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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

Green Supplier Selection in Food Industry: Fuzzy AHP Based Hybrid GRA and Axiomatic Design Approach

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Abstract

Today, most consumers are more conscious and sensitive about environmental sensitivity. The development of technology and the increasing awareness of people have led businesses to produce products in line with the "green" preferences of consumers in order to sustain their existence. In this context, selecting the most suitable supplier has gained importance. The concept of a green supply chain covers all activities from raw material procurement to production, logistics to marketing, and recycling to re-inclusion in the production cycle throughout the life cycle of products. Green supply chain management applies to all sectors, positively impacting businesses and the environment. One of these sectors is the food sector. Food is an essential consumption need that increases with the rising population. This study addresses the problem of green supplier selection for an integrated meat plant in the red meat sector in Sakarya. In this multi-criteria decision-making (MCDM) problem, two different methods, Gray Relational Analysis (GRA) and Axiomatic Design (AD), have been applied separately for supplier selection. In the problem, both the needs and demands of the consumer and the expectations of the producer have been evaluated, and the most appropriate criteria for the sector have been created by considering expert opinions because of literature research. However, since the importance level of each of these criteria is different, the Fuzzy Analytic Hierarchy Process (FAHP) method has been used to calculate the criteria weights. As a result of the study, the best green supplier ranking has been created for the company after determining which criterion is more critical and evaluating both methods. According to the results obtained in BAHP, the most essential criterion is "quality," which is 0.27. The results evaluated in terms of green criteria show that the most suitable supplier is the S2 supplier in both hybrid applications and the S4 supplier in the last place. As a result of the research, it has been observed that the supplier companies are susceptible to their green policies, but some areas need to be improved.

Keywords: Green supply chain, Fuzzy analytic hierarchy process, Gray relational analysis, Axiomatic design

I. INTRODUCTION

In today's world, with increasing environmental awareness, individuals and societies have become more sensitive to environmental sustainability. This increased sensitivity has directly affected consumers' product selection and consumption habits and forced companies to be more selective in their production and supply processes. Competition among firms has become incredibly intense, making adopting environment-friendly policies necessary. This situation requires companies to develop environmentally sensitive strategies to sustain their existence. Sustainable supply chain practices in developed and developing countries are significant for environmentally responsible companies. In accordance with global trends, the concept of "sustainability" has also become increasingly crucial in Türkiye. According to research, consumers are affected by the sustainability approach of brands and are inclined towards more sustainable brands by customizing their consumption habits accordingly. Consumer behavior in recent years reveals that many consumers (85%) have adopted sustainable shopping habits, and 60% consider sustainability as an essential criterion in their purchasing decisions [1]. Companies' efforts to increase customer satisfaction and performance are not limited to their processes. It is also directly related to the performance of the suppliers they cooperate with.

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The rising environmental awareness and global pressures on sustainability require companies to consider their environmental responsibilities while evaluating their suppliers [2]. Therefore, a supplier's environmentally sensitive production and service processes increase the chance of preference.

Companies prioritize environmental sustainability criteria in supplier selection and can fulfill their ecological responsibilities and achieve competitive advantages by creating a green brand identity in the sight of customers. This leads to an increase in customer loyalty in the long term and positively affects the company's overall performance. Thus, each link of the supply chain contributes to the company's sustainability goals, helping to create a more holistic and sustainable business model [3,4].

This study makes a unique contribution to the literature by examining the issue of green supplier selection, which is usually addressed through durable and long shelf-life products, in the context of sensitive products like red meat, which has a high risk of spoilage. In this context, the study aims to contribute theoretically to literature by integrating industry-specific elements like food safety and cold chain sustainability into green supplier selection criteria. This study also examines the process of determining the most suitable suppliers among seven suppliers of a company in the food sector in line with customer demands and sustainability policies. In the second part, literature research on green supplier selection is presented. The third section describes the methods used. The fourth section presents the results.

II. LITERATURE REVIEW

The use of multi-criteria decision-making (MCDM) methods in the supplier selection process is an instrument that facilitates the correct and sustainable supplier selection of enterprises. In supplier selection, different multi-criteria decision-making methods such as AHP, TOPSIS, PROMETHEE, SWARA, WASPAS, ANP, VIKOR, and ELECTRE have come to prominence in the literature and have been found to provide successful results in complex supplier selection processes [5]. In supplier selection problems, MCDM methods have seen many applications in several sectors.

Supçiller and Çapraz (2011) have evaluated AHP and TOPSIS methods with criteria such as cost, quality, and delivery; Çakın and Özdemir (2013) have used ANP and ELECTRE methods in the automotive industry, while Alakaş et al. (2019) has used AHP, TOPSIS and VIKOR methods in the health sector. Ergül (2018) evaluated FAHP, GIA, and MOORA methods in the food sector, while Demirci (2020) focused on the AT technique in logistics supplier selection. Adalı and Işık (2017) have conducted supplier selection by applying SWARA and WASPAS methods in the textile industry [6–9]. Opricovic, in the study aimed at determining the consequences of choosing the right supplier for firms, found that the compliance of suppliers to the business improves trust and loyalty to them [10]. Kılınç has emphasized that in the past years, factors such as quality and cost have been the priorities in traditional supplier selection problems. Still, today, in addition to these factors, all kinds of studies, including environmental activities, have gained importance in sustainable supplier selection [11].

Legal regulations and the increasing environmental sensitivity of customers have encouraged businesses to reorganize their supply chain activities to minimize adverse environmental impacts. Green supplier selection is essential for green supply chain management in this context. In Yin et al.'s study, supplier selection for a construction company in China has been analyzed, and the main criteria including sustainable business potential, green operations, green technology, and sub-criteria regarding environmentally friendly materials, green logistics, green manufacturing, green R&D innovation, green certification have been used [13]. Batur and Özyörük discussed the importance of infant food in human health and made a green supplier selection for an infant formula manufacturer using the AD method [14]. Ardalı analyzed the green supplier selection problem for a company in the automotive industry by using the FAD method weighted with FAHP and used green design, green logistics, green production, green purchasing and green reverse logistics criteria [15]. Soyer and Türkay used the ANP method in the green supplier selection model developed in the home appliance industry and identified five main criteria for the model: green competencies, environmental effectiveness, organizational factors, costs and green image [16].

Human health is adversely affected by several reasons, including environmental pollution, deterioration of the ecological system, and climate change. Societies, states, and producers take specific measures to ensure this balance. In the food industry, it is highly recommended to adopt processes that meet consumer demands in the production, processing, and consumption stages and, at the same time, do not cause harm to the natural balance [17].

Recent studies have highlighted that businesses have an increasing tendency to work with environmentally friendly suppliers and that this selection plays a critical role in sustainable supply chain management. The studies conducted in sustainable supplier selection in diverse fields are analyzed, and selected methods and criteria in the literature are given in Table 1.

Table 1. Methods and criteria from literature

Author	Year	Industry	Criteria	Methodology
[18]	2015	Automotive	Price, Quality, Technology, Resource Consumption, Pollution Generation, Management Commitment	Analytic Network Process (ANP) Gray Relational Analysis (GRA)
[19]	2022	Health Care	Green Production, Green Packaging Green Design, Green Distribution Green Procurement, Green Storage Reverse Logistics	AHP, TOPSIS
[20]	2017	Nutrition	Financial Stability, Environmental Management Systems, Waste Disposal Program, Management Commitment, Quality Control Systems, Manufacturing, Plant, Reverse Logistics	Quality Function Deployment (QFD) Complex Proportional Assessment (COPRAS) Multi-objective Optimization Based on Ratio Analysis (MOORA)
[21]	2015	Plastic	Quality, Price, Delivery Capability Service, Environmental Management Corporate Social Responsibility Pollution Control, Green Product Green Image, Green Innovation Hazardous Material Management	Fuzzy Axiomatic Design (FAD)
[15]	2020	Automotive	Green Design, Green Logistics, Green Logistics, Green Manufacturing, Green Procurement, Green Reverse Logistics	Fuzzy Analytic Hierarchy Process (FAHP) Axiomatic Design (AD)

It has been observed that different methods have been applied in literature on the subject, and it has been determined that fuzzy methods, which have become prominent in recent years, are preferred and produce more accurate results. Consequently, two different hybrid methods (WFGRA and WFAD) have been proposed by using fuzzy logic and multi-criteria decision-making techniques together in the solution process of the problem. This study aims to provide a new perspective to the literature by examining the issue of red meat supply, which has a high risk of spoilage during supply in the food sector, which has not been sufficiently addressed before. The paper is a systematic study that evaluates supplier selection criteria that prioritize environmental sustainability for companies in the food sector.

III. MATERIALS AND METHODS

In many areas of life, there are situations where a correct decision is needed. The decision-making process, an important step, consists of the steps in Figure 1. It is recommended to implement this process in a planned and effective manner for a correct decision.

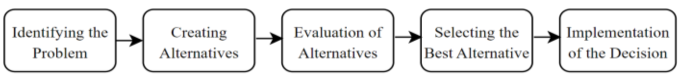

Figure 1. Decision Making Process

One of the decision analysis techniques is MCDM methods. As a field of operations research, it is one of the preferred decision analysis methods. These methods are analytical methods designed to be used with quantitative and/or qualitative criteria to identify the best alternatives. In this study, for a red meat retailing company that needs to make a sustainable supplier selection, seven supplier alternatives have been evaluated using WFGRA and WFAD methods through five criteria determined by experienced experts. The steps followed in the study are as shown in Figure 2.

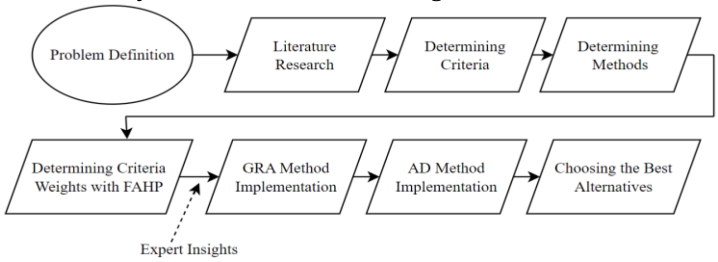

Figure 2. Application Model Flow Chart

In this study, the green supplier selection problem for an integrated meat plant operating in Sakarya is considered. There are five different criteria and seven suppliers in the problem. The criteria have been determined by prioritizing the suitable criteria for the food sector according to the literature studies and by taking the opinions of the experts in the company. The criteria in the problem are listed as follows. Among these criteria, quality (C1), green image (C2), use of environmentally friendly technology (C3) and waste management (C4) are verbal criteria and have been evaluated by the experts in the company through a questionnaire, fuel use (C5) is a numerical criterion and has been taken as estimated data from the suppliers through the integrated meat plant. Before starting the implementation steps, firstly, a survey has been conducted to convert the evaluations of seven experts in the company into quantitative data for this green supplier selection problem in the red meat sector and an initial evaluation matrix has been created as shown in Table 2. The initial matrix has been created to evaluate the data, classified as "Very Weak Poor (VP)", "Poor (P)", "Moderately Poor (MP)", "Average (F)", "Moderately Good (MG)", "Good (G)", and "Very Good (VG)".

Table 2. Initial expert opinion supplier evaluation matrix

Criteria	Expert	Supplier						
		S1	S2	S3	S4	S5	S6	S7
	E1	G	G	VG	G	MG	G	MG
	E2	G	VG	VG	G	G	G	G
	E3	MG	G	G	G	MG	G	MG
Quality	E4	G	VG	G	MG	MG	MG	MG
	E5	G	VG	VG	G	G	G	MG
	E6	MG	VG	G	MG	MG	VG	G
	E7	G	G	VG	G	G	G	MG
	E1	MG	MG	MG	F	G	G	MG
	E2	F	MG	MG	F	MG	G	MG
	E3	MG	G	G	MG	MG	MG	MG
Green Image	E4	F	G	MG	F	G	G	F
	E5	F	MG	G	MG	G	G	MG
	E6	F	MG	MG	F	MG	MG	F
	E7	MG	G	MG	MG	MG	MG	F
	E1	MG	G	MG	F	MG	MG	G
	E2	F	MG	MG	F	MG	F	MG
Eco-friendly Technology Usage	E3	MG	MG	F	MG	MG	F	MG
	E4	MG	MG	MG	F	F	MG	MG
	E5	MG	G	MG	MG	MG	F	G
	E6	F	MG	MG	F	MG	F	G
	E7	MG	MG	F	MG	F	MG	MG
	E1	MG	F	MG	F	G	MG	G
	E2	F	F	MG	MG	G	MG	G
	E3	F	F	G	MG	G	G	G
Fuel Utilization	E4	MG	MG	G	MG	G	MG	G
	E5	MG	F	G	F	MG	MG	MG
	E6	MG	F	MG	F	G	MG	G
	E7	F	F	MG	MG	MG	MG	MG

3.1. Fuzzy AHP Implementation (FAHP)

AHP is a method frequently used in decision making problems. Nevertheless, reaching the right decision in criteria evaluation and decision-making problems is not always sufficient. For this purpose, AHP and fuzzy logic have been combined, and the FAHP process has emerged. The solution phases are as follows.

Creation of a pairwise comparison matrix for the criteria as Eq. 1 and 2.

The comparison between the two criteria has been performed by assigning the numbers corresponding to the linguistic expression using the fuzzy importance levels shown in Table 3, which Akyüz uses for linguistic expressions [22]. For the criterion evaluation, the opinion of an experienced expert in the company is in question.

Table 3. Fuzzy importance levels

Importance Level	Fuzzy Scale	Corresponding Scale
Equally Important	1, 1, 1	1, 1, 1
A Few More Important	2/3, 1, 3/2	2/3, 1, 3/2
More Important	3/2, 2, 5/2	2/5, 1/2, 2/3
Very Important	5/2, 3, 7/2	2/7, 1/3, 2/5
Absolutely Important	7/2, 4, 9/2	2/9, 1/4, 2/7

Step 1: The fuzzy geometric mean is calculated with the help of geometric mean as Eq 3.

$$r_i = \sqrt[n]{a_{i1} \otimes a_{i2} \dots \otimes a_{in}} \tag{3}$$

Step 2: The fuzzy weights for each criterion are calculated as Eq 4.

$$\tilde{w}_i = r_i \otimes (r_1 + r_2 \dots + r_n)^{-1} \tag{4}$$

Step 3: A weight calculation is created for each criterion as Eq 5.

$$w = \frac{[(u_{wi} - l_{wi}) + (m_{wi} - l_{wi})]}{3} + l_{wi} \tag{5}$$

3.2. Gray Relational Analysis Implementation

In gray system theory, white represents known data, black represents unknown data, and gray represents partially known or predicted data. GRA is used in these uncertainty conditions. Before the implementation steps of the GRA, the criteria are separated into numerical and verbal, and the verbal expressions are converted into gray number equivalents, as shown in Table 4 [24]. This verbal evaluation includes the opinions of seven experts who have experience evaluating all suppliers and are employed in different departments. The solution phases are as follows.

Table 4. Gray number equivalents for verbal criteria

Rating	Abbreviation	Gray Number Equivalent
Very Weak Poor	VP	0-10
Poor	P	10-30
Moderately Poor	MP	30-40
Average	F	40-50
Moderately Good	MG	50-60
Good	G	60-90
Very Good	VG	90-100

Step 1: Calculation of the data set and creation of the decision matrix as Eq. 6 and 7.

$$x_i = (x_i(j), \dots, x_i(n)), \quad i = 1,2,\dots,n \text{ and } j = 1,2,\dots,n \tag{6}$$

$$X = \begin{matrix} x_1(1) & x_1(1) & x_1(n) \\ x_2(1) & x_2(1) & x_2(n) \\ x_m(1) & x_m(1) & x_m(n) \end{matrix} \tag{7}$$

Step 2: Creation of the reference series and comparison matrix.

Where $(x_0(j))$, represents the best value of criterion j among the normalized criteria as Eq. 8.

$$x_i = (x_0(j)) \text{ and } j = 1,2,\dots,n \tag{8}$$

Step 3: Normalizing the decision matrix and creating the normalization matrix: The normalization process varies according to the way the data affects the objective function. That is, if a larger value of the series (max) has a positive effect on the objective, the normalization process as Eq 9.

$$x_i^* = \frac{x_i(j) - \min(x_i(j))}{\max(x_i(j)) - \min(x_i(j))} \tag{9}$$

Normalization if a minimum series value (min) positively affects the objective as Eq. 10.

$$x_i^* = \frac{\max(x_i(j)) - x_i(j)}{\max(x_i(j)) - \min(x_i(j))} \tag{10}$$

Normalization of the series values according to an optimum value as Eq. 11 and 12.

$$x_i^* = \frac{|x_i(j) - x_0(j)|}{\max(x_i(j)) - x_0(j)} \quad (11)$$

$$X^* = \begin{matrix} x_1^*(1) & x_1^*(2) & x_1^*(n) \\ x_2^*(1) & x_2^*(2) & x_2^*(n) \\ x_m^*(1) & x_m^*(2) & x_m^*(n) \end{matrix} \quad (12)$$

Step 4: Creating the absolute value table as Eq. 13 and 14.

$$\Delta_{0i} = |x_0^*(j) - x_i^*(j)|, \; i = 1,2,\dots,n \quad ve \quad j = 1,2,\dots,n \quad (13)$$

$$\Delta_{0i} = \begin{matrix} \Delta_{01}(1) & \Delta_{01}(2) & \Delta_{01}(n) \\ \Delta_{02}(1) & \Delta_{02}(2) & \Delta_{02}(n) \\ \Delta_{0m}(1) & \Delta_{0m}(2) & \Delta_{0m}(n) \end{matrix} \quad (14)$$

Step 5: Creating the gray relational coefficient matrix as Eq. 15 and 16.

$$\gamma_{0i}(j) = \frac{\Delta_{min} + \zeta\,\Delta_{max}}{\Delta_{0i}(j) + \zeta\,\Delta_{max}} \quad (15)$$

$$\Delta_{max} = \max_i + \max_j \Delta_{0i}(j) \quad ve \quad \Delta_{min} = \min_i + \min_j \Delta_{0i}(j) \quad (16)$$

Step 6: Calculation of gray relational degrees: Gray relational degrees are calculated in two different ways depending on whether the criteria are of equal or different importance. If of equal importance as Eq. 17.

$$r_{0i} = (1/\mathrm{n})\frac{1}{n}\sum_{j=1}^{n} \gamma_{0i}(j) \quad ve \quad i = 1,2,\dots,m \quad (17)$$

If the criteria weigh different as Eq. 18.

$$r_{0i} = \sum_{j=1}^{n} [w_i(j).\gamma_{0i}(j)] \quad ve\; i = 1,2,\dots,m \quad (18)$$

3.3. Axiomatic Design (AD) Implementation

The aim of AD, developed by Suh, is to reduce the random search space and time for designers, minimizing erroneous and repetitive processes and leading the designer to a solution [25]. In certain cases, it is not possible to reach exact data in this method used for ranking and decision making. In similar cases, researchers have proposed the FAD method.

A functional need Fi whose information content is expressed as Ii, has a probability as p of fulfillment. Another name for this equation is the Shannon. Equation I_i calculation as Eq. 19.

$$\mathrm{I}_i = \log_2(1/\mathrm{p}_i) \quad (19)$$

Logarithmic expressions are used to generate information content. Given F_i, the information content is equal to the sum of these probabilities as Eq. 20.

$$\mathrm{I}_{system} = \sum_{i=1}^{n} \log_2(1/\mathrm{p}_i) \quad (20)$$

The probability of the realization of F_i is formulated by calculating the design range dr and the system range sr for the design that provides the functional requirements F_i. When the system probability distribution function of an F_i is uniform, the region where the design range is determined by the designer and the system range realized by the system intersect is called the common area and this area is the solution area [26] Figure 3 shows these areas.

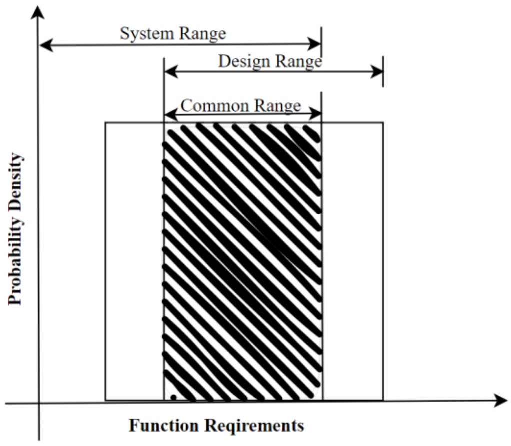

Figure 3. Probability distribution of design parameter

P_i, which is the probability of occurrence if the system probability distribution function is uniform as Eq. 21.

$$\mathrm{P}_i = \frac{Common\ Range}{System\ Range} \quad (21)$$

Information content as Eq. 22.

$$\mathrm{I}_i = \log_2 \frac{System\ Range}{Common\ Range} \quad (22)$$

The information content of P_i if F_i is a continuous random variable as Eq. 23.

$$\mathrm{P}_i = \int_{dr_1}^{dr_u} P_s(F\mathrm{i}_i)dF i_i \quad (23)$$

The probability of realization of the system range is derived by calculating the integral of the probability density function. In Figure 4, the system range is defined [27], and the probability density function is shown according to the functional requirements.

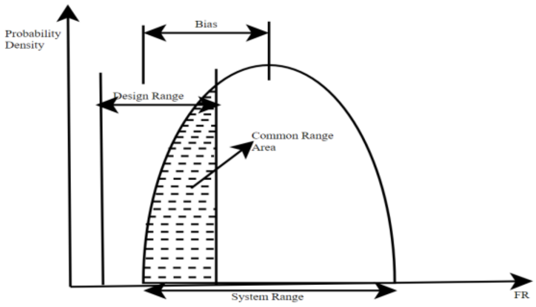

Figure 4. Common area of system range and design range

The region where only F_i is achieved is represented as the common area cr between the design range and the system range. Consequently, the area of the system range divided by the area of the common range is equal to the probability of obtaining the target set for the design as Eq 24.

$$I = \log_2(A_{sr}/A_{cr}) \quad \textbf{(24)}$$

The area of the system range is denoted by A_{sr} and the area of the common range is denoted by A_{cr}, shown hatched with lines in Figure 4.

$$I = \log_2(1/A_{cr}) \quad \textbf{(25)}$$

Calculation of information content as a conclusion as Eq 26.

$$I = \log_2\left(\frac{Triangular\ Fuzzy\ Sys.Design}{Common\ Area}\right) \quad \textbf{(26)}$$

In the AD, the weight of each criterion is generally considered equal. However, since each criterion has a different weight value, the following expression is used to calculate the information content. This structure is expressed as Eq. 27.

$$I_{ij} = \begin{cases} \left[log_2\left(\frac{1}{p_{ij}}\right)\right]^{\frac{1}{w_j}} & , \quad 0 \le I_{ij} \le 1 \\ \left[log_2\left(\frac{1}{p_{ij}}\right)\right]^{\frac{1}{w_j}} & , \quad I_{ij} \ge 1 \\ w_j & , \quad I_{ij} = 1 \end{cases} \quad \textbf{(27)}$$

IV. RESULTS

The gray relational coefficients considering the criteria weights have been found as shown in Table 5. The S2 supplier, with the highest coefficient value, has been found to be the best supplier alternative.

Table 5. Weighted gray relational coefficient (WGRC)

	C1Max	C2 Max	C3 Max	C4 Max	C5 Min	GRC	Rank
$\mathbf{w_i}$	0.2711	0.2494	0.1274	0.2181	0.134	-	-
S1	0.429	0.333	0.385	0.381	0.375	0.382	6
S2	1	0.75	0.714	0.333	0.667	0.711	1
S3	1	0.6	0.385	0.667	0.545	0.688	2
S4	0.429	0.333	0.333	0.381	0.333	0.37	7
S5	0.36	0.75	0.385	1	0.857	0.667	4
S6	0.529	1	0.333	0.5	1	0.678	3
S7	0.333	0.353	1	1	0.462	0.586	5

Calculation results according to weighted fuzzy axiomatic design (WFAD) method: S2 supplier with the lowest total information content has been found to be the best supplier alternative. The results of total information content according to WFAD method are as shown in Table 6.

Table 6. WFAD knowledge content results

	Quality	Green Image	Eco-friendly Technology Usage	Waste Management	Fuel Utilization	Total	Rank
S1	0.05428	1.0988	0.147	1.0064	0.055	2.3614	5
S2	0.039	0.01246	0.00000582	1.0064	0.00451	1.06238	1
S3	0.039	1.0988	0.147	0.00215	0.00000277	1.28695	3
S4	0.05428	1.0988	0.147	1.0064	0.134	2.40448	7
S5	1.2309	0.01246	0.147	0.00215	1.0472	2.43971	6
S6	0.05428	0.01246	0.147	1.0064	0	1.22006	2
S7	1.2309	1.0988	0.00000582	0.00215	0.0183	2.3505	4

This study evaluates the criteria that are effective in supplier selection. It consists of five criteria (quality, green image, use of environmentally friendly technology, waste management, fuel use) that consumers demand, supports the company's sustainable policies, is regarded as adequate by experts, and is also preferred in literature.

According to the criteria weights determined by FAHP, the essential criterion is "quality." Therefore, it would be appropriate for suppliers with low sustainability performance to prioritize the quality criterion. The best supplier ranking for the two different methods applied is as shown in Table 7.

Table 7. Rankings according to the applied methods

Rank	WFGRA	WFAD
1	S2	S2
2	S3	S6
3	S6	S3
4	S5	S7
5	S7	S1
6	S1	S5
7	S4	S4

According to Table 7, supplier S2 is seen as the best alternative in both hybrid methods. Both hybrid methods found the lowest sustainable supplier performance as an S4 supplier.

V. CONCLUSION AND DISCUSSION

Green image is an important criterion that directly affects consumer preferences, provides a competitive advantage, and increases trust in the brand. Green image is a strategic element that affects not only the present but also the future success of a company. Waste management is highly essential in terms of the prevention of environmental pollution, protection of natural resources, and human health. In addition, companies that are successful in waste management also have economic advantages. The use of environmentally friendly technology: even though companies do not prefer it due to its costs, its importance has been understood in recent years, and its benefits are high with the long-term savings. Minimizing fuel use, reducing carbon emissions, and improving air quality are essential criteria for cost savings.

The information observed in the study emphasizes how sustainable supplier selection is significant for companies and societies. The findings of this study provide a basis for sustainable supplier selection and may offer new approaches for a more detailed examination of the field. In addition, the cost savings to be achieved through these and similar practices are expected to contribute to the national economy.

This study proposes an integrated model to contribute to the sustainability-based decision-making process in the food sector, especially in the supply of perishable products like red meat. The criteria weights determined by fuzzy AHP are supported by GRA and AD methods for a more comprehensive supplier evaluation. The results show that the evaluation of sector-specific critical factors including cold chain sustainability, logistics competence and quality assurance in addition to environmental performance has a positive impact on decision-making processes. The study both contributes to theoretical literature and provides guidance to practitioners on green supplier selection.

In future research, it could be useful to apply the model to different food product groups (e.g. dairy, seafood, frozen foods) to test the generalizability of the methods. Multiple criteria decision-making methods can be applied on the same data set to analyze the consistency of the results and the impact of the selection of the method. In this study, an evaluation has been made based on expert opinions; future research with official supplier data could improve the accuracy of the method. Integration of multi-criteria decision-making methods with artificial intelligence-based models can contribute to making supplier selection processes more automated.

Conflict of interest

The authors declare that they have no conflict of interest.

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