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Evaluating Logistics Flexibility in Istanbul-Based Companies Using Interval-Valued Fermatean Fuzzy SWARA

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Abstract: In the dynamic and unpredictable landscape of modern logistics, the capability to swiftly and effectively adapt to market and consumer fluctuations is imperative for service quality enhancement and competitive positioning. This research delves into the pivotal role of logistics flexibility as a mechanism for logistics firms, particularly those with a corporate identity, to navigate rapid market changes, customer demands, and service differentiation. The primary focus is the appraisal of logistical flexibility, utilizing the Interval-Valued Fermatean Fuzzy (IVFF) Stepwise Weight Assessment Ratio Analysis (SWARA) method to meticulously weigh identified criteria crucial for assessing this flexibility. The methodology's rigor lies in its comprehensive analysis and structured approach, which prioritizes criteria based on their relevance and impact. The findings underscore the paramount importance of 'Logistics Information Integration' as a critical factor in assessing logistics flexibility, highlighting its role in the seamless execution of logistics operations. Conversely, 'Asset Efficiency', while significant, ranks lower in the hierarchy of criteria, suggesting a lesser impact on overall logistics flexibility. These insights offer a strategic roadmap for logistics firms aiming to enhance their adaptive capabilities and provide a foundational framework for stakeholders and model developers seeking to optimize logistics operations. This study contributes to the logistics field by offering a nuanced understanding of flexibility parameters and their implications for service excellence and market differentiation.

Keywords: Logistics flexibility; Interval-Valued Fermatean Fuzzy Set (IVFFS); Stepwise Weight Assessment Ratio Analysis (SWARA); Multi-Criteria Decision Analysis (MCDA); Logistics Information Integration

1 Introduction

Logistics, the cornerstone of interactions among suppliers, manufacturers, retailers, and customers within the supply chain, emerges as a critical sector for both manufacturing and service-oriented entities. In contemporary business environments, the pursuit of enhanced competitiveness and operational efficiency is a universal objective among companies. This has led to the adoption of flexible structures within organizations. A crucial aspect of evaluating service quality and competitiveness is the assessment of a company's logistics flexibility. Logistics flexibility, widely acknowledged as a pivotal indicator, significantly influences service quality, customer satisfaction, and overall business success [1].

The capability of logistics flexibility to adapt to varying supply sources, based on location, customer requirements, or transfer processes, is a subject of extensive discussion. Simangunsong et al. [2] articulated logistics flexibility as an organization's capacity to modify its logistics network sensitively, thereby crafting a competitive edge. Diversifying this concept, logistics flexibility is segmented into four key categories: supply, purchasing, distribution, and demand management. Within this framework, Zhang et al. [3] characterized logistics flexibility as a company's proficiency in responding promptly and efficiently to evolving customer demands concerning deliveries, support activities, and other services. Maldonado-Guzman et al. [4] highlighted logistics flexibility as an essential competency for companies striving for heightened competitiveness. Specifically, logistics flexibility is recognized for its role in enhancing the capacity of logistics service providers, integrating logistics operations, and fostering connectivity and innovation in response to customer needs [5].

Flexibility is increasingly recognized as a pivotal element in enhancing business agility. It has been observed that a high degree of operational flexibility positively influences customer satisfaction and augments the logistical efficiency of companies [6]. Additionally, logistics flexibility encompasses the capacity to transition the production of a product from one region of the supply chain to another, a capability that is often contingent upon the organization's strategy for sourcing components or materials, whether through a single, dual, or multiple sourcing approach [7].

Ercan and Çelik [5] posited that logistical flexibility is crucial in evaluating the alignment between the quality of logistics services and customer expectations in the offered segment. It is posited that entities or departments responsible for these services should fully leverage logistical flexibility to meet these expectations. This underscores an inextricable link between logistical flexibility and the caliber of logistics services [8].

The adaptability afforded by flexible logistics options facilitates the customization of service offerings to individual customer requirements. This may include the addition of unique product features or the provision of bespoke packaging, labeling, and product configurations. Logistics flexibility is thus deemed one of the most effective strategies for significantly enhancing a company's competitive edge. Mastery in logistics flexibility paves the way for advancements in production flexibility, thereby enabling companies to meet diverse customer needs and interests more effectively [4].

The implementation of flexible systems within enterprises is increasingly recognized as a vital mechanism to manage and adapt to unforeseen environmental and operational crises. Such systems enable organizations to incorporate resilience into their structure, allowing them to respond efficiently to various challenges [9]. In scenarios of significant adversities, companies with a strong foundation in logistical flexibility contribute substantially to the reorganization and restructuring of resources and capabilities, thereby facilitating rapid response to catastrophic events [10]. Furthermore, the competitive landscape of logistics service providers is increasingly being shaped by their innovation capacity, alongside characteristics like speed, quality, and flexibility [11].

This backdrop has provided ample motivation for the current investigation. Logistic flexibility is identified as a crucial concept for businesses and users, heavily influenced by the expertise, experience, and knowledge of decision-makers. Factors such as sustainability efforts, customer satisfaction, and service quality enhancement have forged a new link between logistics flexibility practices and business operations, paving the way for innovative modeling opportunities. The integration of logistics flexibility factors - key in reducing costs, enabling immediate responses, and bolstering competitiveness - into business strategies is viewed as one of the most promising approaches for service-oriented businesses. Moreover, this study holds significance in offering an effective and applicable solution to decision-making challenges encompassing logistics flexibility application factors, especially in the critical domain of the logistics sector. Additionally, the study presents interest in its potential to create a model enabling companies to self-assess logistics flexibility criteria.

This study serves as a strategic guide, aiming to ensure the sustainability of logistics flexibility criteria, foster immediate responsiveness, and secure a competitive edge in the logistics industry. It also undertakes a comparative analysis of logistics flexibility criteria among companies within a specific industry, assessing the degree to which these criteria are reflected in their operations. Consequently, the research proposes a practical action plan tailored for the logistics sector. Another key contribution of this study lies in its theoretical and practical implications: the development of a robust, effective, and practical decision-making model designed to navigate current uncertainties. The primary objective is not only to provide a sustainable solution to decision-making challenges pertinent to the logistics sector but also to offer a comprehensive methodological framework. This framework seeks to bridge theoretical gaps in existing literature by leveraging methodologies pertinent to the logistics industry.

Through this approach, the study aspires to aid in resolving similar challenges across diverse sectors. Moreover, given the specificity of the research results to the logistics sector and their applicability to other industries, this study is anticipated to make a substantial contribution to the broader business landscape, particularly in domains such as sustainable development, sustainable services, and energy efficiency.

The measurement of logistics flexibility is increasingly acknowledged as a paramount factor in enhancing agility and securing a competitive edge for businesses. The criteria for evaluating logistics flexibility within logistics companies are pivotal in addressing key concerns such as efficiency, effectiveness, cost management, and competitiveness, impacting both beneficiaries and users. Additionally, it is evident that this measurement plays a significant role in ensuring corporate sustainability and optimizing business processes. Minor disruptions in logistics process management can have far-reaching effects, impacting not only customer satisfaction but also the entire supply chain. Hence, the careful consideration of logistics flexibility measurement is deemed essential.

The primary objective of this study is to identify and prioritize the criteria for measuring logistics flexibility in logistics enterprises with a corporate identity based in Istanbul, utilizing a MCDA approach. Fermatean fuzzy sets (FFSs) are employed to model uncertainties in decision-making more effectively than intuitionistic fuzzy sets and

Pythagorean fuzzy sets, due to their capacity to maintain the sum of the third powers of membership and non-membership degrees at or below one. Furthermore, the SWARA methodology is integrated into the study. This approach offers a comprehensible framework for experts not versed in MCDA, facilitating the assessment of criteria significance. Therefore, the IVFF-SWARA methodology has been selected for addressing the decision-making challenges in this context.

2 Literature Review

Logistics flexibility, recognized as a critical factor in the logistics service sector, is imperative for addressing unforeseen scenarios and meeting evolving customer demands. The literature presents a plethora of studies exploring various facets of logistics flexibility, as outlined below.

• Barad and Sapir [12] conducted an examination of the benefits of flexibility in logistics systems, discussing existing frameworks and proposing a new, bottom-up approach for flexibility in these systems.

• Mattsson [13] explored the correlation between the variability and flexibility of potential suppliers and the overall logistics performance.

• Zhang et al. [3] provided a comprehensive definition of logistics flexibility, offering a framework for its understanding and relation to customer satisfaction.

• Aprile et al. [14] delved into supply chain configurations, focusing on different levels of flexibility and articulating supply chain flexibility in terms of both process and logistics.

• Kumar et al. [15] investigated global supply chain flexibility from diverse perspectives, proposing multiple suggestions.

• Kumar et al. [16] identified and evaluated the relationships between flexibility suppliers in the global supply chain and established a hierarchy to understand their mutual influences.

• Wadhwa et al. [17] proposed a value-added MCDM approach for alternative selection in reverse logistics systems using flexible decision models.

• Liu and Luo [18] examined the impacts of logistics process efficiency, logistics flexibility capability, and Logistics Information Integration on competitive advantage and business performance.

• Ramírez and Morales [19] investigated the effects of reverse logistics applications on business flexibility and organizational performance.

• de Grahl et al. [20] conducted an empirical study measuring the flexibility of logistics service providers and its influence on customer loyalty.

• Yu [21] identified factors affecting logistics flexibility in China, providing future-oriented suggestions.

• Shah and Sharma [22] discussed logistics flexibility and its comprehensive effect on customer satisfaction.

• Jafari [23] conducted a systematic review of logistics flexibility, making future recommendations.

• Jafari et al. [24] examined postponement and logistics flexibility in retailing through a multiple case study in Sweden.

• Maldonado-Guzman et al. [4] explored the impact of logistics flexibility on customer satisfaction in the Spanish furniture industry.

• Korucuk [25] in his study on supply chain management performance elements, identified flexibility as the most crucial factor.

• Aunyawong et al. [26] examined the mediating roles of supply chain collaboration and logistics flexibility on the performance of auto parts manufacturing companies in Thailand.

• Ercan [27] investigated the moderating role of environmental uncertainty in the effects of logistical and relational flexibility on logistics service quality and perceived relational satisfaction.

• Phaxaisithidet and Banchuen [28] examined the influences of logistics flexibility and service quality on the competitive advantage of logistics service users in a special economic zone.

• Sandberg [29] explored the dynamic possibilities of creating logistics flexibility within a conceptual framework.

• Ng et al. [30] proposed a new multidisciplinary system for flexible logistics and warehouse operations in the context of Industry 4.0.

• Singagerda et al. [31] examined the role of visibility, supply chain agility, and supplier development on the business performance of logistics companies.

• Ercan and Çelik [5] analyzed the relationship between logistics flexibility, relational flexibility, and logistics service quality, considering environmental uncertainty as a moderating variable.

• Hamour et al. [32] studied the effects of strategic intelligence, effective decision-making, and strategic flexibility on logistics performance.

• Aygün and Akyüz [33] utilized a structural equation model to examine the impact of shipping companies' flexibility and service quality on customer trust, satisfaction, and loyalty.

These seminal studies highlight the global scope of research on logistics flexibility, encompassing reverse logistics, flexibility levels, supplier comparison, process efficiency, warehouse operations, and customer-centric metrics like satisfaction and loyalty. Notably, there appears to be a gap in research specifically focused on measuring logistics flexibility in logistics companies. This study aims to address this gap, contributing both to the logistics sector and the broader academic literature.

3 Methodology

In addressing the inherent uncertainties within logistics flexibility measurement, a more nuanced approach is necessitated. This involves representing fuzziness as a range rather than a singular fuzzy value, thus enabling a more accurate depiction of uncertainty [34–37]. In alignment with this perspective, this study employs Interval Valued Fermatean Fuzzy Sets (IVFFSs). Given a finite non-empty set *X*, a IVFFS is defined as *T* as per Eq. (1) [38–40]. $\alpha_{TL}(x)$ and $\alpha_{TU}(x)$ represent the lower and upper bounds of the membership degree, respectively. Similarly, $\beta_{TL}(x)$ and $\beta_{TU}(x)$ denote the lower and upper bounds of the non-membership degree, respectively.

$$T = \{< [\alpha_{TL}(x), \alpha_{TU}(x)], [\beta_{TL}(x), \beta_{TU}(x)] >| \, x \in X\} \tag{1}$$

The conditions $\alpha_{TL}(x), \alpha_{TU}(x), \beta_{TL}(x), \beta_{TU}(x) \in [0,1]$, and $0 \leq (\alpha_{TU}(x))^3 + (\beta_{TU}(x))^3 \leq 1$ are valid for IVFFSs. The indeterminacy or the hesitant degree of x to T is obtained by $\pi_T(x) = [\pi_{TL}(x), \pi_{TU}(x)]$, where $\pi_{TL}(x) = \sqrt[3]{1 - (\alpha_{TU}(x))^3 - (\beta_{TU}(x))^3}$, $\pi_{TU}(x) = \sqrt[3]{1 - (\alpha_{TL}(x))^3 - (\beta_{TL}(x))^3}$ [38, 39].

In this study, the pair of $[\alpha_L(x), \alpha_U(x)], [\beta_L(x), \beta_U(x)]$ is named IVFF number (IVFFN) for simplicity. Let $\mathfrak{z} = ([\alpha_L, \alpha_U], [\beta_L, \beta_U])$, $\mathfrak{z}_1$=$([\alpha_{1L}, \alpha_{1U}], [\beta_{1L}, \beta_{1U}])$, and $\mathfrak{z}_2$=$([\alpha_{2L}, \alpha_{2U}], [\beta_{2L}, \beta_{2U}])$ be three IVFFNs. Then, the IVFF weighted aggregation operators, the score function (s($\mathfrak{z}$)), the accuracy function (h($\mathfrak{z}$)), and the Euclidean distance measure (d($\mathfrak{z}_1, \mathfrak{z}_2$)) are given in Eqs. (2)-(9), where $\lambda > 0$ [38, 39].

$$\mathfrak{z}_1 \oplus \mathfrak{z}_2 = \left(\left[\sqrt[3]{\alpha_{1L}^3 + \alpha_{2L}^3 - \alpha_{1L}^3\alpha_{2L}^3}, \sqrt[3]{\alpha_{1U}^3 + \alpha_{2U}^3 - \alpha_{1U}^3\alpha_{2U}^3} \right], [\beta_{1L}\beta_{2L}, \beta_{1U}\beta_{2U}] \right) \tag{2}$$

$$\mathfrak{z}_1 \oplus \mathfrak{z}_2 = \left([\alpha_{1L}\alpha_{2L}, \alpha_{1U}\alpha_{2U}], \left[\sqrt[3]{\beta_{1L}^3 + \beta_{2L}^3 - \beta_{1L}^3\beta_{2L}^3}, \sqrt[3]{\beta_{1U}^3 + \beta_{2U}^3 - \beta_{1U}^3\beta_{2U}^3} \right] \right) \tag{3}$$

$$\lambda\mathfrak{z} = \left(\left[\sqrt[3]{1 - (1 - \alpha_L^3)^\lambda}, \sqrt[3]{1 - (1 - \alpha_U^3)^\lambda} \right], \left[{\beta_L}^\lambda, {\beta_U}^\lambda \right] \right) \tag{4}$$

$$\mathfrak{z}^\lambda = \left(\left[\alpha_L^\lambda, \alpha_U^\lambda \right], \left[\sqrt[3]{1 - (1 - \beta_L^3)^\lambda}, \sqrt[3]{1 - (1 - \beta_U^3)^\lambda} \right] \right) \tag{5}$$

$$\mathfrak{z}^c = ([\beta_L, \beta_U], [\alpha_L, \alpha_U]) \tag{6}$$

$$s(\mathfrak{z}) = \frac{{\alpha_L}^3 + {\alpha_U}^3 - {\beta_L}^3 - {\beta_U}^3}{2} \tag{7}$$

$$h(\mathfrak{z}) = \frac{{\alpha_L}^3 + {\alpha_U}^3 + {\beta_L}^3 + {\beta_U}^3}{2} \tag{8}$$

$$d(\mathfrak{z}_1, \mathfrak{z}_2) = \sqrt{\frac{\begin{array}{c}(\alpha_{1L}^3 - \alpha_{2L}^3)^2 + (\alpha_{1U}^3 - \alpha_{2U}^3)^2 + (\beta_{1L}^3 - \beta_{2L}^3)^2 + (\beta_{1U}^3 - \beta_{2U}^3)^2 \\ + ((1 - \alpha_{1L}^3 - \beta_{1L}^3) - (1 - \alpha_{2L}^3 - \beta_{2L}^3))^2 + ((1 - \alpha_{1U}^3 - \beta_{1U}^3) - (1 - \alpha_{2U}^3 - \beta_{2U}^3))^2\end{array}}{6}} \tag{9}$$

The IVFF Weighted Arithmetic Average (IVFFWAA) operator is computed using Eq. (10), where $\varkappa_i = \varkappa_1, \varkappa_2, \ldots, \varkappa_m$ [39, 40].

$$\text{IVFWAO}_w\left(\varkappa_1, \varkappa_2, \ldots, \varkappa_m\right) = \left(\left[\sqrt[3]{1 - \prod_{i=1}^{m}\left(1 - \alpha_{iL}^3\right)^{\lambda_i}}, \sqrt[3]{1 - \prod_{i=1}^{m}\left(1 - \alpha_{iU}^3\right)^{\lambda_i}}\right], \left[\prod_{i=1}^{m}\beta_{iL}^{\lambda_i}, \prod_{i=1}^{m}\beta_{iU}^{\lambda_i}\right]\right) \quad (10)$$

The IVFF Weighted Geometric Average (IVFFWGA) operator is calculated via Eq. (11), where $\varkappa_i = \varkappa_1, \varkappa_2, \ldots, \varkappa_m$ [39, 40]:

$$\text{IVFWAO}_w\left(\varkappa_1, \varkappa_2, \ldots, \varkappa_m\right) = \left(\left[\prod_{i=1}^{m}\alpha_{iL}^{\lambda_i}, \prod_{i=1}^{m}\alpha_{iU}^{\lambda_i}\right], \left[\sqrt[3]{1 - \prod_{i=1}^{m}\left(1 - \beta_{iL}^3\right)^{\lambda_i}}, \sqrt[3]{1 - \prod_{i=1}^{m}\left(1 - \beta_{iU}^3\right)^{\lambda_i}}\right]\right) \quad (11)$$

3.1 The IVFF- SWARA

SWARA, in comparison to the Analytic Hierarchy Process (AHP) and other pairwise comparison methods, offers a reduction in the number of pairwise comparisons required. Additionally, SWARA is characterized by its user-friendly and comprehensible approach. In this study, the IVFF-SWARA method was employed to encapsulate judgments that are inherently ambiguous and uncertain. The implementation steps of IVFF-SWARA are outlined as follows [39, 40]:

Step 1. A vector of importance rating for criteria is constructed based on expert opinions. Experts employ the linguistic terms listed in Table 1 [40, 41]. As a result, $\vartheta_{jk} = \left(\left[\alpha_{jkL}, \alpha_{jkU}\right], \left[\beta_{jkL}, \beta_{jkU}\right]\right)$ shows the expert k's evaluation regarding criterion j, where $j = 1, \ldots, n; k = 1, \ldots, r$.

Table 1. Linguistic terms for assessing importance of criteria

Linguistic Terms	Notations	IVFFNs			
		α_L	α_U	β_L	β_U
Absolutely high importance	AHI	0.90	0.95	0.05	0.10
Very high importance	VHI	0.80	0.90	0.20	0.35
High importance	HI	0.65	0.80	0.40	0.50
Medium-high importance	MHI	0.50	0.65	0.50	0.60
Medium importance	MI	0.40	0.50	0.60	0.70
Medium-low importance	MLI	0.30	0.40	0.70	0.80
Low importance	LI	0.20	0.30	0.80	0.85
Very low importance	VLI	0.10	0.20	0.85	0.90
Absolutely low importance	ALI	0.05	0.10	0.90	0.95

Step 2. The IVFFWAA operator integrates evaluations of experts. Using Eq. (12), the aggregated IVFF importance matrix is created, where λ_k represents the weight coefficient of the k-th expert.

$$\vartheta_w(\vartheta_1, \vartheta_2, \ldots, \vartheta_n) = ([\sqrt[3]{1 - \prod_{k=1}^{r}(1 - \alpha_{jkL}^3)^{\lambda_k}}, \sqrt[3]{1 - \prod_{k=1}^{r}(1 - \alpha_{jkU}^3)^{\lambda_k}}], [\prod_{k=1}^{r}\beta_{jkL}^{\lambda_k}, \prod_{k=1}^{r}\beta_{jkU}^{\lambda_k}]) \quad (12)$$

After that, $\vartheta_j = \left(\left[\alpha_{jL}, \alpha_{jU}\right], \left[\beta_{jL}, \beta_{jU}\right]\right)$ is obtained for each criterion.

Step 3. The score function of ϑ_j is calculated by employing Eq. (13).

$$s\left(\vartheta_j\right) = \frac{{\alpha_{jL}}^3 + {\alpha_{jU}}^3 - {\beta_{jL}}^3 - {\beta_{jU}}^3}{2} \quad (13)$$

Step 4. According to the $s\left(\vartheta_j\right)$ values, criteria are listed in decreasing order. According to this ranking, S_1 stands for the top-ranked criterion and S_n for the bottom-ranked criterion. This ranking order yields the comparative importance $\left(\iota_j\right)$ of $s\left(\vartheta_j\right)$ connected to each criterion. As a result, the first placed criterion's score value is shown by $s\left(\vartheta_{s_1}\right)$, and the last placed criterion's score value is shown by $s\left(\vartheta_{s_n}\right)$.

Step 5. The first-placed criterion's comparative significance is calculated as $\iota_1 = 1$, while the second-placed criterion's comparative significance is calculated as $s(\vartheta_{s_1}) - s(\vartheta_{s_2})$. The remaining criteria are subject to the same procedure.

Step 6. The comparative coefficient (ce_j) of each criterion is computed via Eq. (14):

$$ce_j = \begin{cases} 1, & \text{if } -j = 1, \\ \iota_1 + 1, & \text{if } j > 1. \end{cases} \tag{14}$$

Step 7. The recalculated importance value (v_j) of each criterion is calculated using Eq. (15):

$$v_j = \begin{cases} 1, & \text{if } j = 1, \\ \frac{ce_{(j-1)}}{ce_j}, & \text{if } j > 1. \end{cases} \tag{15}$$

Step 8. The weight coefficients (w_j) of criteria are obtained by employing Eq. (16), where $0 \leq w_j \leq 1$, and $\sum_{i=1}^{n} w_j = 1$.

$$w_j = \frac{v_j}{\sum_{j=1}^{n} v_j} \tag{16}$$

4 Results

The criteria set for measuring logistics flexibility in corporate logistics enterprises was established through an extensive review of relevant literature. Table 2 delineates the comprehensive list of these criteria.

Table 2. The list of criteria and corresponding sources

Codes	Criteria	Source(s)
N1	Physical Supply Elasticity	[1, 42]
N2	Purchasing Flexibility	[4]
N3	Physical Distribution Flexibility	[21]
N4	Demand Management Flexibility	[25]
N5	Production Flexibility	[3, 42]
N6	Logistics Information Integration	[4, 25]
N7	Environmental Uncertainty	[20, 43]
N8	Customer Satisfaction and Relationship Satisfaction	[22]
N9	Asset Efficiency	[44].
N10	Business Age and Size	[21]

In relation to the research topic, interviews were conducted with three experts. These experts encompass diverse roles within the logistics field: one oversees logistical operations, another is responsible for quality assurance, and the third holds a managerial position in a warehouse. In this study, equal weight has been accorded to the insights of each expert. Table 3 illustrates the linguistic evaluations of the criteria as provided by these experts.

Table 3. The linguistic evaluations of experts for importance levels of criteria

	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10
Expert 1	HI	VHI	HI	VHI	MI	VHI	VHI	VHI	HI	VHI
Expert 2	AHI	VHI	AHI	AHI	AHI	AHI	HI	HI	HI	VHI
Expert 3	HI	VHI	HI	VHI	LI	AHI	VHI	AHI	HI	VHI

Eq. (12) was employed to obtain the integrated IVFF importance vector for each criterion. As a result, $\vartheta_j, s(\vartheta_j), s_j$ values were computed, with the results presented in Table 4.

Eqs. (14)- (16) were employed to compute the weight coefficients of the criteria, and the results are given in Table 5.

According to the results in Table 5, the most important criterion is "Logistics Information Integration." Also, the importance ranking order of the criteria is N6 > N4 > N8 > N2 > N10 > N1 > N3 > N7 > N5 > N9.

Table 4. The aggregated IVFF importance values, and the score function values for criteria

	$\boldsymbol{\vartheta}_j$					
	α_{jL}	α_{jU}	$\boldsymbol{\beta}_{jL}$	$\boldsymbol{\beta}_{jU}$	$s\left(\vartheta_j\right)$	s_j
N1	0.7816	0.8777	0.2000	0.2924	0.5604	6
N2	0.8000	0.9000	0.2000	0.3500	0.5951	4
N3	0.7816	0.8777	0.2000	0.2924	0.5604	6
N4	0.8429	0.9210	0.1260	0.2305	0.6829	2
N5	0.7170	0.7962	0.2884	0.3904	0.3950	9
N6	0.8752	0.9373	0.0794	0.1518	0.7448	1
N7	0.7624	0.8752	0.2520	0.3942	0.5181	8
N8	0.8154	0.9020	0.1587	0.2596	0.6273	3
N9	0.6500	0.8000	0.4000	0.5000	0.2988	10
N10	0.8000	0.9000	0.2000	0.3500	0.5951	4

Table 5. The results regarding the weight coefficients of criteria

Criteria	$s\left(\vartheta_{s_j}\right)$	ι_j	ce_j	v_j	w_j	**Ranking**
N6	0.7448		1.0000	1.0000	0.1189	1
N4	0.6829	0.0619	1.0619	0.9417	0.1120	2
N8	0.6273	0.0557	1.0557	0.8921	0.1061	3
N2	0.5951	0.0322	1.0322	0.8642	0.1028	4
N10	0.5951	0.0000	1.0000	0.8642	0.1028	4
N1	0.5604	0.0347	1.0347	0.8352	0.0993	6
N3	0.5604	0.0000	1.0000	0.8352	0.0993	6
N7	0.5181	0.0423	1.0423	0.8013	0.0953	8
N5	0.3950	0.1654	1.1654	0.7167	0.0852	9
N9	0.2988	0.2192	1.2192	0.6572	0.0782	10

5 Conclusions

In the contemporary business landscape, leveraging logistical flexibility factors has emerged as a critical pathway for companies to attain cost advantages and ensure sustained customer satisfaction. This study investigated the determinants of logistics flexibility in corporations with a distinct identity in the logistics sector in Istanbul. The research findings indicate that the most pivotal criteria impacting logistics flexibility include “Logistics Information Integration,” ”Demand Management Flexibility,” “Customer Satisfaction and Relationship Satisfaction,” ”Purchasing Flexibility,” and “Business Age and Size,” in descending order of importance.

The study reveals a strong correlation between logistics flexibility factors and the efficacy of corporate IT systems. Efficient logistics information systems have a positive impact on demand management and add value through enhanced purchasing flexibility. The current customer and relationship strategies of logistics companies significantly influence the flexibility concept and warrant careful consideration.

This research offers substantial insights for policymakers, practitioners, and stakeholders in the logistics industry. The identified criteria set facilitates the evaluation of factors influencing logistics flexibility and lays the groundwork for a model to balance these factors with business strategies. It proposes a flexible and structured decision-making environment, accommodating a variety of perspectives. Moreover, the study encourages decision-makers to reconsider transportation routes in light of the identified flexibility factors and global market conditions.

However, this study is not without limitations. It is geographically confined to a specific province and sector. The number of experts consulted was limited due to time constraints and accessibility issues. The focus on logistical flexibility factors may have overshadowed other pertinent logistics studies. The selection of search terms was somewhat subjective. Additionally, the literature review and expert reports did not yield a comprehensive set of criteria on logistics flexibility factors.

The outcomes of this study are presumed to directly influence the flexibility coefficients of logistics companies, contingent on their age and type of activity. Neglecting the concept of logistics flexibility could lead companies to face significant challenges in demand, purchasing, customer satisfaction, and relationships. This study serves as a guide to address these issues and can be further expanded upon in future research using alternative multi-criteria decision analysis methods.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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