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Evaluating Supplier Selection Criteria with Interval Pythagorean Fuzzy AHP

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Abstract

Supplier selection is one of the most critical decisions a business must make today. Especially with the rise of globalization and increasing competition, both the process of selecting suppliers and the criteria considered during selection have gained greater significance. In this context, the purpose of this paper is to determine the importance levels of supplier selection criteria for a furniture manufacturing company. For this purpose, nine criteria—quality, delivery on time, material price, information sharing, after-sales service, lead time, quantity discount, occupational health and safety system, and transportation costs—were evaluated. The Interval-Valued Pythagorean Fuzzy AHP (IVPF-AHP) method was employed to assess the importance levels of these criteria. Based on evaluations from three experts and subsequent calculations, transportation costs emerged as the most critical criterion in supplier selection. This was followed, respectively, by delivery on time, material price, quality, quantity discount, lead time, after-sales service, information sharing, and the occupational health and safety system.

Keywords: *Interval-Valued Pythagorean Fuzzy AHP, Supplier selection criteria, Furniture sector.*

Öz

Tedarikçi seçimi günümüzde bir işletmenin vermesi gereken en önemli kararlardan birisidir. Özellikle küreselleşme ve rekabetin artması ile birlikte tedarikçi seçimi ve tedarik seçerken göz önünde bulundurulması gereken kriterler daha önemli olmaktadır. Bu doğrultuda bu çalışmanın amacı, mobilya üretici bir işletmenin tedarikçi seçim kriterlerini önem derecesini belirlemektedir. Bu amaç doğrultusunda 9 kriter - kalite, zamanında teslimat, malzeme fiyatı, bilgi paylaşımı, satış sonrası hizmet, teslimat süresi, miktar indirimi, iş sağlığı ve güvenliği sistemi ve taşımacılık maliyetleri – değerlendirmeye alınmıştır. Kriterlerin önem dereceleri belirlenirken Aralık değerli Pisagor bulanık AHP (Interval Valued Pythagorean Fuzzy AHP / IVPF-AHP) yöntemi uygulanmıştır. Üç uzman görüşü alınarak değerlendirilen kriterler ve yapılan hesaplamalara göre tedarikçi seçiminde en önemli kriter taşımacılık maliyetleri olarak belirlenmiştir. Taşımacılık maliyetleri kriterini sırasıyla zamanında teslimat, malzeme fiyatı, kalite, miktar indirimi, teslimat süresi, satış sonrası hizmet, bilgi paylaşımı ve iş sağlığı ve güvenliği sistemi kriterleri takip etmiştir.

Anahtar Kelimeler: *Aralık değerli Pisagor bulanık AHP, Tedarikçi seçim kriterleri, Mobilya sektörü*

Introduction

Supplier selection is a highly strategic decision for businesses, as it plays a crucial role in integrating supply chain relationships and ensuring the entire chain operates cohesively, almost as a single enterprise. Choosing the most effective and appropriate supplier is one of the most critical responsibilities of purchasing managers, aimed at enhancing organizational performance across many firms. It is also a key component of production and logistics management (Chang, Chang & Wu, 2011, p.1850; Thiruchelvam & Tookey, 2011, p.438). Academics and industry professionals have noted that in most industries, materials—whether raw, semi-finished, or finished—constitute approximately 60% to 70% of total production costs (Arabsheybani, Paydar & Safaei, 2018, p.577; Ghobadin, Stainer, Liu & Kiss, 1993, p.103). Therefore, working with the right supplier not only helps reduce production costs but also shortens product development cycles, enhances product quality, reduces inventory levels, and significantly improves a company's competitive edge (Çebi & Otay, 2013, p.143).

In an increasingly globalized and competitive business environment, the selection of suppliers has emerged as a strategic function within supply chain management. Supplier selection is no longer a purely operational task focused on cost minimization; instead, it plays a vital role in ensuring supply chain resilience, enhancing product and service quality, promoting innovation, and aligning with corporate sustainability goals. As companies strive to enhance their performance, the strategic importance of collaborating with the right suppliers has grown significantly.

Moreover, recognizing that a well-selected group of suppliers can create a strategic advantage by enabling continuous improvement in customer satisfaction has spurred the pursuit of new and more effective supplier evaluation and selection methods (Pal, Gupta & Park, 2013, p.2667). Supplier selection is inherently a multi-criteria decision-making problem that necessitates the joint evaluation of both quantitative and qualitative factors (Güneri, Yücel & Ayyıldız, 2009, p.9223; Kılınçcı & Önal, 2011, p.9656), as strategic and operational elements such as quality, delivery, and flexibility must be considered alongside price.

Accordingly, the purpose of this study is to determine the importance of supplier selection criteria for a manufacturing firm operating in the furniture industry. To achieve this, the Interval Valued Pythagorean Fuzzy Analytic Hierarchy Process (IVPF-AHP) method was employed to calculate the weighting of each criterion. Because, when constructing comparison matrices using Pythagorean Fuzzy Sets (PFS), the evaluation is conducted along two dimensions—membership and non-membership unlike the AHP method which relies on a single dimension—degree of importance—for comparisons (Miloševic, Miloševic, Stevic & Kovacevic, 2023, p.7). In addition, experts may employ interval numbers instead of crisp values to better capture uncertainty when evaluating criteria in the decision-making process (Ayyıldız & Gümüş, 2021, p.567).

The biggest contribution of this study is one of the first applications focusing on the weighting of supplier selection criteria with the IVPF-AHP method, specific to the furniture sector.

Literature Review

Supplier selection is one of the principal domains within supply chain management. One of the earliest studies on this subject was conducted by Dickens (1966), who identified 23 criteria for supplier selection based on survey responses from 273 purchasing representatives. The study concluded that quality, delivery, and past performance were the top three most important criteria (Ha & Krishnan, 2008, p.1304).

Weber et al. (1991) reviewed 74 articles published between 1966 and 1990 in the manufacturing and retail sectors, which addressed supplier selection criteria. They found that most of these studies considered the 23 criteria originally defined by Dickens. Furthermore, they identified net price, delivery, and quality as the three most critical selection factors.

Akyüz et al. (2020) employed the Analytic Hierarchy Process (AHP) to determine the most suitable supplier for a company in the furniture industry. The study assessed five main criteria—quality, price, delivery, flexibility, and service—and 24 sub-criteria. Among these, quality, price, delivery, flexibility, and service were ranked as the most significant main criteria, respectively.

Tekez and Bark (2016) applied the fuzzy TOPSIS method to solve the supplier selection problem of a furniture company based in Sakarya. Six of the 23 criteria from Dickens' study were adopted in their evaluation: production equipment capacity, cost advantage, quality, performance, on-time delivery, and geographical location.

A review of the literature reveals that while Dickens' 23 criteria are frequently referenced in supplier selection, not all are utilized. The selection criteria often vary and are narrowed down depending on the industry, the type of enterprise, and consultations with decision-makers or experts.

Ali et al. (2023) aimed to establish a general framework for supplier selection criteria applicable across various businesses. They scanned databases such as Web of Science, Google Scholar, and Scopus, analyzing relevant studies using the PRISMA methodology. From this, they identified 30 key criteria and used a random forest classifier and feature selection algorithm to determine the nine most critical ones: quality, delivery on-time, material cost, information sharing, after-sales service, delivery time, volume discount, occupational health and safety system, and transportation cost. These nine criteria were adopted in this study.

Prioritizing supplier selection criteria constitutes a multi-criteria decision-making (MCDM) problem (Güneri, Yücel & Ayyıldız, 2009, p.9223; Kılınçcı & Önal, 2011, p.9656).

Various methods have been employed in the literature for this purpose, including AHP, ANP, Fuzzy AHP, ANN, DEA, Integer Programming, Genetic Algorithms, and its combinations (Sultana et al., 2016, s.56). Tursun & Özkoç (2022) conducted a bibliometric analysis of studies using MCDM techniques for supplier selection between 2000 and 2020. According to their findings, the most frequently used methods are AHP (Zolfani et al., 2012; Supçiller & Çapraz, 2011; Perçin, 2006), Fuzzy AHP (Chan, et al., 2008; Chen et al., 2016; Laosirihongthong et al., 2019; Kahraman et al., 2003), Fuzzy TOPSIS (Petrovic et al., 2019), VIKOR (Demir et al., 2018), and PROMETHEE (Dağdeviren & Eraslan, 2008).

In a pioneering study, Erdebilli et al. (2023) combined the AHP and COPRAS methods with interval-valued Pythagorean fuzzy (IPF) logic. They identified four criteria for supplier selection and used the IPF-AHP method to determine their importance rankings: quality, delivery time, service performance, and cost.

Yalçın (2024) utilized the IPF-AHP method to identify key criteria for companies using 3D printers in their supplier selection processes. Based on literature review and expert opinion, the study evaluated five main and eighteen sub-criteria, concluding that quality is the most critical main criterion, followed by technical service, cost, accessibility to technology, and logistical support.

The literature review indicates that no prior studies have applied the interval-valued Pythagorean fuzzy AHP method to determine the importance of supplier selection criteria specifically for furniture manufacturing firms.

Table 1. Supplier Selection Criteria

Criteria	Definition of Criteria
Quality **(Q)**	It is the supplier's ability to consistently meet quality attributes—including material, dimensions, design, durability—product variety, manufacturing quality such as production lines, techniques, and machinery, as well as quality systems and continuous improvement.
Delivery On-Time **(DOT)**	It refers to the supplier's ability to fulfill specified delivery schedules, including delivery time, on-time performance, fill rate, return management, location, transportation, and incoterms.
Material Cost **(MC)**	It encompasses unit price, pricing conditions, exchange rates, taxes, and discounts.
Information Sharing **(IS)**	It is the disclosure of all essential information about the company to stakeholders.
Service After Sales **(SAS)**	It is the supplier's capability to restore damaged, defective, or worn items to a good condition.
Delivery Time **(DT)**	It is the duration between placing an order and receiving the products.
Quantity Discount **(QD)**	It is the price reduction granted based on the quantity of products purchased.
Occupational Health and Safety Systems **(OHSS)**	It involves the implementation of measures aimed at protecting employees' health and lives.
Transportation Costs **(TC)**	It refers to the cost incurred in transporting goods.

Source: Ali, M. R., Nipu, S. M. A., & Khan, S. A. (2023). A decision support system for classifying supplier selection criteria using machine learning and random forest approach. Decision Analytics Journal, 7, 100238.

Similarly, the method's general use in supplier selection studies remains limited, highlighting the significance of this research.

Material and Methods

In this research, interval-valued Pythagorean fuzzy AHP method was implemented to prioritize the importance of supplier selection criteria for a furniture manufacturing firm. According to the literature review, nine criteria identified by Ali et al. (2023)—quality, delivery on time, material cost, information sharing, after-sales service, delivery time, quantity discount, occupational health and safety systems, and transportation costs—were adopted for the study. Criteria and definition of criteria were represented in Table 1.

These criteria were evaluated by production manager, purchasing manager and quality control manager.

Pythagorean Fuzzy Set

Decision making problems generally base on opinions, intuitions and experiences of decision makers. This situation leads to uncertainty and impreciseness with decision taken. Pythagorean Fuzzy Set including Intuitionistic Fuzzy Set was developed by Yager (2013) in order to better represent to uncertain, suspicious and indefinite environments (Erdoğan, Onay & Karamaşa, 2019, p.340; Gürsoy, 2024, p.809).

Definition 1. A Pythagorean Fuzzy Set P as shown in Equation 1.

$$A = \{\langle x[\mu_{A_L}(x), \mu_{A_U}(x)], [\nu_{A_L}(x), \nu_{A_U}(x)]\rangle \, ; \in X\} \qquad (1)$$

$\mu_{\tilde{P}}(x) : X \mapsto [0,1]$ and $\nu_{\tilde{P}}(x) : X \mapsto [0,1] x \in X \, in \, \tilde{P}$ expresses the degree of membership and non-membership in the set. Equation (2) shows that the sum of the squares of the degrees of membership and non-membership cannot be greater than 1.

$$0 \le \mu_{A_L}(x), \mu_{A_U}(x), \nu_{A_L}(x), \nu_{A_U}(x) \le 1, \quad \text{and} \quad \left(\mu_{A_L}(x)\right)^2 + \left(\nu_{A_L}(x)\right)^2 \le 1, \quad x \in X \qquad (2)$$

The hesitation interval formula of Pythagorean fuzzy sets with respect to A is as in Equation (3):

$$\pi_A(x) = [\pi_{A_L}(x), \pi_{A_U}(x)] = \left[\sqrt{1 - \left(\mu_{A_U}(x)\right)^2 - \left(\nu_{A_U}(x)\right)^2}, \sqrt{1 - \left(\mu_{A_L}(x)\right)^2 - \left(\nu_{A_L}(x)\right)^2}\right] \qquad (3)$$

If all $x \in X$, $\mu_A(x) = \mu_{A_L}(x) = \mu_{A_U}(x)$ and $\nu_A(x) = \nu_{A_L}(x) = \nu_{A_U}(x)$ then the interval-valued Pythagorean fuzzy set becomes a Pythagorean fuzzy set. For interval-valued Pythagorean fuzzy set $\langle[\mu_{A_L}(x), \mu_{A_U}(x)], [\nu_{A_L}(x), \nu_{A_U}(x)]\rangle$ is expressed as interval-valued Pythagorean fuzzy number. The score function for the interval-valued Pythagorean fuzzy number α=[a,b],[c,d] is defined as in Equation (4).

$$S(\alpha) = \frac{a^2+b^2-c^2-d^2}{2} \qquad (4)$$

where $(\alpha) \in [-1,1]$. It is known that this function may not always be successful when ranking IVPF numbers (Ayyıldız vd., 2021; Kavus vd., 2023). For this reason, as in Equation (5) the accuracy function is proposed (Garg, 2017):

$$H(\alpha) = \frac{a^2+b^2+c^2+d^2}{2} \qquad (5)$$

Interval Valued Pythagorean Fuzzy AHP (IVPF-AHP)

The analytical hierarchy process approach is a multi-criteria decision-making method that allows both objective and subjective criteria to be evaluated together. The method consists of five steps: (1) defining the problem, (2) creating the hierarchical structure, (3) creating the pairwise comparison matrix, (4) performing priority analyses, and (5) verifying consistency (Temiz &Cingöz, 2015, p.537).

The steps of Interval Valued Pythagorean Fuzzy AHP is as followed (İlkbahar et al., 2018, s.127; Bhat et al., 2021, p.43; Akhtar et al., 2022, p. 470-471; Erdebilli et al., 2023, p.124):

Step 1: Pairwise comparison matrices are created in accordance with the linguistic terms (İlkbahar et al., 2018, p.127).

Table 2. Weighting Scale for Interval Valued Pythagorean Fuzzy Numbers

Linguistic terms	μ_L	μ_U	ν_L	ν_U	Saaty
Absolutely Low (AL)	0.00	0.00	0.90	1.00	1/9
Very Low (VL)	0.10	0.2	0.8	0.9	1/7
Low (L)	0.20	0.35	0.65	0.8	1/5
Medium Low (ML)	0.35	0.45	0.55	0.65	1/3
Equal (E)	0.45	0.55	0.45	0.55	1
Medium High (MH)	0.55	0.65	0.35	0.45	3
High (H)	0.65	0.80	0.20	0.35	5
Very High (VH)	0.80	0.90	0.10	0.20	7
Absolutely Highly (AH)	0.90	1.00	0.00	0.00	9

Step 2: The consistency of each matrix is calculated. If the consistency ratio is greater than 0.1, the matrix is inconsistent, if it is less than 0.1, the matrix is consistent and we proceed to Step 3. While calculating the consistency, it is calculated using the net values developed by Saaty and the consistency formulation developed by Saaty (Saaty, 2004).

Step 3: The matrix $D = (d_{ij})_{m\times m}$ is constructed with lower and upper bounds for membership and non-membership degrees. Equation (6) and Equation (7) are used when creating a matrix.

$$d_{ij_L} = \mu_{ij_L}^2 - \nu_{ij_U}^2 \quad (6)$$

$$d_{ij_U} = \mu_{ij_U}^2 - \nu_{ij_L}^2 \quad (7)$$

Step 4: Calculate the multiplicative matrix $S = (s_{ij})_{m\times m}$ by Equations (8) and (9).

$$s_{ij_L} = \sqrt{1000^{d_{ij_L}}} \quad (8)$$

$$s_{ij_U} = \sqrt{1000^{d_{ij_U}}} \quad (9)$$

Step 5: Calculate the hesitancy values $H = (h_{ij})_{m\times m}$ using Equation 10.

$$h_{ij} = 1 - (\mu_{ij_U}^2 - \mu_{ij_L}^2) - (\nu_{ij_U}^2 - \nu_{ij_L}^2) \quad (10)$$

Step 6: Using Equation (11) determine the un-normalized weights $T = (t_{ij})_{m\times m}$

$$t_{ij} = \left(\frac{s_{ij_L} + s_{ij_U}}{2}\right) h_{ij} \quad (11)$$

Step 7: Determine the criterion weight using Equation (12) for each criterion.

$$w_i = \frac{\sum_{i=1}^{m} t_{ij}}{\sum_{i=1}^{m}\sum_{j=1}^{m} t_{ij}} \quad (12)$$

Findings

In the study, to ensure the reliability and representativeness of the evaluation, three expert opinions were consulted. The verbal statements of the experts were created according to the criteria comparison scale in Table 2. Accordingly, the pairwise comparison matrices from Experts 1–3 are presented in Tables 3–5.

Table 3. Pairwise Comparisons Matrix created by Expert 1

	Q	DOT	MC	IS	SAS	DT	QD	OHSS	TC
Q	E	E	MH	MH	H	MH	MH	H	E
DOT	E	E	MH	MH	H	MH	MH	H	E
MC	ML	ML	E	E	MH	MH	MH	MH	ML
IS	ML	ML	E	E	MH	E	E	MH	ML
SAS	L	L	ML	ML	E	MH	MH	H	L
DT	ML	ML	ML	E	ML	E	E	MH	ML
QD	ML	ML	ML	E	ML	E	E	MH	ML
OHSS	L	L	ML	ML	L	ML	ML	E	L
TC	E	E	MH	MH	H	MH	MH	H	E

Table 4. Pairwise Comparisons Matrix created by Expert 2

	Q	DOT	MC	IS	SAS	DT	QD	OHSS	TC
Q	E	ML	L	MH	H	ML	ML	H	VL
DOT	MH	E	MH	H	MH	MH	E	VH	ML
MC	H	ML	E	VH	MH	MH	E	VH	ML
IS	ML	L	VL	E	MH	ML	L	MH	VL
SAS	L	ML	ML	ML	E	ML	ML	E	L
DT	MH	ML	ML	MH	MH	E	E	H	ML
QD	MH	E	E	H	MH	E	E	H	L
OHSS	L	VL	VL	ML	E	L	L	E	VL
TC	VH	MH	MH	VH	H	MH	H	VH	E

Table 5. Pairwise Comparisons Matrix created by Expert 3

	Q	DOT	MC	IS	SAS	DT	QD	OHSS	TC
Q	E	MH	MH	MH	E	MH	MH	MH	ML
DOT	ML	E	ML	MH	ML	E	ML	MH	ML
MC	ML	MH	E	MH	ML	MH	E	MH	ML
IS	ML	ML	ML	E	ML	ML	ML	MH	ML
SAS	E	MH	MH	MH	E	MH	MH	MH	ML
DT	ML	E	ML	MH	ML	E	ML	MH	ML
QD	ML	MH	E	MH	ML	MH	E	H	ML
OHSS	ML	ML	ML	ML	ML	ML	L	E	VL
TC	MH	MH	MH	MH	MH	MH	MH	VH	E

Initially, the consistency of expert opinions was assessed. During consistency calculations, the steps of the Analytic Hierarchy Process were followed. The consistency ratios for pairwise comparison matrices provided by the three experts were 0.0716, 0.0937, and 0.0771, respectively, indicating that the judgments were consistent.

The Interval Valued Pythagorean Fuzzy Numbers Weighted Geometric Operator (IVPFWG) (Rahman et al., 2017, p.7) was used to combine the pairwise comparison matrices created by the experts.

The difference matrix was created as in Table 6 in line with the process steps.

Table 6. Differences Matrix

	Q	DOT	MC	IS	SAS	DT	QD	OHSS	TC
Q	[-0.10, 0.10]	[-0.10, 0.10]	[-0.14, 0.09]	[0.10, 0.30]	[0.17, 0.43]	[-0.03, 0.17]	[-0.03, 0.17]	[0.23, 0.50]	[-0.41, -0.20]
DOT	[-0.10, 0.10]	[-0.10, 0.10]	[-0.03, 0.17]	[0.17, 0.40]	[0.03, 0.27]	[0.03, 0.27]	[-0.10, 0.10]	[0.33, 0.57]	[-0.23, -0.03]
MC	[-0.09, 0.14]	[-0.17, 0.03]	[-0.10, 0.10]	[0.20, 0.41]	[-0.03, 0.17]	[0.10, 0.30]	[-0.03, 0.17]	[0.27, 0.47]	[-0.30, -0.10]
IS	[-0.30, -0.10]	[-0.40, -0.17]	[-0.41, -0.20]	[-0.10, 0.10]	[-0.03, 0.17]	[-0.23, -0.03]	[-0.33, -0.10]	[0.10, 0.30]	[-0.47, -0.27]
SAS	[-0.43, -0.17]	[-0.27, -0.03]	[-0.17, 0.03]	[-0.17, 0.03]	[-0.10, 0.10]	[-0.03, 0.17]	[-0.03, 0.17]	[0.10, 0.33]	[-0.50, -0.23]
DT	[-0.17, 0.03]	[-0.23, -0.03]	[-0.30, -0.10]	[0.03, 0.23]	[-0.17, 0.03]	[-0.10, 0.10]	[-0.17, 0.03]	[0.17, 0.40]	[-0.30, -0.10]
QD	[-0.17, 0.03]	[-0.10, 0.10]	[-0.17, 0.03]	[0.10, 0.33]	[-0.17, 0.03]	[-0.03, 0.17]	[-0.10, 0.10]	[0.23, 0.50]	[-0.40, -0.17]
OHSS	[-0.50, -0.23]	[-0.42, -0.19]	[-0.47, -0.27]	[-0.30, -0.10]	[-0.50, -0.23]	[-0.40, -0.17]	[-0.50, -0.23]	[-0.10, 0.10]	[-0.73, -0.50]
TC	[0.20, 0.41]	[0.03, 0.23]	[0.10, 0.30]	[0.27, 0.47]	[0.23, 0.50]	[0.10, 0.30]	[0.17, 0.40]	[0.50, 0.73]	[-0.10, 0.10]

The multiplicative matrix was created as in Table 7.

Table 7. Multiplicative Matrix

	Q	DOT	MC	IS	SAS	DT	QD	OHSS	TC
Q	[0.71, 1.41]	[0.71, 1.41]	[0.61, 1.39]	[1.41, 2.82]	[1.77, 4.41]	[0.89, 1.77]	[0.89, 1.77]	[2.24, 5.61]	[0.25, 0.56]
DOT	[0.71, 1.41]	[0.71, 1.41]	[0.89, 1.77]	[1.78, 3.99]	[1.11, 2.50]	[1.12, 2.24]	[0.71, 1.41]	[3.17, 7.07]	[0.45, 0.89]
MC	[0.72, 1.64]	[0.57, 1.13]	[0.71, 1.41]	[2.03, 4.07]	[0.89, 1.77]	[1.41, 2.82]	[0.89, 1.77]	[2.54, 5.10]	[0.35, 0.71]
IS	[0.35, 0.71]	[0.25, 0.56]	[0.25, 0.49]	[0.71, 1.41]	[0.89, 1.77]	[0.45, 0.89]	[0.32, 0.71]	[1.41, 2.82]	[0.20, 0.39]
SAS	[0.23, 0.57]	[0.40, 0.90]	[0.57, 1.13]	[0.57, 1.13]	[0.71, 1.41]	[0.89, 1.77]	[0.89, 1.77]	[1.41, 2.82]	[0.18, 0.45]
DT	[0.57, 1.13]	[0.45, 0.89]	[0.35, 0.71]	[1.12, 2.24]	[0.57, 1.13]	[0.71, 1.41]	[0.56, 1.12]	[1.78, 3.99]	[0.35, 0.71]
QD	[0.57, 1.13]	[0.71, 1.41]	[0.56, 1.12]	[1.41, 2.82]	[0.57, 1.13]	[0.89, 1.78]	[0.71, 1.41]	[2.24, 5.61]	[0.25, 0.56]
OHSS	[0.18, 0.45]	[0.23, 0.51]	[0.20, 0.39]	[0.35, 0.71]	[0.18, 0.45]	[0.25, 0.56]	[0.18, 0.45]	[0.71, 1.41]	[0.08, 0.18]
TC	[2.03, 4.07]	[1.12, 2.24]	[1.41, 2.82]	[2.54, 5.10]	[2.24, 5.61]	[1.41, 2.82]	[1.78, 3.99]	[5.61, 12.57]	[0.71, 1.41]

The degrees of hesitation were calculated using Equation (10). The degrees of hesitation are as shown in Table 8.

Tablo 8. Degrees of Hesitation

	Q	DOT	MC	IS	SAS	DT	QD	OHSS	TC
Q	1.05	0.8	0.76	0.8	0.74	0.8	0.8	0.73	0.8
DOT	1.05	0.8	0.8	0.77	0.77	0.8	0.8	0.77	0.8
MC	1.00	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
IS	1.05	0.77	0.8	0.8	0.8	0.8	0.77	0.8	0.8
SAS	0.98	0.77	0.8	0.8	0.8	0.8	0.8	0.77	0.73
DT	1.05	0.8	0.8	0.8	0.8	0.8	0.8	0.77	0.8
QD	1.05	0.8	0.8	0.77	0.8	0.8	0.8	0.73	0.77
OHSS	0.97	0.77	0.8	0.8	0.73	0.77	0.73	0.8	0.77
TC	0.99	0.8	0.8	0.8	0.73	0.8	0.77	0.77	0.8

The unnormalized weights calculated using Equation (11) are shown in Table 9.

Table 9. Unnormalized Weights Matrix

	Q	DOT	MC	IS	SAS	DT	QD	OHSS	TC
Q	1.11	0.85	0.76	1.69	2.27	1.06	1.06	2.88	0.29
DOT	1.11	0.85	1.06	2.21	1.38	1.34	0.85	3.93	0.54
MC	1.18	0.68	0.85	2.44	1.06	1.69	1.07	3.05	0.43
IS	0.56	0.31	0.29	0.85	1.06	0.54	0.39	1.69	0.24
SAS	0.39	0.50	0.68	0.68	0.85	1.06	1.06	1.76	0.23
DT	0.89	0.54	0.43	1.34	0.68	0.85	0.67	2.21	0.43
QD	0.89	0.85	0.67	1.76	0.68	1.07	0.85	2.88	0.31
OHSS	0.30	0.29	0.24	0.43	0.23	0.31	0.23	0.85	0.10
TC	3.01	1.34	1.69	3.05	2.88	1.69	2.21	6.97	0.85

The weights of the criteria calculated according to Equation (12) are shown in Figure 1.

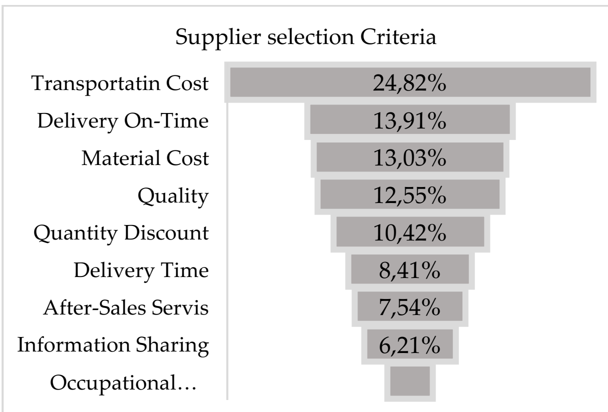

Figure 1. Supplier Selection Criteria Importance Weight

According to the Figure 1, for the furniture manufacturer, transportation costs emerged as the most important criterion in supplier selection (24.82%). This was followed by delivery on-time (13.91%), material cost (13.03%), quality (12.55%), quantity discount (10.42%), delivery time (8.41%), after-sales service (7.54%), information sharing (6.21%), and occupational health and safety systems (3.11%).

Conclusion

Today, globalization, sustainability, and technological advancements have led to a shift in human needs. Consequently, in order to enhance their competitiveness, businesses must meet customer demands anytime, in any form, and at any location the customer desires. This is one of the fundamental functions of the supply chain.

However, to produce the desired product at the expected or familiar level of quality, it is essential to select the right suppliers and establish long-term relationships with them. At this point, supplier selection criteria become critically important.

For this purpose, in the present study, the Interval-Valued Pythagorean Fuzzy AHP method was employed to determine the supplier selection criteria of a furniture manufacturing company operating in the city of Kayseri. Based on a literature review, nine criteria identified by Ali et al. (2023)—quality, delivery on time, material cost, information sharing, after-sales service, delivery time, quantity discount, occupational health and safety systems, and transportation costs—were adopted for the study.

For the furniture manufacturer in this study, transportation costs emerged as the most important criterion in supplier selection (24.82%). This was followed by delivery on-time (13.91%), material cost (13.03%), quality (12.55%), quantity discount (10.42%), delivery time (8.41%), after-sales service (7.54%), information sharing (6.21%), and occupational health and safety systems (3.11%).

In contrast, the results of Ali et al. (2023) identified quality as the most important criterion, followed by delivery on-time, material cost, information sharing, after-sales service, delivery time, quantity discount, occupational health and safety systems, and transportation costs. Comparing the two studies, the shift of transportation costs from the least important to the most critical criterion warrants attention. This change can primarily be attributed to the ongoing conflict between Russia and Ukraine. Since the war began in February 2024, fuel prices have surged—from an average of 14.52 ₺ to 45.12 ₺ per liter—directly inflating transportation costs. In this context, the distance between supplier and manufacturer directly effects on transportation costs. Transportation costs increase based on variables such as the weight, volume, and hazardous nature of the product, which it is transported. The raw materials used in the furniture industry are supplied to businesses in the form of materials such as lumber, veneer, plywood, particleboard, and fiberboard (Yurdakul, Çolak & Çetin, 2013, p.221). Consequently, the importance of transportation costs in supplier selection has significantly increased. In particular, due to the substantial weight of lumber and it is purchase large quantities, transportation costs tend to increase significantly during shipment. Notably, the subsequent rankings of delivery on-time and material cost remain consistent with those reported by Ali et al. (2023).

It is thought that this study will be a guide for furniture manufacturers in selecting suppliers. However, this study is not without limitations. It was conducted within a single furniture manufacturing firm, and criterion weightings may vary across different industries. For future research, applying the same methodology to another company within the same sector could allow for broader generalizations regarding the validity of the findings. Moreover, applying alternative heuristic decision-making methods to the same set of criteria could enhance the robustness of comparative results.

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