prod_{j>i}\left(\alpha_{ij}+\beta\right)\right)^{\frac{1}{n}} \tag{13}$$

$$m=\sum_{i=1}^{n} m_i=\sum_{i=1}^{n}\left(\prod_{j<i}\frac{1}{\alpha_{ji}}\prod_{j>i}\alpha_{ij}\right)^{\frac{1}{n}} \tag{14}$$

4.2 Quantitative differences between the traditional AHP and triangular FAHP

The clarified weights are established as $\overline{w'}=\left[\overline{w'_1}\,\overline{w'_2}\cdots\overline{w'_n}\right]^T$, where each element $\overline{w_i}'$ is the center of area of $\overline{w_i}$, namely $\overline{w_i}'=\dfrac{\frac{l_i}{u}+\frac{m_i}{m}+\frac{u_i}{l}}{3}$.

Definition 1. (Quantitative Difference): the application of the triangular fuzzy numbers makes a quantitative difference **d** if and only if $d=\sum_{i=1}^{n} d_i>0$, where $d_i=\left|\overline{w}'^N_i-w_i^N\right| \quad (1\le i\le n)$.

d means the absolute difference between the corresponding weights obtained by the standard obtained by the classic AHP and the triangle blurred AHP. Given the positive reciprocal matrix $A=\left(\alpha_{ij}\right)$, $i,j=1,2,\ldots,n$, it is confirmed that d is a function of $\beta\left(0<\beta<1\right)$. Here, set β within the range of (0, 1) to ensure the vagueness of the matrix A is feasible, where the smallest element in A is "1." The closed-form expressions of d in the instance where the matrix size equals 2 and 3, are provided below.

Proposition 1. In the instance that matrix size $n=2$, for any $\alpha_{12}\ge 1$, $\alpha_{12}<1$. The quantitative disparity, denoted as d, between the weights derived from the triangular fuzzy AHP and the classical AHP methods is represented by $F\left(\beta\right)=d_1+d_2$.

$$d_1=\left|\frac{\alpha_{12}\left(\alpha_{12}^2-\beta^2\right)^{\frac{1}{2}}\left[\frac{-\beta^2}{\alpha_{12}+1}+2\left(1+\frac{1}{\alpha_{12}+1}\right)\left(\alpha_{12}^2-\beta^2\right)^{\frac{1}{2}}+\frac{\alpha_{12}^2+1}{\alpha_{12}+1}+2\right]}{\left(\alpha_{12}^2-\beta^2\right)^{\frac{1}{2}}\left[-\beta^2+2\left(1+\alpha_{12}\right)\left(\alpha_{12}^2-\beta^2\right)^{\frac{1}{2}}+\alpha_{12}^2+4\alpha_{12}+1\right]+2\alpha_{12}}-\frac{\alpha_{12}}{\alpha_{12}+1}\right| \tag{15}$$

$$d_2 = \left| 1 - \frac{\alpha_{12}\left(\alpha_{12}^2 - \beta^2\right)^{\frac{1}{2}}\left[\frac{-\beta^2}{\alpha_{12}+1} + 2\left(1 + \frac{1}{\alpha_{12}+1}\right)\left(\alpha_{12}^2 - \beta^2\right)^{\frac{1}{2}} + \frac{\alpha_{12}^2+1}{\alpha_{12}+1} + 2\right]}{\left(\alpha_{12}^2 - \beta^2\right)^{\frac{1}{2}}\left[-\beta^2 + 2\left(1+\alpha_{12}\right)\left(\alpha_{12}^2 - \beta^2\right)^{\frac{1}{2}} + \alpha_{12}^2 + 4\alpha_{12} + 1\right] + 2\alpha_{12}} - \frac{1}{\alpha_{12}+1} \right| \quad (16)$$

Through conversion between the two components, scenarios where $\alpha_{12} < 1$ a equate to those where $\alpha_{12} \geq 1$. Proposition 1 suggests that when the size of the matrix or the quantity of criteria considered, denoted as n=2, there will always be a difference greater than zero between the two methods. In essence, discrepancies are inevitable.

In the instance where matrix size n = 3, the results and proofs are similar. Due to limited space, please refer to the study by Hing Kai Chan (2019) for detailed proof. For matrix sizes n ≥ 4, a closed equation expression for the quantitative difference d function cannot be found.

5. Real-life Exemplar Case

Here, this paper uses the triangular fuzzy AHP and classic AHP to the real world to verify the conclusions obtained in Section 3. In order to meet the needs of consumers for green products and the requirements of the municipal government for environmental protection standards, the manufacturer H Company began to produce new EVA materials which are more environmentally friendly. The production of new materials will involve the selection of new suppliers. Due to the enormous number of raw materials used in EVA production, only the main suppliers of raw materials for foaming agents are considered here. Suppose there are three alternative suppliers for company H: vendor A, vendor B, and vendor C.

5.1 Case analysis based on FL

Firstly, according to the analysis steps of FL, the green SS problem of H company is analyzed. The evaluation team experts can use Table 2 to determine the indicators and the semantic rating of the supplier, as shown in Tables 5 and 6.

Table 5 Elicitation procedure for criteria importance weights (FL)

One-level indexes	Relative importance	Two-level indexes	Relative importance
Quality	VH	Quality control rejection rate	H
		Customer rejection rate	M
Delivery	H	Delevery leaad time	H
		Flexibility	H
Blockchain willingness	M	Strong willingness	M
		Weak willingness	M
Cost	H	Purchase price	VH
		Logistics costs	H
Environmental protection	VH	Environmental management system	VH
		Pollution control	H

Table 6 Elicitation procedure for vendor performance ratings (FL)

	Vendor A	Vendor B	Vendor C
Quality control rejection rate	VG	VG	G
Customer rejection rate	G	EX	VG
Delevery leaad time	P	G	P
Flexibility	G	G	VG
Strong willingness	P	G	EX
Weak willingness	VG	VG	G
Purchase price	P	G	G
Logistics costs	VG	G	P
Environmental management system	VG	G	P
Pollution control	G	P	P

As can be seen from table 5, the order of importance of the first-level indicators is quality > environmental protection > cost = delivery > blockchain willingness. This conclusion demonstrates that in the process of green vendor selection, enterprise managers first value product quality and product environmental protection, and then consider the cost and blockchain willingness of products. Additionally, it gives suppliers direction for future development. Suppliers should focus more on enhancing product quality and environmental protection while effectively reducing their own costs. The fuzzy weights of each secondary index obtained from Tables 2, 4 and 6 are as follows:

Quality qualification rate: w_1= (0.6, 0.8, 1.0, 1.0)*(0.4, 0.6, 0.6, 0.8) = (0.24, 0.48, 0.6, 0.8);

Customer return rate: w_2= (0.6, 0.8, 1.0, 1.0)*(0.2, 0.4, 0.4, 0.6) = (0.12, 0.32, 0.4, 0.6);

Delivery lead time: w_3= (0.4, 0.6, 0.6, 0.8)*(0.4, 0.6, 0.6, 0.8) = (0.16, 0.36, 0.36, 0.64);

Delivery flexibility: w_4= (0.4, 0.6, 0.6, 0.8)*(0.4, 0.6, 0.6, 0.8) = (0.16, 0.36, 0.36, 0.64);

Strong willingness: w_5= (0.2, 0.4, 0.4, 0.6)*(0.2, 0.4, 0.4, 0.6) = (0.04, 0.16, 0.16, 0.36);

Weak willingness: w_6= (0.2, 0.4, 0.4, 0.6)*(0.2, 0.4, 0.4, 0.6) = (0.04, 0.16, 0.16, 0.36);

Purchase price: w_7= (0.4, 0.6, 0.6, 0.8)*(0.6, 0.8, 1.0, 1.0) = (0.24, 0.48, 0.6, 0.8);

Logistics cost: w_8= (0.4, 0.6, 0.6, 0.8)* (0.4, 0.6, 0.6, 0.8) = (0.16, 0.36, 0.36, 0.64);

Environmental protection management system: w_9 = (0.6, 0.8, 1.0, 1.0)* (0.6, 0.8, 1.0, 1.0)=(0.36, 0.64, 1, 1);

Contamination Control:w_{10}=(0.6, 0.8, 1.0, 1.0)*(0.4, 0.6, 0.6, 0.8)=(0.24, 0.48, 0.6, 0.8).

Table 7 Supplier performance ratings (FL)

	Fuzzy performance rating	Exact score	Ranking
Vendor A	(4.24, 14.48, 20.4, 39.84)	19.74	2
Vendor B	(4.08, 15.84, 20.32, 42.96)	20.8	1
Vendor C	(2.4, 10.2, 17.56, 39.68)	17.46	3

Similar to the conversion process of the semantic scale of secondary indicators, the fuzzy evaluation judgment matrix of alternative suppliers in Table 5 is multiplied by the fuzzy weight matrix of primary indicators and secondary indicators to obtain the comprehensive ranking of suppliers. Meanwhile, use formula (3) to defuzzify the fuzzy values, convert them into exact scores, and then sort the suppliers according to the scores, as shown in Table 7.

5.2 Case analysis based on AHP

Then, according to the analysis steps of AHP, the green SS problem of H company is analyzed. Firstly, the semantic scale in Table 3 is converted into an exact value according to the conversion rule in Table 2, and then the five indicators in the first-level indicator layer are compared in pairs to obtain Table 8:

Table 8 The judgment matrix for one-level indexes and evaluation (AHP)

Supplier select	Quality	Delivery	Blockchain willingness	Cost	Environmental protection	Wi	Evaluation results
Quality	1	2	4	2	1	0.308	$\lambda_{max}=5$ RI=1.12 CI=0 CR=0<0.1
Delivery	0.5	1	2	1	0.5	0.154	
Blockchain willingness	0.25	0.5	1	0.5	0.25	0.077	
Cost	0.5	1	2	1	0.5	0.154	
Environmental protection	1	2	4	2	1	0.308	

As can be seen from Table 8, the semantic scale conversion rule will not affect the comparative significance ranking of the first-level indicators. Meanwhile, the assessment matrix for the primary-level index has satisfactorily cleared the consistency test. Likewise, the comparative significance weight of each sub-index can be derived. The comprehensive evaluation ranking of suppliers can be obtained by final calculation, as indicated

International Journal of Multiphysics
Volume 18, No. 2, 2024
ISSN: 1750-9548

in Table 8.

Table 9 The comprehensive evaluation for suppliers (AHP)

Two-level indexes	SupplierA	SupplierB	SupplierC
Environmental management system	0.121	0.066	0.018
Pollution control	0.042	0.027	0.034
Quality control rejection rate	0.082	0.082	0.041
Customer rejection rate	0.015	0.059	0.029
Purchase price	0.021	0.041	0.041
Logistics costs	0.029	0.015	0.007
Flexibility	0.019	0.019	0.038
Delevery leaad time	0.019	0.038	0.019
Strong willingness	0.004	0.007	0.027
Weak willingness	0.015	0.015	0.008
Total score	0.367	0.37	0.263

As depicted in Table 9, Vendor B obtains the highest grade, followed by Vendor A in second place, and Vendor C with the lowest grade. It is worth noting that vendor A's score will be the highest in the context of vendor A's improved environmental indicators. Over time, the criteria for enterprises to select suppliers are also evolving. Vendors should actively carry out innovation and always be in line with the advanced technology of society. It can also be found from Table 10 that the proportion of environmental protection management system and product qualification rate is relatively high, the proportion of purchase price and pollution control is relatively high, and the proportion of reliability and empathy is relatively low. This phenomenon shows that when choosing suppliers, enterprises pay more and more attention to the greenness and quality of suppliers' products. There are four main reasons why enterprises pay more and more attention to the greenness and quality of products: ①The shortage of resources and the severity of environmental pollution ② Consumers are becoming more and more aware of environmental protection. ③The government's monitoring and supervision of environmental protection standards of enterprises; ④The quality of products is the source of survival for enterprises.

Next, the yaahp analytic hierarchy process software is used to simulate and analyze the supplier's sensitivity to the index, as shown in Table 10, where the symbol ↑ signifies positive correlation, while the symbol ↓ signifies negative correlation. Simultaneously, in order to present the sensitivity analysis more intuitively, only the sensitivity analysis of the quality index is shown in view of the space limitation, as shown in Figure 2.

Table 10 The sensitivity analysis (AHP)

One-level indexes	Two-level indexes	Vendor A		Vendor B		Vendor C	
Quality	Quality control rejection rate	↓	↑	↑	↓	↓	↓
	Customer rejection rate		↓		↑		↑
Delivery	Delevery lead time	↓	↑	↑	↑	↑	↓
	Flexibility		↑		↓		↑
Blockchain willingness	Strong willingness	↓	↓	↓	↓	↑	↑
	Weak willingness		↑		↑		↓
Cost	Purchase price	↓	↓	↓	↑	↑	↑
	Logistics costs		↑		↓		↓
Environmental protection	Environmental management system	↑	↑	↓	↑	↓	↓
	Pollution control		↓		↓		↑

As shown in Table 10, the performance of suppliers A and C decreases with the increase of quality, and the performance of supplier B increases with the increase of quality. Figure 2 vividly shows the sensitivity analysis of quality indicators. Vendor A decreases as delivery increases, and supplier B and C performance increases as delivery increases. The performance of vendor A and B decreases with the increase of blockchain willingness, while the performance of vendor C increases with the increase of blockchain willingness. The performance of vendors A and B decreases with the increase of cost, and the performance of supplier C increases with the increase of cost. The performance of vendor A decreases declines as environmental protection efforts increase, and the performance of vendors B and C increases with the increase of cost. Due to the space limitation, the vendor's sensitivity analysis of the secondary indicators will not be repeated here.

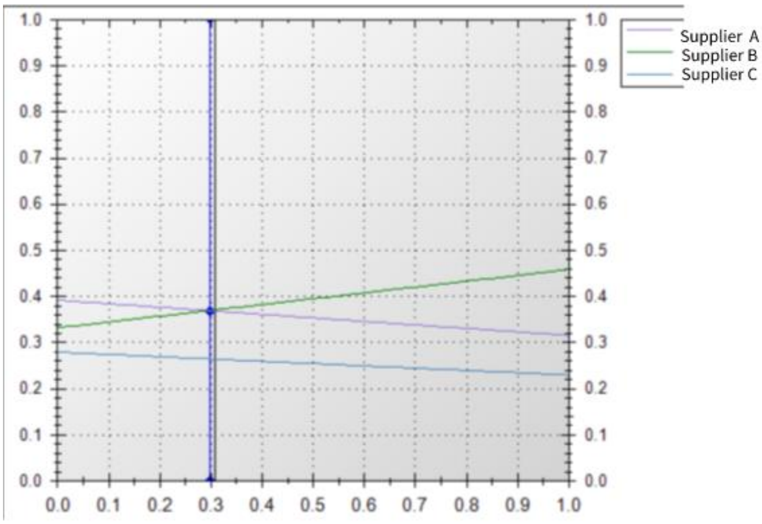

Figure 2 The sensitivity analysis for quality index

The above observation indicates that FL is not only unable to judge whether the judgment matrix of the decision maker is consistent, but also unable to carry out systematic analysis on the sensitivity of the indicators.

5.3 Case analysis based on FAHP

Finally, referring to the analysis steps of FAHP, the green SS problem of H company is analyzed. According to the semantic evaluation grade conversion method in Table 2 and the comparative significance evaluation grade of indicators in Table 4, the comparative significance judgment matrix of primary indicators can be obtained, as shown in Table 11.

Table 11 The relative important for one-level indexes (FAHP)

	Quality	Delivery	Blockchain willingness	Cost	Environmental protection
Quality	(1,1,1,1)	(1,1.333,1.667,2.5)	(1,2,2.5,5)	(1,1.333,1.667,2.5)	(1,1,1,1)
Delivery	--	(1,1,1,1)	(1,1.5,1.5,4)	(1,1,1,1)	(1,0.75,0.6,0.4)
Blockchain willingness	--	--	(1,1,1,1)	(1,0.67,0.67,0.25)	(1,0.5,0.4,0.2)
Cost	--	--	--	(1,1,1,1)	(1,0.75,0.6,0.4)
Environmental protection	--	--	--	--	(1,1,1,1)

Similarly, the importance scale of suppliers in different importance situations of sub-indicators can be obtained, as shown in Table 12.

Table 11 and Table 12 both illustrate, the four cases of L, M, H and VH correspond to four judgment matrices respectively. It is noteworthy that the judgment matrix of some sub-indicators in the VH context can't pass the consistency judgment, such as reliability, logistics cost and ecological preservation administrative structure. The indicators of the environmental protection management system are taken as an example for illustration.

According to the calculation step 3 of FAHP or AHP, Table 13 can be obtained λ max = 3.225 and CI = 0.112, and then CR = 0.216 > 0.1. It is easy to know that this judgment matrix fails the consistency test due to a significant disparity in the relative importance among the indicators within the VH context. It can be found here that although the FAHP method can better capture the fuzziness of human thinking, FAHP has some limitations. This conclusion is inconsistent with the research conclusion of literature, the primary cause is that he assumes that the difference between the importance of indicators is not large, and the size of the matrix he studied is smaller than that of this paper. It is worth noting that found that the magnitude of the matrix will affect the consistency of the FAHP judgment matrix.

Table 12 The relative important for two-level indexes (FAHP)

Pass rate	Vendor A	Vendor B	Vendor C
Vendor A (VG)	(1, 1, 1, 1)	(1, 1, 1, 1)	(1, 1.5, 1.5, 4)
Vendor B (VG)	--	(1, 1, 1, 1)	(1, 1.5, 1.5, 4)
Vendor C (G)	--	--	(1, 1, 1, 1)
Customer return rate			
Vendor A (G)	(1, 1, 1, 1)	(1, 0.5, 0.4, 0.2)	(1, 0.667, 0.667, 0.25)
Vendor B (EX)	--	(1, 1, 1, 1)	(1, 1.333, 1.667,2.5)
Vendor C (VG)	--	--	(1, 1, 1, 1)
Delivery lead time			
Vendor A (P)	(1, 1, 1, 1)	(1, 0.5, 0.111, 0.111)	(1, 1, 1, 1)
Vendor B (G)	--	(1, 1, 1, 1)	(1, 2, 9, 9)
Vendor C (P)	--	--	(1, 1, 1, 1)
Delivery flexibility			
Vendor A (G)	(1, 1, 1, 1)	(1, 1, 1, 1)	(1, 0.667, 0.667, 0.25)
Vendor B (G)	--	1	(1, 0.667, 0.667, 0.25)
Vendor C (VG)	--	--	(1, 1, 1, 1)
Strong willingness			
Vendor A (P)	(1, 1, 1, 1)	(1, 0.5, 0.111, 0.111)	(0.667, 0.2, 0.111, 0.111)
Vendor B (G)	--	(1, 1, 1, 1)	(1, 0.5, 0.4, 0.2)
Vendor C (EX)	--	--	(1, 1, 1, 1)
Weak willingness			
Vendor A (VG)	(1, 1, 1, 1)	(1, 1, 1, 1)	(1, 1.5, 1.5, 4)
Vendor B (VG)	--	(1, 1, 1, 1)	(1, 1.5, 1.5, 4)
Vendor C (G)	--	--	(1, 1, 1, 1)
Purchase price			
Vendor A (P)	(1, 1, 1, 1)	(1, 0.5, 0.111, 0.111)	(1, 0.5, 0.111, 0.111)
Vendor B (G)	--	(1, 1, 1, 1)	(1, 1, 1, 1)
Vendor C (G)	--	--	(1, 1, 1, 1)
Logistics cost			
Vendor A (VG)	(1, 1, 1, 1)	(1, 1.5, 1.5, 4)	(1, 3, 9, 9)
Vendor B (G)	--	(1, 1, 1, 1)	(1, 2, 9, 9)
Vendor C (P)	--	--	(1, 1, 1, 1)
Environmental protection management system			
Vendor A (VG)	(1, 1, 1, 1)	(1, 1.5, 1.5, 4)	(1, 3, 9, 9)
Vendor B (G)	--	(1, 1, 1, 1)	(1, 2, 9, 9)
Vendor C (P)	--	--	(1, 1, 1, 1)
Pollution control			
Vendor A (G)	(1, 1, 1, 1)	(1, 2, 9, 9)	(1, 2, 9, 9)
Vendor B (P)	--	(1, 1, 1, 1)	(1, 1, 1, 1)
Vendor C (P)	--	--	(1, 1, 1, 1)

Table 13 The relative important for environmental management system under VH (FAHP)

Environmental protection management system	Vendor A (P)	Vendor B (G)	Vendor C (EX)
Vendor A (P)	1	4	9
Vendor B (G)	--	1	9
Vendor C (EX)	--	--	1

By correcting the inconsistency in reliability, logistics cost and environmental protection management system, the comprehensive ranking of vendor performance can be finally obtained, as shown in Table 14.

As can be seen from Table 14 that vendor B has the highest comprehensive grade, followed by vendor A, and supplier C has the lowest grade. Combining FL and AHP analysis methods, it can be found that different evaluation methods have no significant impact on the overall ranking of SS.

Table 14 Vendor performance ratings (FAHP)

	Fuzzy number	Exact score	Sort
Vendor A	(0.338, 0.347, 0.357, 0.402)	0.361	2
Vendor B	(0.333, 0.359, 0.405, 0.408)	0.376	1
Vendor C	(0.329, 0.294,0.238, 0.19)	0.263	3

The above observation indicates that different evaluation methods of FL, AHP and FAHP have no significant effect on the comprehensive ranking of vendors, and AHP is particular suitable for a company to select its alternative vendors. Meantime, this paper finds that using fuzzy numbers in the AHP becomes unnecessary when the consistency level of pairwise comparison matrices is unsatisfactory. It suggests that FAHP may not be preferable over classical AHP. The complexity of a method does not necessarily correlate with its effectiveness.

6. Conclusion

Green vendor is not only an essential source of the company's product production, but also an important guarantee for the company's production cost control, quality assurance, sustainable development and other critical linkages. Its significance in the development of the company is self-evident. The existing literature on SS analysis and evaluation methods has a tendency to be more intricate and diverse, and it is unclear if these evaluation methods are more advantageous to SS. This paper takes the green SS of H Company as the research object, takes the construction of scientific vendor evaluation system as the goal, selects the key indicators of SS evaluation, such as quality, delivery, blockchain willingness, cost and environmental protection, and uses FL, AHP and FAHP methods to investigate the effect of each indicator on the green SS, and explores which method is more conducive to screening potential suppliers for enterprises. Endeavor to furnish enterprises with a scientifically grounded decision-making framework for selecting environmentally responsible vendors. It is found that none of the three evaluation methods significantly influences the comprehensive ranking of green SS of H company, and FAHP, which is widely used, will fail to pass the consistency test when the relative importance gap between indicators is large. In addition, it is easier to analyze the sensitivity of indicators in the context of AHP. This paper holds that the simple AHP analysis method is better suited for evaluating SS at H Company. In the SS and evaluation process, the diversity and complexity of the evaluation model should not be excessively dependent on the evaluation model, and the simplest and most suitable evaluation model is the best choice.

Acknowledgement

This research is supported by Shandong Provincial Social Science Foundation of China (22DGLJ28).

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