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Decision making for the selection of vegetable suppliers for foods distributors uses AHP and TOPSIS

Chintya Salwa Sabhira [1*], **Annisa Tri Wahyuni** [1], **Winnie Septianie** [1], **Martino Luis** [2]
[1] Teknik Industri, Universitas Trisakti, Jakarta, 11440
[2] Industrial Engineering, University of Exeter, United Kingdom

***Corresponding Author**: Winnie.septiani@trisakti.ac.id

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ABSTRACT

The evaluation of supplier selection is an important aspect that needs to be considered in supply chain management. The best suppliers contribute to a more efficient supply chain system. Companies operating in the food distribution sector are particularly attentive to their suppliers. One of the products that receives significant attention is spinach, a perishable item, making supplier evaluation crucial. This research aims to evaluate the supplier selection of spinach products based on several criteria, such as delivery, quality, price, service, and location. Weighting is done using the Analytical Hierarchy Process (AHP). In this case, assessment or weighting is carried out by distributing questionnaires to three respondents in the field. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method is employed to determine the rankings of each alternative. The results of this study indicate that the price criterion has the highest weight with a weight of 0.39. The recommended selected alternative is alternative 4, with the highest average value (Vi) based on the assessments of three experts. This model proves capable of addressing the issues of supplier selection evaluation, leading to the selection of alternative or supplier 4 as the spinach supplier for the food distribution company.

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1. INTRODUCTION

One strategy that a corporation can employ to optimize the quality of its products or services involves engaging in supplier selection and conducting supplier evaluations. The acquisition of suppliers who possess the ability to provide superior products or services is crucial. The supplier is needed who can provide the best products or services to face current business competition.

The growing business competition today compels companies to continuously improve and develop operational activities to produce the best products or services that can be accepted by customers, including the supply chain system[1,2]. One important part of supply chain management is selecting suppliers [3]. Customers have a strong need for superior items, thus necessitating enterprises to exert efforts in manufacturing high-quality products that are priced within the acceptable range for the public or customers. The selection of suppliers necessitates careful consideration of their respective advantages and disadvantages in order to identify the most optimal source [4].

Supplier selection will create optimal supply chain management and can have an impact on the quality of the products produced [3, 5, 6]. The supplier selection and evaluation process is expected to reduce operational costs, delivery times and product quality [7- 9]. There are several indicators in selecting suppliers, namely, product quality, information distribution, costs, reliability, and procurement systems [10].

Evaluation and selection of suppliers is very important for companies operating in the perishable product industry [11,12], especially for food products. Meanwhile, when carrying out an evaluation, environmental, social and economic aspects must be considered [13,14]. Food distribution businesses employ supplier evaluation methods to ensure the procurement of fresh items. It is crucial to prioritize this aspect in order to assist business-oriented customers in optimizing their product offerings. Spinach goods are of particular interest to the company. Spinach goods are characterized by their susceptibility to injury and limited shelf life[15]. Several factors have been identified as influential in determining the longevity of spinach. These factors include ambient temperature, physical stress, light levels, and oxygen mass [15].

In this research, an evaluation of the selection of spinach suppliers was carried out using several criteria that took into account the characteristics of the spinach product itself.

Table 1. Spinach criteria in several journals

No	Journal
1	*"A Game Theoretic Decision Model for Organic Food Supplier Evaluation in The Global Supply Chains*[16]
2	*Ranking Based on Optimal Points and Win-Loss-Draw Multicriteria Decision-Making with Application to Supplier Evaluation Problem*[17]
3	*The Ideal Criteria of Supplier Selection for SMEs Food Processing Industry*[18]
4	*Supplier Selection for Food Industry: A Combination of Taguchi Loss Function and Fuzzy Analytical Hierarchy Process* [19]
5	*Green Supplier Selection Using Fuzzy Group Decision Making Methods: A Case Study From The Agrifood Industry* [20]
6	*Application of PROMETHEE Method for Green Supplier Selection: A Comparative Result Based On Preference Functions*[21]
7	*Improving Food Supply Chain Management by a Sustainable Approach to Supplier Evaluation"*[22]

Table 2. Evaluation criteria for selecting spinach suppliers

No	Criteria	Description	References
1	Delivery	The supplier's ability to send goods on time.	1, 2, 3, 4, 5, 6,
2	Price	Product prices offered by suppliers.	1, 2, 3, 5, 6,
3	Quality	Supplier product conformity with company standards.	1, 2, 3, 4, 5, 6, 7
4	Ability to serve customer requests	Flexible supplier with changes in order volume and order time.	1, 2, 3, 5, 6
5	Location	Proximity of the supplier's location to the warehouse.	1, 3

Table 1 and Table 2 display the criteria used in this research along with the theoretical foundation. It can be observed that there are 5 criteria used, namely the supplier's ability to deliver according to the specified time[16], supplier's ability to reduce costs [17], PT XYZ operates in the food industry, making quality crucial, and thus, the primary focus of the evaluation is on the quality offered by the supplier [18], The provision of services is a crucial factor in the realm of business [21] and according to experts, location is a factor for companies. Food products have a limited shelf life, and being unable to withstand prolonged conditions necessitates quick delivery. Therefore, the company requires suppliers located close to the warehouse.

In Siti Wardah's research, one of the companies, PT Kokonako Indonesia, carried out this task. According to this research, choosing a supplier is a strategic process, particularly if that supplier will provide essential or long-term-use items [23]. In her research, AHP was used to select suppliers who were deemed capable of producing optimal results, but in this research it was carried out on non-perishable products so it did not require many criteria and took into account the age of the product.

That's what was done by Lukmandono et.al [24]. His research carried out in selecting suppliers for the manufacturing industry using AHP and TOPSIS.

This research aims to identify the criteria needed by companies in selecting and evaluating suppliers of perishable products using the Analytical Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods. AHP is known for its ability to break down complex problems into several subparts. However, AHP may be less effective when dealing with a large number of criteria and alternatives. Therefore, a combination with another method is necessary to achieve optimal results. On the other hand, TOPSIS is used to rank each alternative in the evaluation process [25 - 27]. However, in using the TOPSIS method, weights are needed in the ranking process. Therefore, the combination of AHP and TOPSIS is expected to provide accurate recommendation results. What makes this study interesting is the use of perishable products, requiring specific criteria and characteristics in selecting and evaluating spinach product suppliers.

2. METHOD

The research involved multiple stages, which were instrumental in facilitating the research process. These stages encompassed the implementation of various methods, including observations, interviews, and the distribution of questionnaires. The data obtained from the completed questionnaires was subsequently processed to yield results. In Figure 1 and Figure 2 we see examples of the use of the AHP and the TOPSIS.

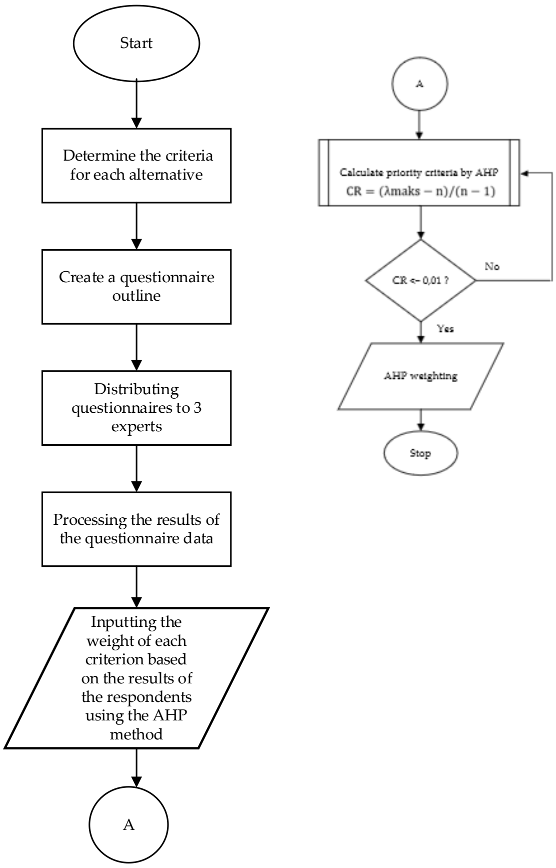

Figure 1. Criteria weighting stages using AHP

Figure 1 illustrates the sequential steps involved in the process of weighting criteria using the AHP. The initial step in AHP involves the identification and establishment of criteria for evaluating each alternative. The criteria employed in this study are derived from prior scholarly investigations. Subsequently, the framework for the questionnaire was established. The target participants consist of two procurement professionals who have responsibility for the purchasing process and supplier selection, as well as one individual who serves as the head of supply chain excellence and possesses a comprehensive understanding of the supply chain system.

The method of weighing criteria using the AHP is covered in this paper. By segmenting complex problems into several smaller sub-sections, the AHP is acknowledged as a methodology that can be used to solve them successfully [28].

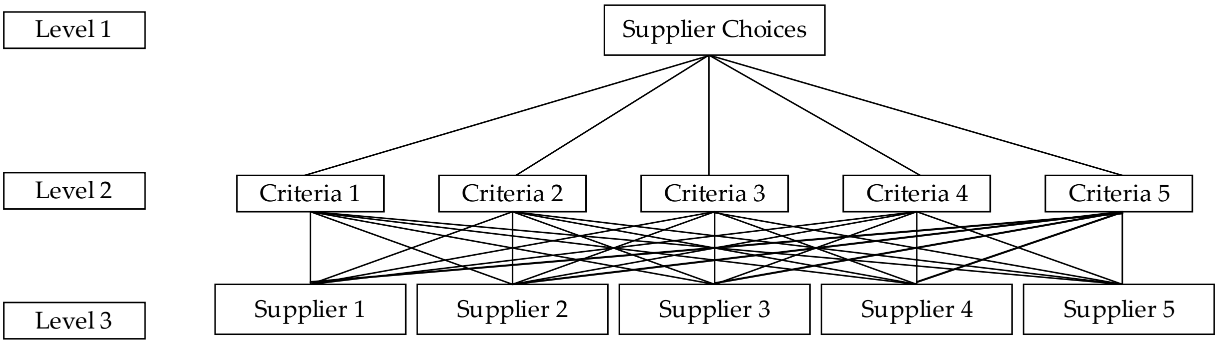

Figure 2. An illustration of the AHP implementation in the context of supplier selection.

An example of the application of the AHP technique for supplier evaluation and selection is shown in Figure 2. To help with its resolution, the challenges associated with supplier selection are broken down into many tiers [29]. Certain standards that are established by the product's attributes serve as a reference for the selection of suppliers. There are four options in this criteria.

Appropriate weights must be assigned to each criterion at the second level in order to find the best provider [30]. Experts in respective domains perform the weighting.

The next step is that the results from the respondents are processed and weighted against the criteria. Figure 3 depicts the sequence of operations required to implement the TOPSIS method. The output from the AHP is fed into the TOPSIS method.

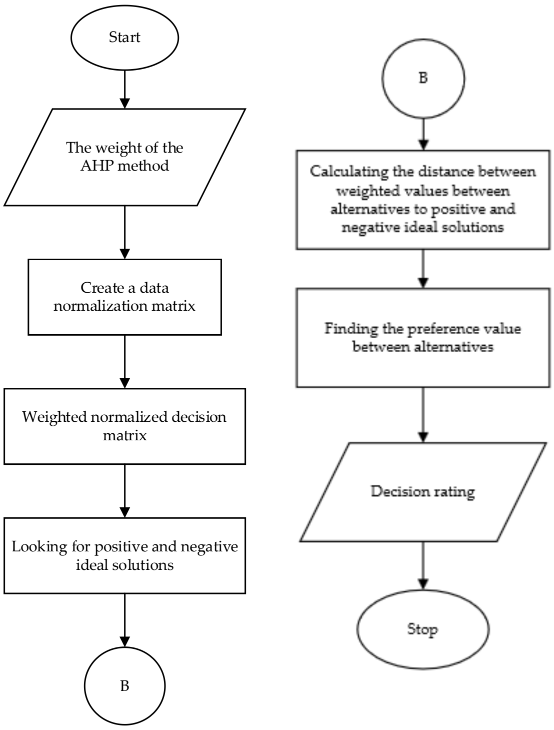

Figure 3. Alternative evaluation stages using TOPSIS

The next step is an evaluation utilising the TOPSIS technique, which stands for TOPSIS. Each potential course of action is evaluated against a common set of criteria using the TOPSIS technique. The first stage of the TOPSIS decision-making procedure is to identify a set of alternatives that are similar to the optimal choice [31]. The TOPSIS method is predicated on the assumption that the optimal decision must lie somewhere between the positive and negative optimal solutions [32, 33]. When choices are available, the best one can be selected by ranking them [34].

The following are some examples of how the TOPSIS method can be put to use:

Step 1:
Normalize data on the decision matrix with the formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{1=1}^{n} x_{ij}{}^{2}}} \tag{1}$$

x_{ij} = Numerical of the i^th alternative with j criteria

Step 2
The normalised decision matrix is multiplied by the weights in the following formula:

$$V_{ij} = w_{ij} r_{ij} \tag{2}$$

Step 3
Next, the negative ideal solution and positive ideal solution are determined

$$A^{*} = \{(\max v_{ij} \mid j \in J), (\min v_{ij} \mid j \in J'')\} \tag{3}$$

$$A^{-} = \{(\min v_{ij} \mid j \in J), (\max v_{ij} \mid j \in J')\} \tag{4}$$

J = 1, 2, 3, …, n
J′ = 1, 2, 3, …, n

Step 4
Calculate the distance from each positive and negative ideal solution
The distance to the positive ideal solution is as follows:

$$S_i^{*} = \sqrt{\sum_{J=1}^{n} (v_{ij} - v_j^{*})^2} \tag{5}$$

Meanwhile, the negative ideal solution is obtained from:

$$S_i^{-} = \sqrt{\sum_{J=1}^{n} (v_{ij} - v_j^{-})^2} \tag{6}$$

Note ➔ I = 1, 2, 3, …, n

Step 5
Next, the preference value is calculated using the following formula:

$$Ci^{*} = \frac{S_i^{-}}{S_i^{*} + S_i^{-}} = 0 \leq C_i^{*} \leq 1 \tag{7}$$

Step 6
Ranking each alternative according to its preference value.

3. RESULT AND DISCUSSION

The food distribution company has five alternatives for spinach suppliers, designated as supplier 1, supplier 2, supplier 3, supplier 4 and supplier 5. When choosing suppliers for perishable products, many theoretical frameworks are employed to establish criteria for selection. This action was undertaken in response to the company's incurred losses, which were mostly attributed to the delivery of products in a suboptimal state, resulting in a significant number of customer grievances.

3.1 Criteria Weighting with AHP

Three experts or responders from PT XYZ—two from the procurement division and one from the supply chain division—are given questionnaires to complete in order to evaluate the weight and significance of each choice. This process creates a comparison matrix between the criteria. Table 3, Table 4, Table 5 present the comparative matrix illustrating the comparison between criteria. The matrix is utilized to ascertain the preeminent criteria in the process of selecting multiple options. After, the process of data normalization is carried out, which involves figuring out how much weight to give each criterion until the data is in a state of coherence. In the event of inconsistency, it is imperative to reacquire data from participants until a state of consistency is achieved. Subsequently, the data that has exhibited consistent patterns is subjected to an aggregate computation employing the geometric mean for each criterion

Table 3. Matrix for comparing criteria Respondent 1

	Quality	**Price**	**Delivery**	**Service**	**Location**
Quality	1,00	0,33	4,00	2,00	6,00
Price	3,00	1,00	5,00	4,00	6,00
Delivery	0,20	0,20	1,00	0,33	3,00
Service	0,50	0,25	3,00	1,00	4,00
Location	0,17	0,17	0,17	0,25	1,00

Table 4. Matrix for comparing criteria Respondent 2

	Quality	**Price**	**Delivery**	**Service**	**Location**
Quality	1,00	0,33	5,00	6,00	3,00
Price	3,00	1,00	2,00	5,00	4,00
Delivery	0,20	0,50	1,00	2,00	0,33
Service	0,16	0,20	0,50	1,00	0,25
Location	0,33	0,25	3,00	4,00	1,00

Table 5. Matrix for comparing criteria Respondent 3

	Quality	**Price**	**Delivery**	**Service**	**Location**
Quality	1,00	0,33	5,00	5,00	4,00
Price	3,00	1,00	4,00	5,00	2,00
Delivery	0,20	0,25	1,00	2,00	0,50
Service	0,20	0,20	0,50	1,00	0,30
Location	0,25	0,50	2,00	3,00	1,00

Table 6, Table 7, Table 8, Table 9, Table 10 present a comprehensive compilation of all criteria. Subsequently, the process of normalization and weight computations is conducted in order to derive the value of the consistency ratio. The retrieval of inconsistent data necessitates a subsequent attempt. Using weights will make it easier to assess the consistency of data.

Table 6. Aggregation of the geometric mean of quality criteria

	Quality			
	R 1	**R2**	**R 3**	**Geomean Value**
Quality	1,00	1,00	1,00	1,00
Price	3,00	3,00	3,00	3,00
Delivery	0,25	0,20	0,20	0,22
Service	0,50	0,17	0,20	0,26
Location	0,17	0,33	0,25	0,24

Table 7. Aggregation of the geometric mean of price criteria

	Price			
	R 1	**R2**	**R 3**	**Geomean Value**
Quality	0,33	0,33	0,33	0,33
Price	1,00	1,00	1,00	1,00
Delivery	0,20	0,50	0,25	0,29
Service	0,25	0,20	0,20	0,22
Location	0,17	0,25	0,50	0,28

Table 8. Aggregation of the geometric mean of delivery criteria

	Delivery			
	R 1	**R2**	**R 3**	**Geomean Value**
Quality	4,00	5,00	5,00	4,64
Price	5,00	2,00	4,00	3,42
Delivery	1,00	1,00	1,00	1,00
Service	3,00	0,50	0,50	0,91
Location	0,33	3,00	2,00	1,26

Table 9. Aggregation of the geometric mean of service criteria

	Service			
	R 1	**R2**	**R 3**	**Geomean Value**
Quality	2,00	6,00	5,00	3,91
Price	4,00	5,00	5,00	4,64
Delivery	0,33	2,00	2,00	1,10
Service	1,00	1,00	1,00	1,00
Location	0,25	4,00	3,00	1,44

Table 10. Aggregation of the geometric mean of location criteria

	Location			
	R 1	**R2**	**R 3**	**Geomean Value**
Quality	6,00	3,00	4,00	4,16
Price	6,00	4,00	2,00	3,63
Delivery	3,00	0,33	0,50	0,79
Service	4,00	0,25	0,33	0,69
Location	1,00	1,00	1,00	1,00

3.2 Evaluation of Alternatives with TOPSIS

In this research, an alternative approach for evaluating and determining the ultimate ranking was employed: the TOPSIS method in the sequence of accomplishments. TOPSIS rankings take into account both preference and weight when making their determinations. The AHP calculations generated the weights given to each criterion, which would be utilised as input for the TOPSIS technique. Through recalculations, the TOPSIS approach will determine the ranking or prioritization of each alternative in relation to the criteria, ultimately identifying the most favourable alternative. In order to facilitate calculations, a number of annotations have been implemented, as outlined below:

S1 = Supplier 1 C1 = Criteria 1 (Quality)
S2 = Supplier 2 C2 = Criteria 2 (Price)
S3 = Supplier 3 C4 = Criteria 3 (Delivery)
S4 = Supplier 4 C5 = Criteria 4 (Service)
S5 = Supplier 5 C6 = Criteria 5 (Location)

The scale used to access each supplier in this research is 1 - 5:
Very Good = 5
Good Enough = 4

Good = 3
Not Good = 2
Very Not Good = 1

Table 11 shows the appropriateness ranking for each proposal for each criterion. The AHP method is used in this study's TOPSIS computation to establish the weights of the criteria. Table 12 contains the specific annotations that were used in the TOPSIS computation.

Table 11. Rank the suitability of each alternative on each criterion

Alternative	Criteria				
	C1	**C2**	**C3**	**C4**	**C5**
S1	4	3	5	4	4
S2	4	3	3	4	4
S3	4	3	3	3	4
S4	4	4	4	5	4
S5	3	3	4	4	3

Table 12. Weight of each criterion

C1	C2	C3	C4	C5
0,35	0,39	0,08	0,08	0,10

Next, data normalization was carried out by squaring the ranking of each alternative in Table 11 to obtain data normalization results as in Table 13.

Table 13. Normalized decision matrix Respondent 1

Alternative	Criteria				
	C1	**C2**	**C3**	**C4**	**C5**
S1	16	9	25	16	16
S2	16	9	9	16	16
S3	16	9	9	9	16
S4	16	16	16	25	16
S5	9	9	16	16	9

The decision matrix resulting from the ranking of each choice against the criteria is presented in Table 13. Subsequently, the process of data normalization is applied to the weights provided in Table 13. The outcomes of this normalization process are presented in Table 14, which displays the choice matrix. Furthermore, Table 15 presents the positive ideal solution and the negative ideal solution.

Table 14. Respondent 1-weighted decision matrix

	0.164	0.162	0.046	0.035	0.047
	0.164	0.162	0.028	0.035	0.047
R =	0.164	0.162	0.028	0.026	0.047
	0.164	0.216	0.037	0.044	0.047
	0.123	0.162	0.037	0.035	0.035

Table 15. Positive and negative ideal solutions Respondent 1

	y1	**y2**	**y3**	**y4**	**y5**
A+	0,164	0,216	0,046	0,044	0,047
A-	0,123	0,162	0.028	0,026	0,035

The weighted decision matrix from respondent 1 is presented in Table 14. The resultant matrix is derived through the process of multiplying the decision matrix with the respective weight matrices. Table 15 displays the ideal solutions (both positive and negative) provided by Respondent 1. The purpose of determining these answers was to ascertain the highest and lowest values for every alternative and criterion. The negative ideal solution is found to be 0.036, and the minimum value for the positive ideal solution is set at 0.044. Then, as shown in Table 16, Table 17, Table 18, we determine the distance metric between the positive ideal solution and the positive ideal solution.

Table 16, Table 17, Table 18 display the recorded measurements of the spatial separation between the positive ideal solution and the negative ideal solution for each individual participant. Based on the responses provided by respondents 1 and 2, it can be observed that supplier or option 4 exhibits the highest preference value, with corresponding values of 0.889 and 0.512. This is followed by alternative 1, which demonstrates preference values of 0.461 and 0.469, as reported by the same respondents. In the case of respondent 3, it is evident that alternative 3 exhibits the highest preference value of 0.842, while alternative 4 follows closely with a preference value of 0.540. The process of selecting the supplier involved conducting an average calculation based on the responses provided by three individuals. The TOPSIS calculation is conducted one by one to determine the weights of each respondent, which have been obtained from the Analytic Hierarchy Process (AHP) results.

Table 16. Respondent 2 preference value

Alternative	Ideal Positive Solution	Ideal Negative Solution	Vi	Rank
S1	0,055	0,047	0,461	2
S2	0,058	0,044	0,431	3
S3	0,06	0,043	0,417	4
S4	**0,009**	**0,072**	**0,889**	**1**
S5	0,07	0,013	0,157	5

Table 17. Ideal solutions in the positive and negative contexts Respondent 2

Alternative	Ideal Positive Solution	Ideal Negative Solution	Vi	Rank
S1	0,043	0,038	0,469	2
S2	0,057	0,011	0,162	3
S3	0,057	0,008	0,123	4
S4	**0,04**	**0,042**	**0,512**	**1**
S5	0,058	0,000	0,000	5

Table 18. Ideal solutions in the positive and negative contexts Respondent 3

Alternative	Ideal Positive Solution	Ideal Negative Solution	Vi	Rank
S1	0,052	0,038	0,422	4
S2	0,056	0,037	0,398	5
S3	**0,012**	**0,064**	**0,842**	**1**
S4	0,040	0,047	0,54	2
S5	0,046	0,045	0,495	3

The average Vi value of the three responders is presented in **Error! Not a valid bookmark self-reference.**. Supplier 4 possesses the highest average Vi value, which is recorded at 0.647. In this particular scenario, it can be inferred that supplier 4 possesses the highest Vi value, hence rendering it a viable selection.

Table 19. Average Vi

	Ave Vi	Rank
V1	0,451	3
V2	0,33	4
V3	0,461	2
V4	**0,647**	**1**
V5	0,217	5

The main factor influencing this decision is that option 4 shows a comparatively significant weight for each of the four criteria, with the highest weight going to criterion 4, which is service. When compared to the other four options, option 4 offers a higher calibre of service.

4. CONCLUSION

Suppliers play a crucial role within the supply chain and warrant careful consideration. The assessment of supplier selection will exert a significant influence on both the purchasing department and the clientele. The evaluation of suppliers holds significant importance for firms operating within the food industry. This article discusses the challenges associated with multi-criteria decision-making while considering supplier selection.

The AHP and TOPSIS methodologies are viable approaches for addressing this issue. The AHP is recognized for its capability to decompose intricate issues into several sub-problems, thereby facilitating their resolution. The TOPSIS approach is capable of generating the optimal alternative and possesses a user-friendly interface. The efficacy of this model has been demonstrated in addressing the issue of supplier selection evaluation. It identifies alternative 4 or supplier 4 as the optimal choice for supplying spinach goods based on a set of predetermined criteria.

This study has the benefit of focusing on the attributes of products that are susceptible to harm and possess a finite lifespan. The criteria employed in this study are derived from the existing literature pertaining to the management of perishable goods. In addition, the participants involved in this study consist of supply chain professionals who possess a comprehensive understanding of the food or perishable products supply chain. This deliberate selection of respondents aims to enhance the specificity and relevance of the research findings. The revival of research efforts can be achieved by the deliberate consideration of green suppliers or suppliers that prioritize environmental sustainability. This research is expected to assist future studies in developing supplier selection for perishable products.

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