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Supplier Selection Fuzzy Model in Supply Chain Management: Vietnamese Cafe Industry Case

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Abstract: Supplier selection is a vital part of the supply chain and is also a current issue that concerns businesses today as supplier quality directly affects the operations of the organization. Choosing the right supplier can help businesses increase productivity, competitiveness in the market, and profits without having to lower the quality of the products. However, choosing a supplier is not a simple matter, it requires businesses to consider many aspects about their suppliers. Therefore, the goal of this study is to propose an integrated model consisting of two models: Fuzzy Analytics Network Process (Fuzzy-ANP) model and Weighted Aggregated Sum Product Assessment (WASPAS) to solve the problem above. The Fuzzy-ANP model was developed to evaluate the weightings of the supplier selection criteria, and the WASPAS Model was used to rank the suppliers. An example of supplier selection in the coffee industry in Vietnam was studied to validate the model, namely 5 main criteria, with 16 sub-criteria, and 7 suppliers. The model test results show that the Fuzzy ANP and WASPAS integration model was suitable. In future, these developing models can apply to other industries or integrate with other models.

Keywords: Fuzzy-ANP; WASPAS; multi-decision; café industry; supplier selection; supply chain management

1 Introduction

Coffee production has been a major source of income for Vietnam since the early 20th century. First introduced by the French in 1857, the Vietnamese coffee industry has developed through the plantations system, becoming a major economic force of the country [1]. Over a long period of time and strong development, now coffee has brought great export value to the Vietnamese people. With an average of about 2.3 tons/ha, Vietnam's coffee yields are significantly higher than any other coffee-producing country in the world. Vietnam has created a unique brand of "high-intensity Robusta" farming, as Robusta produces more coffee beans per hectare than Arabica, which allows Vietnam to

become the highest production of coffee. At the same time, it also promotes profits for coffee farmers, because many Vietnamese farmers harvest over 3.5 tons/ha [2].

According to data from the General Statistics Office of Vietnam, Vietnam is the world's second-largest coffee exporter. The EU is the largest coffee-consuming market in the world, with imports from foreign countries of 10 billion USD annually. Currently, Vietnam's coffee exports to the EU account for more than 8.5% of the total EU imports and nearly 40% of Vietnam's coffee exports. From 2010 to 2019, each year our country exports an average of more than 1.5 million tons of coffee for export, the average export value falls to over $3 billion. Coffee exports in September 2020 reached 99,700 tons, worth US $ 188.11 million, down 0.5% in volume but up 2% in value compared to August/2020. Generally, in the first 9 months of 2020, coffee exports decreased by 1.4% in volume and 1.0% in value over the same period in 2019, reaching 1.25 million tons, worth $ 2.16 billion.

Currently, in Vietnam, there are 4 famous types of coffee: Arabica, Robusta, Cherry, Culi. If before, anyone could easily make a traditional cup of coffee, now making coffee is an art. The concept of deliciousness with the new Vietnamese coffee culture today is not only delicious in "quality", but the presentation must also look "delicious". To achieve the above, coffee businesses in Vietnam today need to choose the right supply source. Supplier selection is becoming increasingly important to all businesses globally. The quality of the supplier affects the competitiveness of businesses [3]. In order to increase production and business efficiency without having to reduce product quality, increase selling prices, …, choosing a suitable supplier is also one of the important strategies that businesses are interested in and considered. Currently, there are many tools to support businesses in choosing suppliers: Analytical Hierarchical Analysis (AHP), Analytical Network Analysis (ANP), Data Contour Analysis (DEA), … This study proposes the Fuzzy-ANP model and Weighted Aggregated Sum Product Assessment (WASPAS) model to analyze data after consulting experts including 5 main criteria, 16 sub-criteria and 7 suppliers to assist the coffee industry in selecting supplier high quality ensures minimum costs, and maximum quality of raw materials with other factors.

In this study, the FANP model can provide direct supplier queuing results. However, the author wants to combine two models FANP and WASPAS to increase reliability. For the FANP model, the author only uses the evaluation weight results of the criteria from the FANP model and uses it as input of the WASPAS model to rank the supplier.

2 Literature Review

Evaluation and selection of suppliers has attracted the attention of researchers for several decades. Functional role of selected providers in the practice of this new supply chain strategy in the literature references below.

Function selected suppliers are dominated by quantitative methods and mathematical models. Overall, the model focuses on improving the accuracy of the evaluation and performance of the supplier or on the method used to rank and determine suppliers [4]. In Dickson's study, alternative methods have been used to evaluate and select criteria [5]. Most models make decisions about vendor selection based on a set of vendor performance criteria by Pi and Low [6]. Decision-making models differ by having one or more goals or by having different criteria. Timmerman proposed a linear model for decision support, in which the suppliers were ranked by several criteria and these ratings were combined into a single point [7]. Pearson et al. examined the supplier selection and evaluation criteria in small and large electronics companies outlining the criteria used by purchasing managers in choosing suppliers optimally [8].

There are several works applying MCDM approach to selecting suppliers, such as: Samut [9] applied FANP and Mixed Integer Goal Programming model (MIGP) for wind turbine supplier only in wind power plant projects. Tien-Chin Wang et al. [10] presented the MCDM model using FAHP and DEA combined to select solar panel suppliers. Onut et al. [11] have designed a FANP-based approach to the selection of container ports from manufacturing companies for the shipping industry. The MCDM is method to compare support structures for offshore wind turbines [12] or energy plant location selection [13]. Liou et al. [14] combined fuzzy priority programming and ANP to form a model of the selection of strategic alliance partners in the aviation industry. Dubey et al. [15] proposed a framework for green supply chains. Yucel et al. [16] developed a predictive risk assessment model for the hospital information system (HIS) by applying ANP, practical design gap assessment and fuzzy inference system. Büyüközkan et al. [17] have developed a sustainable principles-based supplier selection approach using FANP following a multi-person decision-making scheme with inadequate preference relationships. Vinodh et al. [18] applied FANP to the process of supplier selection in a production organization to remain in the global market. Chen et al. [19] were used in an integrated FANP model with benefits, opportunities, costs, and risks to prioritize smart grid systems. Lee et al. [20] built an integrated fuzzy QFD framework for new product development, with FDM for selecting important factors, fuzzy ISM to define the relationship between important factors and QFD and FANP to calculate the priority of important factors. Carter [21] analysed the role of purchasing in environmental management: Developing cross-functional theory. Chang et al. [22] applied AHP and ANP to evaluating digital video recorder systems.

For the WASPAS model, there are also many case studies such as: Zolfani et al. [23], have developed a multi-criteria decision-making approach to solve the problem of locating shopping centres by how to use SWARA and WASPAS methods. Bagočius et al. [24], proposed a MCDM method based on the WASPAS Method to select and rank viable site sites of wind power farms and to evaluate wind turbines in the external area. Singh et al. [25] applied SWARA and WASPAS methods for supplier selection in an Indian cement industry. Vafaeipour et al. [26] integrated SWARA and WASPAS method to evaluate solar projects based on the priority of the area. Chakraborty et al. [27] applied the WASPAS method to solve a few multi-criteria manufacturing problems such as selection of cutting fluid, electroplating system, forging conditions, arc welding process, etc. Zavadskas et al. [28] extension of weighted aggregated sum product assessment with interval-valued intuitionistic fuzzy numbers (WASPAS-IVIF). Lashgari et al. [29] developed the MCDM approach based on the Quantitative Strategic Planning Matrix (QSPM) and the WASPAS method to define outsourcing strategies.

3 Materials and Methods

To build an effective supplier selection model, the implementation process is carried out according to the main steps as shown in Fig. 1.

Step 1: Identify the problem

To analyze and evaluate the status of the company's supplier selection, the first step is to learn about the purchasing process, the criteria for selecting suppliers at the company through observing the actual operating environment, at the same time, to learn materials related to the problem, in order to make comments more effectively. Identify the core problem that causes ineffective supplier selection, analyze and come up with solutions. Besides, refer to the relevant previous studies to understand the concepts, implementation methods, evaluation and model building of supplier selection.
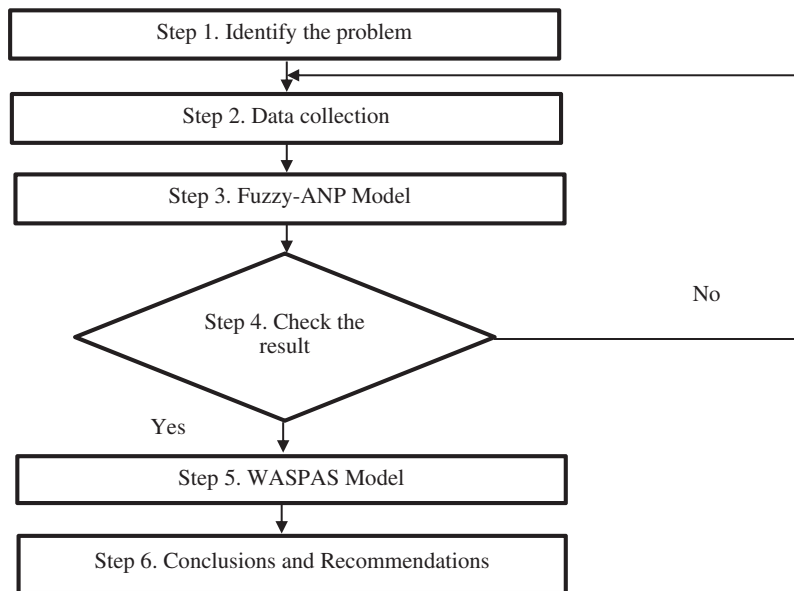
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Figure 1: Research process of the paper

Step 2: Data collection

Collect coffee bean evaluation criteria, gather information about suppliers, set up a team of experts or outsource to evaluation criteria. Synthesize articles related to research issues, information from the General Statistics Office of Viet Nam, Ministry of Agriculture and Rural Development Viet Nam and information of companies supplying coffee beans.

Step 3: FANP model

Build a FANP model to evaluate and rate suppliers. Using a Fuzzy Network Analysis method (Fuzzy Analysis Network Process-FANP).

Step 4: Check the FANP model result

Check the correctness of the model, if the result is false, go back to identify the problem. Selection of the most optimal supplier.

Step 5: WASPAS model

Optimized supplier rating with a combination of two models FANP and WASPAS. Experts will conduct an initial assessment, combined with the weights from the FANP model.

Step 6: Conclusions and recommendations

Analyze and conclude the results achieved when conducting the research, in addition to propose stakeholders to the issues encountered and unsolved in the research process. In addition, it is recommended to develop models, in combination with other methods used in other decision-making areas.

3.1 Data Collected

From the reference documents, we identified a list of criteria for the selection of recommended coffee to experts. We have selected five main criteria with sub-criteria and seven suppliers, which can be seen in Tab. 1.

Table 1: List of supplier selection criteria

Criteria	Symbol	Sub criteria	Symbol	Supplier
Cost	A	Purchasing price	A1	Supplier 1
		Logistics cost	A2	Supplier 2
Quality	B	Product quality	B1	Supplier 3
		Quality control and planning	B2	Supplier 4
		Trade certified	B3	Supplier 5
Service level	C	Before-sales services	C1	Supplier 6
		After-sales services	C2	Supplier 7
		Estimated shipping times	C3	
Supplier's profile	D	Market reputation	D1	
		Financial strengths	D2	
		Technical capability	D3	
		Performance history	D4	
Global factors	E	Geographical location	E1	
		Environmental and ethical factors	E2	
		Political stability	E3	
		Social environment	E4	

3.2 Fuzzy Analytic Network Process Model

The procedure for implementing the Fuzzy-ANP method is as follows:

Step 1: Building FANP model

Construction of the FANP model structure. Set the Analytic Network Process and define the relationship between the criteria and the suppliers shown on Fig. 2:

Step 2: Set up pair comparison matrix

A pairwise comparison of fuzzy numbers is used to perform a pairwise comparison between criteria. The pair comparison matrix is presented as follows:

$$\widetilde{N^k} = \begin{bmatrix} \widetilde{n^k_{11}} & \widetilde{n^k_{12}} \cdots & \widetilde{n^k_{1a}} \\ \widetilde{n^k_{21}} & \widetilde{n^k_{22}} \cdots & \widetilde{n^k_{2a}} \\ \cdots & \cdots \cdots & \cdots \\ \widetilde{n^k_{a1}} & \widetilde{n^k_{a2}} \cdots & \widetilde{n^k_{aa}} \end{bmatrix} \tag{1}$$

where:

$\widetilde{N^k}$ is called a pairwise comparative matrix of fuzzy elements.

$\widetilde{n^k_{aa}}$ is the triangular fuzzy mean value when comparing the pair of priorities between the elements.

Converting fuzzy numbers to real numbers, triangular fuzzy trigonometric methods are presented as follows [30]:

$$z_{\alpha,\beta}(\bar{\alpha}_{ij}) = [\beta.f_\alpha(L_{ij}) + (1 - \beta.f_\alpha(U_{ij})] \tag{2}$$

$0 \leq \beta \leq 1, 0 \leq \alpha \leq 1$

where:

$$f_\alpha(L_{ij}) = (M_{ij} - L_{ij}).\alpha + L_{ij} \tag{3}$$

$$f_\alpha(U_{ij}) = U_{ij} - (U_{ij} - M_{ij}).\alpha \tag{4}$$
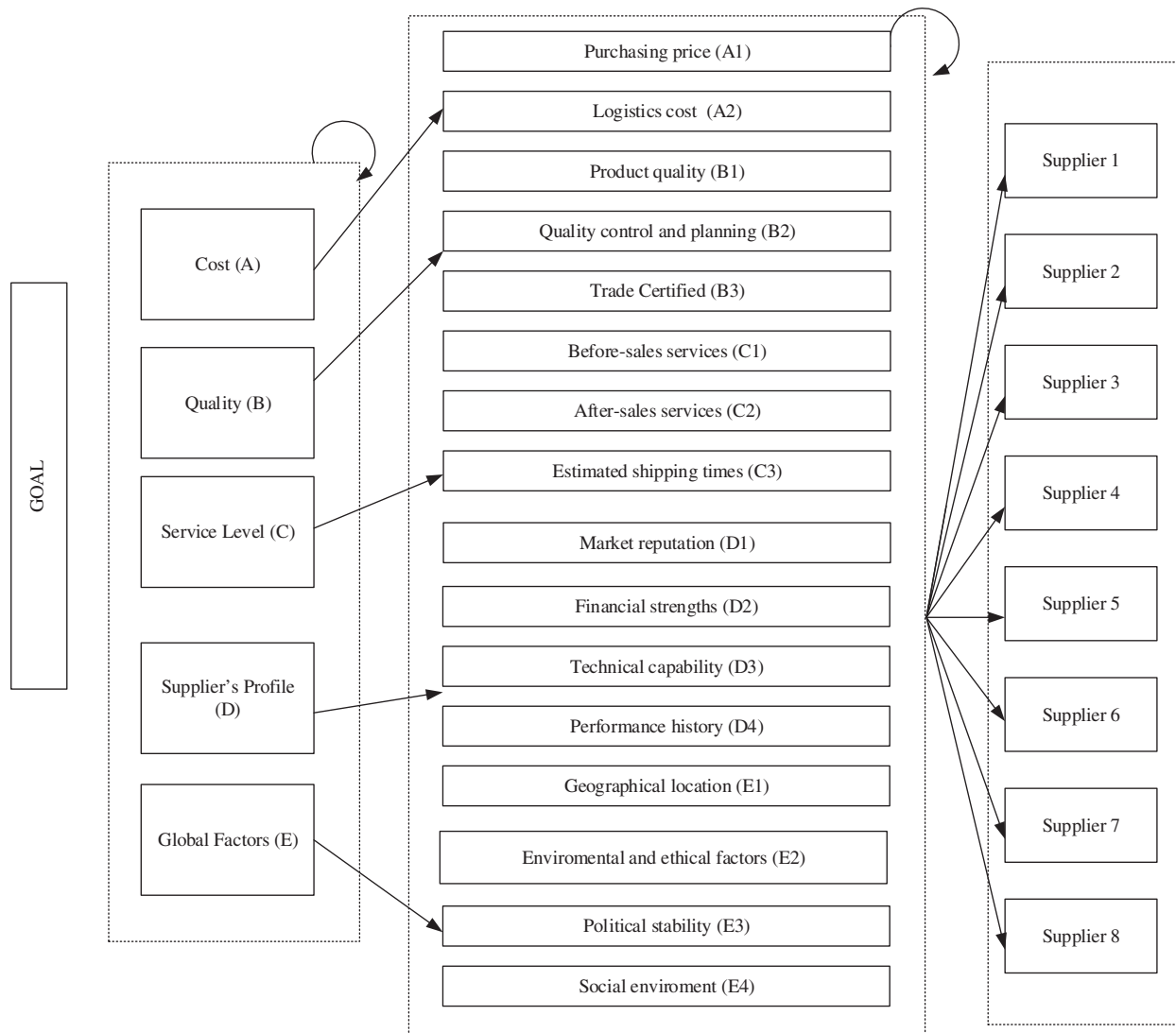

Figure 2: Fuzzy analytics network process structure

When matching the diagonal matrix, we have:

$$z_{\alpha,\beta}(\bar{\alpha}_{ij}) = \frac{1}{z_{\alpha,\beta}(\bar{\alpha}_{ij})} \tag{5}$$

$0 \leq \beta \leq 1, 0 \leq \alpha \leq 1, \ i > j$

After comparing the fuzzy pairs matrix, we obtain a matrix that compares the real numbers. This comparison is made between pairs of indicators and is combined into a matrix of a lines and a columns (a: is the number of indicators). Element shows the importance of the indicator i *vs.* the column criteria

$$N = (m_{ij})_{a \times a} = \begin{bmatrix} 1 & m_{12} & \ldots & m_{1a} \\ m_{21} & 1 & \ldots & m_{2a} \\ \vdots & \vdots & \vdots & \vdots \\ m_{a1} & m_{a2} & \ldots & 1 \end{bmatrix} \tag{6}$$

Step 3: Calculate maximum individual value

To calculate the maximum specific value for the indicator, ANP can use different methods. In particular, the most widely used is Lambda Max (max) by Saaty Proposition [31,32]:

$$|N - \lambda_{max}.I| = 0 \tag{7}$$

where:

λ_{max}: the maximum value of the matrix.

N: Comparative matrix of pairs of elements.

I: unit matrix of the same level with matrix A.

Step 4: Check consistency. Calculates the vector of the matrix

This ratio compares the degree of consistency with the (random) objectivity of the data:

$$CR = \frac{CI}{RI} \tag{8}$$

where:

CI: Consistency Index

RI: Random Index

If CR ≤ 0.1 is satisfactory, otherwise if CR ≥ 0.1 then we must conduct a reevaluation of the pair comparison matrix. Randomized index values corresponding to indicators is shown in Tab. 1

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{9}$$

where:

λ_{max} is the maximum value of the matrix

n is the number of indicators

Table 2: Randomized index values corresponding to indicators [33]

N	1	2	3	4	5	6	7	8	9	10
R	0	0	0.52	0.90	1.12	1.24	1.32	1.41	1.45	1.49

3.3 Weighted Aggregated Sum Product Assessment

The WSM method is very simple, easy to use and easy to understand. It determines the overall score of an alternative as the weighted sum of the attribute values. This is the most known and most

widely used [34] method. WPM was developed to avoid alternatives with poor attribute value. It determines the score of each alternative as a product of the scale rating of each attribute to strength by the attribute's significance weight [35].

The computational procedure of the WASPAS method can be precisely presented as follows:

Step 1: Normalization of the decision matrix

For the WASPAS approach, the approach to normalizing the decision matrix depends on whether the decision criteria are beneficial or not. For the beneficial decision criteria, the normalization of the decision matrix in Tab. 1 is performed as shown in Eq. (10) as follows:

$$q_{ij} = \frac{x_{ij}}{\max x_{ij}}, \ i = 1, 2, \ \ldots, \ n; j = 1, \ 2, \ \ldots, \ m \tag{10}$$

For non-beneficial decision criteria as shown in Eq. (11):

$$q_{ij} = \frac{x_{ij}}{\min x_{ij}}, \ i = 1, 2, \ \ldots, \ n; j = 1, \ 2, \ \ldots, \ m \tag{11}$$

Step 2: Calculate the relative importance of the ith alternative, based on the WSM method as follows:

$$S_i^1 = \sum_{j=1}^{n} q_{ij} \times w_j \tag{12}$$

Step 3: The performance index of the ith alternative is evaluated by WPM as given in Eq. (14):

$$S_i^2 = \prod_{j=1}^{n} (q_{ij})^{w_j} \tag{13}$$

Step 4: With the combination of Eqs. (12) and (13), we create a WASPAS model to calculate the total relative importance. Sum of relative importance, or more precisely, the general criterion of the weighted synthesis of the addition and multiplication methods as follows:

$$F = \lambda S_i^1 + (1 - \lambda)S_i^2 = \lambda \sum_{j=1}^{n} q_{ij} \times w_j + (1 - \lambda) \prod_{j=1}^{n} (q_{ij})^{w_j} \tag{14}$$

where λ is the coefficient and $\lambda \in [0,1]$

When decision-makers have no preference in relation to the coefficient, its value is set to $\lambda = 0.5$.

The alternatives are ranked based on an index of performance, and the optimal alternative is the one with the highest weight of F.

4 Result

After collecting all the required criteria and suppliers, a fuzzy assessment matrix related to the goal is given in Tab. 3. Then, the decision-maker compares the attributes related to the criterion. The pairwise comparison matrix is made, and weight vector of each matrix is calculated. All properties are compared against each individual criterion by following the same procedure as below:

To convert fuzzy numbers into real numbers, we conduct the fuzzy solution by the triangular fuzzy number method. In the process of solving fuzzy we take the coefficients $\alpha = 0.5$ and $\beta = 0.5$. In particular, α present uncertain environment, β represents the attitude of the assessment is fair.

$$g_{0.5,0.5}(\overline{a_{A,B}}) = [(0.5 \times 1.5) + (1 - 0.5) \times 2.5] = 2$$

$$f_{0.5}(L_{A,B}) = (2\text{--}1) \times 0.5 + 1 = 1.5$$
$$f_{0.5}(U_{A,B}) = 3\text{--}(3\text{--}2) \times 0.5 = 2.5$$
$$g_{0.5,0.5}(\overline{a_{B,A}}) = 1/2$$

Table 3: Matrix comparison of pairs between main criteria by fuzzy numbers

Criteria	A	E	B	C	D
A	(1, 1, 1)	(1, 1/2, 1/3)	(1, 2, 3)	(1, 1, 1)	(1, 2, 3)
E	(1/3, 1/2, 1)	(1, 1, 1)	(3, 4, 5)	(1, 1/2, 1/3)	(2, 3, 4)
B	(3, 2, 1)	(1/5, 1/4, 1/3)	(1, 1, 1)	(1/2, 1/3, 1/4)	(1/2, 1/3, 1/4)
C	(1, 1, 1)	(3, 2, 1)	(4, 3, 2)	(1, 1, 1)	(1, 2, 3)
D	(1/3, 1/2, 1)	(1/4, 1/3, 1/2)	(4, 3, 2)	(1/3, 1/2, 1)	(1, 1, 1)

The remaining calculations for other criteria are similar to the above calculation. The real number priority when comparing the main criteria pairs are shown in Tab. 4:

Table 4: Real number priority

Criteria	A	E	B	C	D	Weight
A	1	1/2	2	1	2	0.2013
E	2	1	4	1/2	3	0.2924
B	1/2	1/4	1	1/3	1/3	0.0743
C	1	2	3	1	2	0.2985
D	1/2	1/3	3	1/2	1	0.1335

Results of the inputs given by the Software are listed in Tab. 5 which describes the criteria which are more important in criteria and supplier relationship. Each of these attributes may be more or less important in developing assessmentcriteria for the supplier's selection performance. Results of WASPAS model are shown in Tabs. 6–8.

Table 5: Weight of sub-criteria

Sub-criteria	Weight
After-sales services	0.05422
Before-sales services	0.05001
Environmental and ethical factors	0.03052
Estimated shipping times	0.05563
Financial strengths	0.02862
Geographical location	0.02297
Logistics cost (transportation, storage)	0.13878
Market reputation	0.03678
Performance history	0.02609
Political stability	0.04332

(Continued)

Table 5: Continued

Sub-criteria	Weight
Product quality	0.13001
Purchasing price	0.13884
Quality control and planning	0.09759
Social environment	0.04182
Technical capability	0.0398
Trade certified	0.06499

Table 6: Data input of WASPAS model

Guide to determine kind of criteria		
Kind of criteria	Profit	Cost
	1	−1
Number of criteria	16	
Number of suppliers	7	

Table 7: Normalized matrix

	A1	A2	A3	A4	A5	A6	A7
S1	0.8889	1.0000	0.8889	0.7778	0.7778	0.8889	0.8889
S2	0.7778	1.0000	0.8889	0.8889	0.8889	0.7778	0.7778
S3	0.8750	1.0000	0.7778	0.8750	0.8750	0.8750	0.7778
S4	0.7778	1.0000	1.0000	0.8889	1.0000	0.8889	0.7778
S5	1.0000	0.7778	0.6667	1.0000	0.8889	1.0000	0.7778
S6	1.0000	0.8750	0.8750	1.0000	0.8750	0.7500	0.7500
S7	0.6667	1.0000	0.8571	0.8571	0.6667	0.6667	0.7500
S8	0.7778	0.8889	0.8889	1.0000	0.8889	0.8889	0.7778
S9	1.0000	0.7778	0.6667	0.8889	0.8889	0.8889	0.8889
S10	0.8889	0.6667	0.7778	0.8889	0.6667	0.6667	1.0000
S11	0.6667	1.0000	0.8571	1.0000	1.0000	0.6667	1.0000
S12	1.0000	0.8571	0.7500	0.6667	0.8571	0.6667	0.6667
S13	0.8889	0.7778	0.8889	1.0000	0.7778	0.7778	0.8889
S14	0.8889	0.6667	1.0000	0.6667	0.7778	0.8889	0.8889
S15	0.8750	1.0000	0.7500	0.8750	0.8750	0.7500	0.8750
S16	0.8889	1.0000	1.0000	0.6667	0.8889	0.7778	0.8889

Table 8: Weighted normalized matrix

	A1	A2	A3	A4	A5	A6	A7
S1	0.0482	0.0542	0.0482	0.0422	0.0422	0.0482	0.0482
S2	0.0389	0.0500	0.0445	0.0445	0.0445	0.0389	0.0389
S3	0.0267	0.0305	0.0237	0.0267	0.0267	0.0267	0.0237
S4	0.0433	0.0556	0.0556	0.0494	0.0556	0.0494	0.0433
S5	0.0286	0.0223	0.0191	0.0286	0.0254	0.0286	0.0223
S6	0.0230	0.0201	0.0201	0.0230	0.0201	0.0172	0.0172
S7	0.0925	0.1388	0.1190	0.1190	0.0925	0.0925	0.1041
S8	0.0286	0.0327	0.0327	0.0368	0.0327	0.0327	0.0286
S9	0.0261	0.0203	0.0174	0.0232	0.0232	0.0232	0.0232
S10	0.0385	0.0289	0.0337	0.0385	0.0289	0.0289	0.0433
S11	0.0867	0.1300	0.1114	0.1300	0.1300	0.0867	0.1300
S12	0.1388	0.1190	0.1041	0.0926	0.1190	0.0926	0.0926
S13	0.0867	0.0759	0.0867	0.0976	0.0759	0.0759	0.0867
S14	0.0372	0.0279	0.0418	0.0279	0.0325	0.0372	0.0372
S15	0.0348	0.0398	0.0299	0.0348	0.0348	0.0299	0.0348
S16	0.0578	0.0650	0.0650	0.0433	0.0578	0.0505	0.0578

Table 9: Exponentially weighted

	A1	A2	A3	A4	A5	A6	A7
S1	0.9936	1.0000	0.9936	0.9865	0.9865	0.9936	0.9936
S2	0.9875	1.0000	0.9941	0.9941	0.9941	0.9875	0.9875
S3	0.9959	1.0000	0.9924	0.9959	0.9959	0.9959	0.9924
S4	0.9861	1.0000	1.0000	0.9935	1.0000	0.9935	0.9861
S5	1.0000	0.9928	0.9885	1.0000	0.9966	1.0000	0.9928
S6	1.0000	0.9969	0.9969	1.0000	0.9969	0.9934	0.9934
S7	0.9453	1.0000	0.9788	0.9788	0.9453	0.9453	0.9609
S8	0.9908	0.9957	0.9957	1.0000	0.9957	0.9957	0.9908
S9	1.0000	0.9935	0.9895	0.9969	0.9969	0.9969	0.9969
S10	0.9949	0.9826	0.9892	0.9949	0.9826	0.9826	1.0000
S11	0.9487	1.0000	0.9802	1.0000	1.0000	0.9487	1.0000
S12	1.0000	0.9788	0.9608	0.9453	0.9788	0.9453	0.9453
S13	0.9886	0.9758	0.9886	1.0000	0.9758	0.9758	0.9886
S14	0.9951	0.9832	1.0000	0.9832	0.9895	0.9951	0.9951
S15	0.9947	1.0000	0.9886	0.9947	0.9947	0.9886	0.9947
S16	0.9924	1.0000	1.0000	0.9740	0.9924	0.9838	0.9924

To be able to select the best supplier, after receiving the comparison weights the criteria from the FANP model will be used as input to the WASPAS model. Data input will show in below:

In the WASPAS method, λ represents the parameter and $\lambda \in [0, 1]$. The results of each alternative with different values of λ are shown in Tab. 10. The Supplier 2 (S2) is the best choice, and the six supplier performs poorly in any case. According to Tab. 10, the alternatives are ranked as S2>S4 >S3 >S5>S7>S1>S6.

Table 10: The result of supplier selection

Alternatives	Q_{i1}	Q_{i2}	Q_i	Ranking
S1	0.8364	0.8272	0.8318	6
S2	0.9110	0.9034	0.9072	1
S3	0.8529	0.8481	0.8505	3
S4	0.8580	0.8482	0.8531	2
S5	0.8418	0.8418	0.8418	4
S6	0.7591	0.7591	0.7591	7
S7	0.8319	0.8319	0.8319	5

5 Conclusion and Discussion

Selecting suppliers is an important activity of the supply chain to boost your business and increase profits in the coffee industry. However, the supplier selection process tends to be based on the decision-maker's experience, inaccurate and ambiguous. Therefore, the objective of this study is to propose an optimal supplier selection model for coffee businesses. The author used the FANP method combined with the WASPAS model, the study used secondary data including books, literatures, and published documents to have empirical knowledge base. A model test problem on supplier selection of coffee beans was performed as follows: Evaluation criteria are listed first through documentary review and interview with experts, and they are used to build a network with 5 criteria, 16 sub-criteria and 7 suppliers. After the experts answered the questionnaire, the Fuzzy ANP was used to calculate the importance of the criteria and sub-criteria and to assess the importance between the criteria. In this case, purchasing price and logistics cost are the most important criterion, followed by the technical capability, quality control and planning, etc. Such results are consistent with the fact that most businesses focus on cost, then quality, followed by global factors, supplier's profile, and service level. The results obtained from the fuzzy ANP model will be used as input data in conjunction with expert evaluation of the WASPAS model to ranking suppliers. The results of ranking suppliers from WASPAS model show that Supplier 1 (S1) is the most suitable. From the result of test, the proposed model is feasible.

The proposed FANP-WASPAS model can support more optimal decision-making because it considers based on many criteria and checks their correlation. It also considers the ambiguity, uncertainty, and subjectivity of many different decision makers and criteria experts. Therefore, the model in this study supports coffee companies to make more accurate decisions. The contribution of this research is to propose a MCDM under fuzzy environment conditions. Although the study is only applicable to the coffee industry in Vietnam, the proposed model can be adapted and applied to other industries or different countries as a reference in the multi-criteria decision making.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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