IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received 14 March 2024, accepted 29 March 2024, date of publication 3 April 2024, date of current version 24 April 2024.

Digital Object Identifier 10.1109/ACCESS.2024.3384874

RESEARCH ARTICLE

A Novel Interval-Valued-q-Rung Orthopair Fuzzy-Additive Ratio Assessment Model for Evaluating Logistics Service Quality

SELÇUK KORUCUK[1], AHMET AYTEKİN[2], AND SARBAST MOSLEM[3]
[1]Department of Logistics Management, Giresun University, Bulancak, 28300 Giresun, Turkey
[2]Department of Business and Administration, Artvin Çoruh University, Hopa, 08600 Artvin, Turkey
[3]School of Architecture, Planning and Environmental Policy, University College Dublin, Dublin 4, D04 V1W8 Ireland

Corresponding author: Sarbast Moslem (sarbast.moslem@ucd.ie)

ABSTRACT Logistics service quality is crucial for companies to satisfy customers, gain an advantage over competitors, minimize costs, make effective business processes, and maintain corporate reputation. Companies work with 3PL service providers to ensure the quality of their logistics services. Now, companies adopt technology adoption models closely related to 3PL service and logistics service quality. In this context, this research aims to determine the ideal technology adoption model for ensuring logistics service quality in companies that employ 3PL services. It also seeks to determine the criteria and their significance levels that must be considered to attain the specified aim. A decision-making methodology, including IV-q-ROF-ARAS, has been used to attain these goals. The research revealed that the essential criteria for the quality of logistics services are "reliability, regularity, flexibility, and service usability," "delivery time and request," and "availability of ordering information." According to the study, logistics companies must be reliable and flexible. The "technology acceptance model" has been identified as the ideal adoption model for Turkish companies receiving 3PL services. The study, which focuses on logistics service quality, 3PL service providers, and technology adoption structures, presents significant implications for the literature and companies.

INDEX TERMS ARAS, businesses receiving 3PL service, IV-q-ROF-ARAS, IV-q-ROF-MCDA, logistics service quality.

I. INTRODUCTION

Every company wants to improve its competitiveness and increase its business efficiency. For this reason, companies usually choose a flexible structure. The function of this flexibility and competitiveness is the quality of the company's logistics performance. Logistics service quality is generally accepted as a critical indicator of customer satisfaction and business success [1]. In contemporary research on service quality in general and logistics service quality in particular, subjective and objective approaches are mentioned to shape the definition and conceptualization of this subject. According to the subjective approach, a service's quality can be determined by tailoring it to the requirements established by its suppliers [2]. On the other hand, the objective approach found that quality is based on customer ratings and perceptions [3].

Gajewska [2] proposed four different definitions of service quality. The first definition of service quality refers to the quality of the service provided. The second definition includes the degree achieved through objectively measured criteria. The third definition is the perceived quality of the service and the customer's assessment of the service provided. Finally, expected service quality refers to the implicit or explicit desired quality level and service quality the customer expects. Service quality is the level the service provider expects to achieve. According to Mentzer et al. [4], the quality of logistic services includes seven dimensions: concreteness,

The associate editor coordinating the review of this manuscript and approving it for publication was Wenbing Zhao.

reliability, responsiveness, price, certainty, empathy, and relevance. Moreover, Mentzer et al. [4] emphasized that the quality of logistics services has become an essential source of differentiation for the competitive advantage of companies. While elements of logistics service quality can be used to segment customers horizontally or vertically, culture and organizational characteristics can change the relationship between customer satisfaction and logistics service quality.

Considering all these facts, technological application changes and development require new models, making them essential for operational efficiency and customer satisfaction. According to Marangunić and Granić [5], the ongoing development of information and communication technologies has led to several theories and models on the acceptance and effective use of technology. These models are generally known as technology acceptance models. Their primary purpose is to provide a comprehensive interpretation of technology user behaviour and to provide fundamental or theoretical explanations of the determinants of technology acceptance [6]. This model has five main variables: perceived ease of use, perceived usefulness, attitude, intentions, and actual use of the system [6].

In this context, the study contributes to the subject under consideration. When the relevant literature was examined, it was found that while several domestic and international research studies have been undertaken on the model concepts used in logistics service quality and technology adoption, only a few academic studies have assessed these concepts. However, it is critical for practitioners and researchers to evaluate these concepts within the context of the research itself, depending on perceptions of the quality of logistics services and the companies' target customers. On this basis, the current study aims to fill this gap in the literature. Furthermore, this study differs from previous studies in that it analyzes the quality of logistics services in an integrated manner using technological models. In terms of logistics service quality, a third-party logistics company should be able to serve businesses with diverse characteristics, experiences, and technological models. The study will contribute uniquely to the field by incorporating this perspective into a reliable and valid framework. This study examines the factors that affect logistics service quality, customer satisfaction, efficiency, and productivity in business operations. It provides a roadmap for improving logistics services for companies using 3PL services. The study also investigates the quality of logistics services provided by numerous organizations in a specific industry, how they differ from one another, and how much this may reflect in the quality of their work. Therefore, the study provides a practical roadmap for developing the quality of logistics services and technology adoption, as well as the selection of the model used for companies using 3PL services. In this context, the study analyzed companies' experiences with the quality of logistics services and technology models with global applicability. The study is expected to open a new perspective and significantly contribute to companies and researchers in this field. The study also makes a theoretical and practical contribution by proposing an effective, efficient, and robust decision-making model capable of dealing with existing uncertainties in the sector.

This framework aims to classify the quality factors of logistic services and select the model to introduce the ideal technology strategy for companies receiving 3PL services with an international corporate identity in Istanbul province. Much multicriteria decision analysis (MCDA) methods can be employed to solve decision problems. On the other hand, the studied problem includes uncertainty and many conflicting criteria. Methods based on fuzzy logic are employed to solve such problems. Fuzzy logic aims to handle uncertain problems with reasoning, deduction, and computation with inadequate knowledge outside conventional methods' scope [7].

As the field of MCDA continues to evolve, embracing new methods and expanding its extensions, it is crucial to look at the recent advancements and trends within this domain. Hence, the latest applications and evolving directions in the practical implementation of MCDA can be indicated, highlighting its ever-growing relevance in current problem-solving scenarios [8].

The general advantages of the studies are:

- Evaluating the importance of quality practices in logistics services using an integrated model.
- Providing a comprehensive framework for selecting the model for deploying the ideal technology in logistics companies with corporate identity.
- Providing concrete and significant benefits to beneficiaries and companies commensurate with the practical experience, competence, perspective, and knowledge of experts.
- Proposing a new fuzzy decision-making model to evaluate and rank issues related to quality factors for logistics services.
- Examining the similarities and differences in logistics service quality factors among companies in a particular industry and to what extent they are reflected.
- Providing a reliable, valid, and robust decision-making model proposal can cope with uncertainty and be used in similar problems in different fields, logistics, and supply chains.
- Providing a different perspective on the field by considering technology acceptance, 3PL service, and service quality dimensions together.

A. ORGANIZATION OF THE STUDY

There are six sections in this study. Section II includes a literature review on logistics service quality and 3PL service providers. Section III contains the proposed methodology and theoretical explanations. Section III, Sub-section A explains IV-q-ROF sets, whereas Sub-section B details the proposed IV-q-ROF MCDA methodology. Section IV contains an application to identify the best technology model for businesses receiving 3PL services. Section IV,

TABLE 1. Literature review.

Author(s)	Objective & Key Findings	Method(s)
Gil Saura et al. [24]	Evaluating the quality of logistic service delivery, customer satisfaction, and loyalty sequence. The reliability and validity tests depicted satisfactory outcomes.	Structural Equation Modeling (SEM)
Kersten and Koch [25]	Estimating the relationships between quality management, service quality, and business success, the results depicted a positive impact of service quality on business success.	Conceptual model
Thai [3]	Identifying the quality of logistics service and the related indicators by creating a conceptual model.	Exploratory factor analysis and confirmatory factor analysis
Jang et al. [26]	The results of detecting the impact of logistics service quality on customer loyalty showed that improving service quality increases loyalty.	SEM
Alkhatib et al. [27]	Selecting the best logistics service providers.	Decision-making trial and evaluation laboratory (DEMATEL)
Roslan et al. [22]	Estimating the provided logistics service quality by third-party logistics, the results approved the positive relationship between customer satisfaction and service quality.	SERVQUAL
Limbourg et al. [23]	Evaluating logistic service quality in Da Nang City, the outcomes showed the demand for improving research and development.	SERVQUAL
Rahmat and Faisol [28]	The results of investigating the related indicators of logistics service quality that satisfy the users showed that timeliness and service condition are the most critical indicators.	Qualitative method
Gupta et al. [29]	Evaluating third-party logistics service quality, the results showed that services were the most important indicator, followed by reliability.	AHP
Murfield et al. [10]	Estimating the impact of logistics service quality on consumer satisfaction and loyalty, the results showed that availability and timeliness significantly influence satisfaction and loyalty.	Empirical, survey-based method
Dang and Yeo [30]	Evaluating logistic service quality in Vietnam, the results showed that minimizing logistics costs is a significant indicator of improving the system.	Consistent fuzzy preference relations
Karim et al. [31]	Evaluating warehouse activity in developing a logistic performance index, they found that labour productivity was the most critical indicator to improve warehouse productivity.	Fuzzy AHP
Tsai et al. [32]	Estimating the most critical indicators affecting port logistics service quality, the results showed that professional skills and responsiveness are the most significant indicators.	AHP, DEMATEL, and Analytic Network Process (ANP)
Huma et al. [33]	Identifying the logistics service quality indicators that affect customer loyalty	SEM
Michalski and Montes-Botel [34]	This paper aims to determine how the level of logistics service quality facilitates logistics performance in emerging markets.	SERVQUAL and partial least squares SEM
Ren et al. [35]	Investigating intelligent service capacity allocation for logistics operations.	Deep Learning Approach
Liu et al. [36]	Examining an order allocation model based on cumulative expectation theory and capacity matching constraints in the logistics service supply chain.	Cumulative Prospect Theory and Capacity Matching Constraint

Sub-section A, provides comparative sensitivity analyses of the results obtained using the proposed methodology. Section V presents a discussion of the results. Finally, Section VI covers practical and managerial implications, limitations, and future directions.

II. LITERATURE REVIEW

In the global logistics market, customer service has become an essential indicator of determining competitiveness. Numerous explanations exist for logistics customer service quality. Over the past decade, various studies have explored the theoretical realm of service quality within a business-to-business (B2B) context, focusing on logistics service quality. Since logistics can be classified as a service industry, it is imperative to estimate service quality. However, service quality has been a focal point of research in logistics. This emphasis on quality, management, and business satisfaction parallels the interest in service quality. The leading essential indicators of logistics service quality have been highlighted in several studies, and the researchers adopted different methods to evaluate and ameliorate the service quality of the logistics system [3], [9], [10], [11]. Hence, the indicators of logistics service quality are critical for estimating and ameliorating logistics service quality. The leading indicators have been spotted in several articles, such as reliability, assurance, tangibles, empathy, and responsiveness, which were defined in detail in many studies [3], [4], [12], [13]. La Londe and Zinszer [14] discussed the importance of users' demands in the satisfaction process. Grönroos [15] highlighted service delivery and functional characteristics as significant indicators. Mentzer et al. [16] and Feng et al. [17] lighted on the order accuracy, order quality, timeliness, availability, and condition of the delivered items as important indicators to be counted in the evaluation process. Hussein et al. [18] presented the order release quantities, the order discrepancy, the quality of information, and ordering procedures as the leading related indicators of the logistics service quality. In this regard, the most commonly highlighted indicators to improve the logistics system quality and increase customer satisfaction were the accuracy of the order, the quality of the order, the condition of the order, the discrepancy of the order, the release quantities of the order, the information quality, timeliness. Indeed, customer satisfaction significantly benefits logistics service quality, which was approved in several studies [19], [20]. Vázquez et al. [21] confirmed that physical distribution quality from suppliers had the most significant impact on customer satisfaction.

Several methodologies have been adopted for estimating and ameliorating logistics service quality, as seen in Table 1. SERVQUAL was the most employed approach for measuring logistics service quality [20], [22], [23].

Because of the hesitation in human judgments, fuzzy logic has been adopted, where conventional dual logic is not a suitable tool to deal with the uncertainty and vagueness in evaluators' estimations [9].

Therefore, these studies' significant contributions are listed below:

- To provide a comprehensive framework for evaluating the importance levels by determining the factors affecting the quality of logistics service using an integrated model and selecting the ideal model to adopt the ideal technology in enterprises that receive 3PL services with corporate identity.
- To assess the factors affecting logistics service quality and select the best strategy, a novel fuzzy decision-making model within the scope of IV-q-ROFS is proposed. This model is applied to companies with corporate identities receiving 3PL services in Istanbul.
- To evaluate the validity and reliability of the study's solutions using sensitivity and comparison analyses based on different approaches.
- To provide scientific guidance to companies on improving their current processes by dealing with a real-life problem, including many conflicting business factors. As a result, a scientific framework for 3PL organizations to assess their service quality requirements will be presented.

III. METHODOLOGY

Uncertainty is prevalent in decision problems due to various unknowns and limited information on the problem's elements. Methods based on fuzzy logic are employed to solve such problems. Fuzzy logic aims to handle uncertain problems with reasoning, deduction, and computation with inadequate knowledge outside conventional methods' scope [7]. Fuzzy logic has become an essential tool for modelling and solving problems for which conventional methods are insufficient. For this purpose, many fuzzy sets have been designed to help problem-solving. Because of the fuzziness of decision-making environments and the complexity of real-life decision problems, expressing attribute values of alternatives by exact values, as seen in conventional fuzzy sets, is insufficient.

In order to describe complicated fuzzy information, Atanassov's [37] intuitionistic fuzzy set (IFS), which is an extension of Zadeh's [38] fuzzy sets (FSs), is handy. It has membership and non-membership functions that indicate the degree of satisfaction and dissatisfaction, respectively [39]. However, due to the requirement that the sum of the degrees of membership and non-membership be equal to or less than 1, the range of applications for IFSs is limited. Some information about decision evaluation cannot be conveyed adequately in this situation.

Yager [40] proposed the Pythagorean fuzzy set (PFS) to address these issues. Its key feature is that the square sum of membership and non-membership degrees must be less than or equal to 1. However, it has been noted that PFS is also affected by the same problem. With the continuous complication of society and the development of theory, a new concept was presented again by Yager [41], the q-rung ortho-pair fuzzy sets (q-ROFs), where the total of the qth power of the membership degree and the qth power of the of non-membership degree is restricted to 1. As the q rung increases, the space of acceptable orthopairs expands and more orthopairs satisfy the boundary restriction. As a result, q-ROFs can express a more excellent range of fuzzy information [39], [42], [43]. In other words, we can continue to adjust the value of the q parameter to determine the information expression range. Thus, q-ROFs are more flexible and suitable for uncertain environments [39]. In addition, interval-valued (IV) q-ROFs have been defined as a substantial extension of fuzzy sets, allowing uncertainty to be expressed in a broader range rather than a fuzzy number [44].

IV-q-ROFSs generally model uncertainty using an interval with a specific upper and lower limit rather than a specific fuzzy number. One of the critical advantages of interval-valued fuzzy sets is that they produce more reliable results with less particular information [7]. Representing the fuzziness with a range rather than a precise value can provide a more accurate representation of the uncertainty [42], [44], [45]. Obtaining more reliable results by modelling the uncertainty in an interval-valued form is one of the main reasons for using the IV-q-ROF-MCDA methodology in this study. Furthermore, there is a problem with not satisfying the condition that the total of the first and second powers of membership and non-membership degrees is equal to or less than one, as can be seen in IV-IFSs and IV-PFSs. The IV-IFS and IV-PFS can only be solved if the stated condition is met. This issue will be solved by IV-q-ROFS [44], [46]. The IV-q-ROFS is a powerful tool for dealing with uncertain or imprecise information in accurate life decision-making procedures [47]. Due to its easy-to-follow procedures that result in reasonable, acceptable, and generally accurate rankings of alternatives based on how well they perform against chosen weighted evaluation criteria, the additive ratio assessment (ARAS) method is widely used and expanding quickly. ARAS utilizes the concept of optimality degree to achieve an order of priority. The main advantages of ARAS include a proportional and direct relationship with criterion weights, the ability to handle complex decision problems, and the use of several direct and simple steps to evaluate many alternatives based on their performance in comparison to the criteria [43], [48], [49], [50]. In this context, the ideal technology in companies receiving 3PL services will be determined using the IV-q-ROF-MCDA methodology, including IV-q-ROF-ARAS.

A. INTERVAL-VALUED Q-RUNG ORTHOPAIR FUZZY SETS

Yager [41] proposed q-ROFSs with configurable preference space and information allocation related to uncertainty. In q-ROFSs, a regulating factor (q) broadens the preference space by considering the degree of membership (ς) and non-membership (υ). A q-ROFS F on the universal set X is defined in (1), where ≥ 1, $a_F(x) \in [0,1]$, $b_F(x) \in [0,1]$, $0 \leq (a_F(x)^q + b_F(x)^q) \leq 1$, $a_F(x)$ is the membership degree, and $b_F(x)$ depicts the non-membership degree of $x \in X$ [41].

$$F = \{\langle x, (\varsigma_F(x), \nu_F(x))\rangle \mid x \in X\} \quad (1)$$

On the other hand, representing the fuzziness with a range rather than a precise value can provide a more accurate representation of the uncertainty. The information obtained from the experts could be more transparent and precise. In such cases, decision-makers are advised to express their opinions using a subset of the closed interval [1, 0] [42], [44], [51]. In this study, IV-q-ROFS, an extension of q-ROFS, is preferred to express the uncertainties in the problem efficiently. An IV-q-ROFS H on X is defined in Eq. (2), where $q \geq 1$, $[a_H^L(x), a_H^U(x)] \in [0,1]$, $[b_H^L(x), b_H^U(x)] \in [0,1]$, $0 \leq \left((a_H^U(x))^q + (b_H^U(x))^q\right) \leq 1$ [25], [69].

$$H = \left\{\left\langle x, \left[a_H^L(x), a_H^U(x)\right], \left[b_H^L(x), b_H^U(x)\right]\right\rangle \mid x \in X\right\} \quad (2)$$

In Eq. (2), $a_H^L(x)$ denotes the lower bound of the membership degree, while $a_H^U(x)$ is the upper bound of it. $b_H^L(x)$ and $b_H^U(x)$ are the lower and upper bounds of the non-membership degree, respectively. Also, the indeterminacy membership degree is defined as $\pi_H = [\pi_H^L(x), \pi_H^U(x)] = \left[\sqrt[q]{1-(a_H^U(x))^q + (b_H^U(x))^q}, \sqrt[q]{1-(a_H^L(x))^q + (b_H^L(x))^q}\right]$. For simplicity, the IV-q-ROF number (IV-q-ROFN) can be written as $\varphi = ([a^L, a^U], [b^L, b^U])$. Also, the conditions, $[a^L, a^U] \in [0,1]$, $[b^L, b^U] \in [0,1]$, $0 \leq (a^U)^q + (b^U)^q \leq 1$, are satisfied. Let $\varphi_1 = ([a_1^L, a_1^U], [b_1^L, b_1^U])$ and $\varphi_2 = ([a_2^L, a_2^U], [b_2^L, b_2^U])$ be two IV-q-ROFNs. Then, some operations, score function, and accuracy function on IV-q-ROFSs are defined below, where $\daleth > 0$, and $q \geq 1$ [42], [44], [52], [53]. Eqs. (3)–(9), as shown at the bottom of the next page.

The IV-q-ROF Weighted Arithmetic Average (IV-q-ROFWAA) operator is defined below, where $\varphi_j = \varphi_1, \varphi_1, \ldots, \varphi_n$, $0 \leq ϟ_j \leq 1$, $\sum_{j=1}^n ϟ_j = 1$. The IV-q-ROF Weighted Geometric Average (IV-q-ROFWGA) operator is defined below, where $\varphi_i = \varphi_1, \varphi_1, \ldots, \varphi_m$, $0 \leq ϟ_j \leq 1$, $\sum_{j=1}^n ϟ_j = 1$ [52], [54]:

$$IV-q-ROFWAA(\varphi_1, \varphi_1, \ldots, \varphi_n) = \left(\begin{array}{l}\left[\sqrt[q]{1-\prod_{j=1}^n\left(1-\left(a_j^L\right)^q\right)^{ϟ_j}}, \sqrt[q]{1-\prod_{j=1}^n\left(1-\left(a_j^U\right)^q\right)^{ϟ_j}}\right], \\ \left[\prod_{j=1}^n\left(b_j^L\right)^{ϟ_j}, \prod_{j=1}^n\left(b_j^U\right)^{ϟ_j}\right]\end{array}\right). \quad (10)$$

$$IV-q-ROFWGA(\varphi_1, \varphi_1, \ldots, \varphi_n) = \left(\begin{array}{l}\left[\prod_{j=1}^n\left(a_j^L\right)^{ϟ_j}, \prod_{j=1}^n\left(a_j^U\right)^{ϟ_j}\right], \\ \left[\begin{array}{l}\sqrt[q]{1-\prod_{j=1}^n\left(1-\left(b_j^L\right)^q\right)^{ϟ_j}}, \\ \sqrt[q]{1-\prod_{j=1}^n\left(1-\left(b_j^U\right)^q\right)^{ϟ_j}}\end{array}\right]\end{array}\right). \quad (11)$$

Eq. (12) gives the Minkowski distance between φ_1 and φ_1, where $[\pi_1^L, \pi_1^U]$ and $[\pi_2^L, \pi_2^U]$ are indeterminacy membership degrees of φ_1 and φ_1, respectively [52].

$$\begin{aligned} M_p(\varphi_1, \varphi_2) &= \left(\frac{1}{4}\left|\left(a_1^L\right)^q - \left(a_2^L\right)^q\right|^p + \left|\left(a_1^U\right)^q - \left(a_2^U\right)^q\right|^p \right. \\ &\quad + \left|\left(b_1^L\right)^q - \left(b_2^L\right)^q\right|^p + \left|\left(b_1^U\right)^q - \left(b_2^U\right)^q\right|^p \\ &\quad \left. + \left|\left(\pi_1^L\right)^q - \left(\pi_2^L\right)^q\right|^p + \left|\left(\pi_1^U\right)^q - \left(\pi_2^U\right)^q\right|^p\right)^{1/p} \end{aligned} \quad (12)$$

When $p = 1$, Eq. (12) is used to compute Hamming distance; when $p = 2$, it is used to calculate Euclidean distance.

B. THE PROPOSED IV-Q-ROF MCDA METHODOLOGY

During the solution process of the studied problem, the criteria will be weighted, and the alternatives will be ranked. In this context, alternatives will be ranked using the IV-q-ROF-ARAS method, and criteria will be weighted via the IV-q-ROF-subjective weighting approach (Fig. 1).

The implementation steps of the proposed IV-q-ROF MCDA methodology, including the IV-q-ROF-subjective weighting approach and IV-q-ROF-ARAS, can be presented as follows:

Step 1. The decision problem is defined. In this context, $\{A_1, A_2, \ldots, A_m\}$ as a set of alternatives, $\{C_1, C_2, \ldots, C_n\}$ as a set of criteria, and $\{E_1, E_2, \ldots, E_r\}$ as a group of experts are determined.

Step 2. The weight value is assigned to the expert evaluations. Linguistic terms listed in Table 2 are used in this regard [55]. As a result, ι_k depicts the IV-q-ROF importance value of the k-th expert.

Eq. (13) is used to compute the weight value of each expert, where $k = 1, \ldots, r$, and $\iota_k = ([a_k^L, a_k^U], [b_k^L, b_k^U])$.

$$ϟ_k = \frac{\frac{1}{4}\left[\left(1+(a_k^L)^q - (b_k^L)^q\right) + \left(1+(a_k^U)^q - (b_k^U)^q\right)\right]}{\sum_{k=1}^r \frac{1}{4}\left[\left(1+(a_k^L)^q - (b_k^L)^q\right) + \left(1+(a_k^U)^q - (b_k^U)^q\right)\right]} \quad (13)$$

Step 3. Each expert assesses the importance levels of criteria based on the linguistic terms listed in Table 2. As a result, $\iota_{jk} = \left(\left[a_j^{L(k)}, a_j^{U(k)}\right], \left[b_j^{L(k)}, b_j^{U(k)}\right]\right)$ depicts the importance assessment of criterion j by expert k.

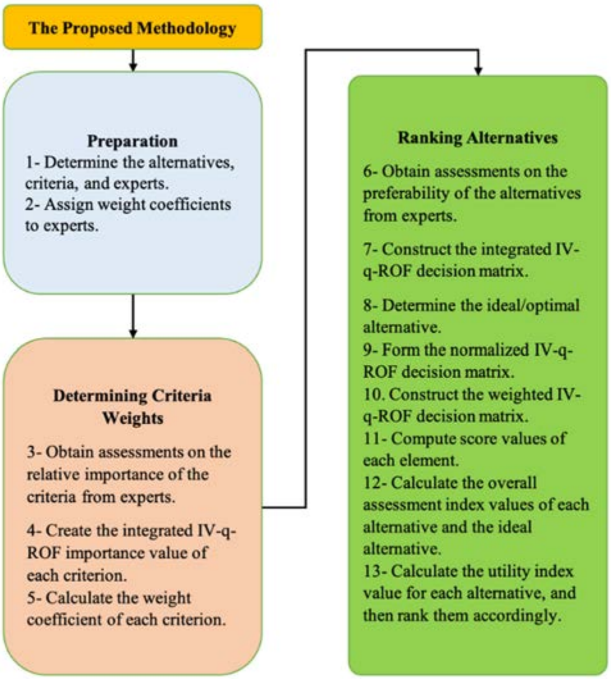

FIGURE 1. The procedure of the proposed methodology.

Step 4. Each criterion's Integrated IV-q-ROF importance value is computed using Eq. (14).

$$\iota_j = \left(\begin{array}{c} \left[\begin{array}{c} \sqrt[q]{1 - \prod_{k=1}^{r} \left(1 - \left(a_j^{L(k)}\right)^q\right)^{\varsigma_k}}, \\ \sqrt[q]{1 - \prod_{k=1}^{r} \left(1 - \left(a_j^{U(k)}\right)^q\right)^{\varsigma_k}} \end{array} \right], \\ \left[\prod_{k=1}^{r} \left(b_j^{L(k)}\right)^{\lambda_k}, \prod_{k=1}^{r} \left(b_j^{U(k)}\right)^{\varsigma_k} \right] \end{array} \right) \tag{14}$$

TABLE 2. Linguistic terms for evaluating the experts, criteria, and alternatives.

Linguistic Terms for Evaluating Experts and Criteria	Codes	Linguistic Terms for Evaluating Alternatives	Codes	Numbers
Extremely low importance	ELI	Extremely low	EL	([0.10,0.15], [0.90,0.95])
Very low importance	VLI	Very low	VL	([0.20,0.25], [0.80,0.85])
Low importance	LI	Low	L	([0.30,0.35], [0.70,0.75])
Medium-low importance	MAIL	Medium-low	ML	([0.40,0.45], [0.60,0.65])
Medium importance	MI	Medium	M	([0.50,0.55], [0.50,0.55])
Medium-high importance	MHI	Medium-high	MH	([0.60,0.65], [0.40,0.45])
High importance	HI	High	H	([0.70,0.75], [0.30,0.35])
Very high importance	VHI	Very high	VH	([0.80,0.85], [0.20,0.25])
Extremely high importance	EHI	Extremely high	EH	([0.90,0.95], [0.10,0.15])

Step 5. The weight coefficient of each criterion is calculated by applying Eq. (15), where $\iota_j = \left(\left[a_j^L, a_j^U\right], \left[b_j^L, b_j^U\right]\right)$.

$$w_j = \frac{\frac{1}{4}\left[\left(1+\left(a_j^L\right)^q-\left(b_j^L\right)^q\right)+\left(1+\left(a_j^U\right)^q-\left(b_j^U\right)^q\right)\right]}{\sum_{j=1}^{n}\frac{1}{4}\left[\left(1+\left(a_j^L\right)^q-\left(b_j^L\right)^q\right)+\left(1+\left(a_j^U\right)^q-\left(b_j^U\right)^q\right)\right]} \tag{15}$$

Step 6. Each expert evaluates each A_i alternative about the C_j criterion via IV-q-ROF linguistic terms listed in Table 2.

$$\varphi_1 \oplus \varphi_2 = \left(\begin{array}{c} \left[\sqrt[q]{(a_1^L)^q + (a_2^L)^q - (a_1^L)^q (a_2^L)^q}, \sqrt[q]{(a_1^U)^q + (a_2^U)^q - (a_1^U)^q (a_2^U)^q} \right], \\ \left[b_1^L b_2^L, b_1^U b_2^U\right] \end{array} \right) \tag{3}$$

$$\varphi_1 \otimes \varphi_2 = \left(\begin{array}{c} \left[a_1^L a_2^L, a_1^U a_2^U\right], \\ \left[\sqrt[q]{(b_1^L)^q + (b_2^L)^q - (b_1^L)^q (b_2^L)^q}, \sqrt[q]{(b_1^U)^q + (b_2^U)^q - (b_1^U)^q (b_2^U)^q} \right] \end{array} \right) \tag{4}$$

$$\varsigma\varphi_1 = \left(\left[\sqrt[q]{1 - (1 - (a_1^L)^q)^{\varsigma}}, \sqrt[q]{1 - \left(1 - (a_1^U)^q\right)^{\varsigma}} \right], \left[\left(b_1^L\right)^{\varsigma}, \left(b_1^U\right)^{\varsigma} \right] \right) \tag{5}$$

$$\varphi_1^{\varsigma} = \left(\left[\left(a_1^L\right)^{\varsigma}, \left(a_1^U\right)^{\varsigma} \right], \left[\sqrt[q]{1 - (1 - (b_1^L)^q)^{\varsigma}}, \sqrt[q]{1 - \left(1 - (b_1^U)^q\right)^{\varsigma}} \right] \right) \tag{6}$$

$$(\varphi_1)^c = \left(\left[b_1^L, b_1^U\right], \left[a_1^L, a_1^U\right] \right) \tag{7}$$

$$S(\varphi_1) = \frac{1}{4}\left[\left(1 + \left(a_1^L\right)^q - \left(b_1^L\right)^q\right) + \left(1 + \left(a_1^U\right)^q - \left(b_1^U\right)^q\right)\right], S(\varphi_1) \in [0, 1] \tag{8}$$

$$\mathcal{A}(\varphi_1) = \frac{(a_1^L)^q + (a_1^U)^q + (b_1^L)^q + (b_1^U)^q}{2}, \quad \mathcal{A}(\varphi_1) \in [0, 2] \tag{9}$$

Hence, the individual IV-q-ROF decision matrix $X^{(k)}$ including the elements $x_{ij}^{(k)} = \left(\left[a_{ij}^{L(k)}, a_{ij}^{U(k)}\right], \left[b_{ij}^{L(k)}, b_{ij}^{U(k)}\right]\right)$ is formed, where $i = 1, \ldots, m; j = 1, \ldots, n$. Therefore, $x_{ij}^{(k)}$ refers to the IV-q-ROFN assigned to *the* i-th alternative with regard to *the* j-th criterion by the k-th expert.

Step 7. The integrated IV-q-ROF-decision matrix X is formed using Eq. (16):

$$x_{ij} = \left(\left[a_{ij}^{L}, a_{ij}^{U}\right], \left[b_{ij}^{L}, b_{ij}^{U}\right]\right) = \left(\begin{bmatrix} \sqrt[q]{1 - \prod_{k=1}^{r}\left(1 - \left(a_{ij}^{L(k)}\right)^{q}\right)^{\lambda_k}}, \\ \sqrt[q]{1 - \prod_{k=1}^{r}\left(1 - \left(a_{ij}^{U(k)}\right)^{q}\right)^{\lambda_k}} \end{bmatrix}, \left[\prod_{k=1}^{r}\left(b_{ij}^{L(k)}\right)^{\lambda_k}, \prod_{k=1}^{r}\left(b_{ij}^{U(k)}\right)^{\lambda_k}\right]\right). \tag{16}$$

Step 8. The ideal/optimal alternative is determined via Eq. (17), where J^b shows benefit criteria, and J^c denotes cost criteria [48], [52], [56].

$$x_{0j} = \begin{cases} \left(\begin{pmatrix} \max_i a_{ij}^{L}, & \max_i a_{ij}^{U} \end{pmatrix} \\ \begin{pmatrix} \min_i b_{ij}^{L}, & \min_i b_{ij}^{U} \end{pmatrix}\right), & j \in J^b \\ \left(\begin{pmatrix} \min_i a_{ij}^{L}, & \min_i a_{ij}^{U} \end{pmatrix} \\ \begin{pmatrix} \max_i b_{ij}^{L}, & \max_i b_{ij}^{U} \end{pmatrix}\right), & j \in J^c \end{cases} \tag{17}$$

Step 9. The normalization of X is executed by applying Eq. (18), where $i = 0, .1, \ldots, m$. Thus, the normalized IV-q-ROF decision matrix R is obtained.

$$r_{ij} = \begin{cases} \left(\left[a_{ij}^{L}, a_{ij}^{U}\right], \left[b_{ij}^{L}, b_{ij}^{U}\right]\right), & j \in J^b \\ \left(\left[b_{ij}^{L}, b_{ij}^{U}\right], \left[a_{ij}^{L}, a_{ij}^{U}\right]\right), & j \in J^c \end{cases} \tag{18}$$

Step 10. The weighted normalized IV-q-ROF decision matrix is constructed using Eq. (19).

$$v_{ij} = w_j r_{ij} \tag{19}$$

Step 11. The score values $S\left(v_{ij}\right)$ are computed via Eq. (8).

Step 12. Overall assessment index values for each alternative and the ideal alternative are calculated using Eq. (20).

$$\varrho_i = \sum_{j=1}^{n} S\left(v_{ij}\right) \quad \forall i. \tag{20}$$

Step 13. The utility index value of each alternative is computed using Eq. (21), where ϱ_0 shows the overall assessment value of the ideal alternative.

$$\zeta_i = \frac{\varrho_i}{\varrho_0} \quad \forall i. \tag{21}$$

Finally, alternatives are ranked in descending order of their ζ_i values.

IV. RESULTS

It is generally accepted that the quality of logistics service is one of the most critical factors determining customer satisfaction and the position of logistics companies in the competitive market. In the face of changing conditions and growing customer demands, logistics companies are forced to react quickly and develop new innovative solutions [57].

In this case, the quality of the logistic service is essential to ensure customer satisfaction. In this context, the following table gives a detailed overview of the literature, quality criteria for logistics services, models for using technologies, and their explanations.

Considering Table 3, general conclusions have been reached, such as drawing attention to the issues in the relevant applications, developing business processes, effective technology management, and providing a perspective on ensuring and managing customer satisfaction and making it sustainable. Based on this, we collected preliminary information on the main aspects, parameters, needs, and characteristics of the quality of logistics services and technology models in companies receiving 3PL logistics services. Furthermore, in examining the general structure of the current problem, we have attempted to determine the criteria and factors used in previous literature studies by conducting a detailed and comprehensive literature review.

Then, considering the dynamics of the sector and the decision-making problem, we established a high-expert committee consisting of two highly experienced experts with extensive knowledge of the problems with technological models in businesses that use third-party logistics services and the quality of logistics services. We have set several requirements for joining the panel of experts, including graduates in related subjects and at least ten years of experience in the industry. Therefore, this study identified 13 candidate experts who used the 3PL logistics service or owned companies receiving 3PL services. At the end of the first elimination process, were 11 experts left. Then, we continued to eliminate them with a rigorous assessment until only ten experts were left. At the end of the preparation phase, we formed an expert group of 10 highly qualified experts. The list of experts and their information are presented in Table 4.

Table 5 shows the experts' linguistic assessments of the importance levels of the criteria.

Appendix A includes the IV-q-ROFNs corresponding to linguistic assessments of the criteria. Table 6 shows the criteria's integrated IV-q-ROF importance values and weight coefficients.

When the weighting results were analyzed, the most critical factor was determined as the "C2.1. reliability, regularity, behaviour, and ease of service use." According to Duan et al. [76], service quality elements such as cost, time, frequency, visibility and security should be examined, and those unsuitable for marketing purposes based on only a single feature should be highlighted. As a result, maintaining

TABLE 3. Criteria and alternatives related to logistics service quality.

Codes	Criteria	Explanation
C1	Logistics Service Quality for Delivery	It expresses delivery-related applications within the scope of service [1].
C1.1	Done on Time	It is the timely and efficient fulfilment of tasks [3], [30].
C1.2	Delivery Time and Request	Logistics service quality is determined by delivery time and demand [58].
C1.3	Order Fulfillment Time	Order processing times and logistical service quality calculations [59].
C1.4	Backorder Time	It is used to describe the backorder processes in logistics service quality [30].
C1.5	Error Handling Rate	It is defined as the computation of errors in business operations [60].
C1.6	Order Dispute Management	It is defined as managing order disputes/inconsistencies [1].
C2	Physical Distribution Service Quality	It relates to corporate processes such as tools, machinery, location, time, and security [3].
C2.1	Reliability, regularity, flexibility, and availability of the service	It is the expression of the service's reliability, regularity, flexibility, and usability [61].
C2.2	Time and Place to Fulfill the Order According to the Contract Terms	These are the difficulties concerning the time and location where the order must be completed under the contract terms [62].
C2.3	Special Delivery Terms	It is a compilation of concerns for special delivery circumstances [63].
C2.4	Consistency of service performance	Concerns about the consistency of service performance [62].
C2.5.	Warranty, safety, and security on delivery	The delivery warranty declares essential safety and security components [64].
C2.6	Reliability of documentation	It expresses the reliability of documentation in logistics service quality [65].
C3	Information Quality Level	It expresses the level of information exchange on the quality of logistics services [66].
C3.1	Managing Order Inconsistencies	It is the management of disturbances caused by inconsistencies in order [67].
C3.2	Knowledge Level of Sales Personnel	It is an expression of the sales personnel's knowledge [68].
C3.3	IT and "EDI" application in customer service	The level of IT and EDI (Electronic Data Interchange) applications in customer service determines the quality of logistical services [3].
C3.4	Shipment Tracking Feature	Applications associated with the shipment tracking feature [1].
C3.5	Availability of order information	It indicates the availability of order information [65].
C3.6	Other Factors (shipment tracking, report generation, etc.)	It includes other elements such as shipment tracking and report generation [69].
C4	Personnel Communication Quality Level	It expresses the quality of communication among employees [69].
C4.1	Attitudes and behaviours of staff in meeting customer satisfaction	It expresses personnel attitudes and behaviours toward meeting customer satisfaction [1].

TABLE 3. *(Continued.)* Criteria and alternatives related to logistics service quality.

Codes	Criteria	Explanation
C4.2	Responsiveness / Understanding of customers' needs and requirements	It expresses responsiveness and comprehension of customer demands and requirements [23].
C4.3.	Personnel Skills / Training	It is the employees' competency level and education [70].
C4.4	Handling customer feedback	It expresses the effort and processes used to deal with customer feedback [68].
C4.5	Cooperation of service personnel	It is an expression of service personnel collaboration [69].
C4.6	Communication Ability / Skills	It represents the staff's communication skills [71].
C5	Other Factors	It refers to different aspects that influence the quality of logistics services [23].
C5.1	Price Sensitivity	It shows the price sensitivity of the quality of logistical services [71].
C5.2	The company's reputation for reliability in the market	It explains the company's reputation for reliability in the market [1].
C5.3	Ethical image of the company	It explains the company's ethical image [1].
C5.4	Environmentally safe/friendly operations	It refers to elements of company operations that are ecologically safe [65].
C5.5	Performance statement and vision for community responsibility	It explains the company's performance statement and collective accountability vision [69].
C5.6	Website design, system availability/reliability, etc.	It explains the business's website design, usability, and reliability [70].
Codes	Alternatives	Explanation
A1	Technology Acceptance Model	It is one of the most powerful and widely used theories for studying individual adoption of new technology [72].
A2	Business-Technology Compliance Model	It is commonly used to explain and predict how the match between business and technological features improves performance and technology adoption [73].
A3	Combined Technology Acceptance and Usage Model	Its purpose is to provide a more comprehensive understanding and forecast of user behaviour than prior models could [74].
A4	Technology - Organization - Environment Model	This model offers a three-stage framework consisting of technological, organizational, and environmental factors [75].

a reasonable and safe level of service is critical. At the same time, the service obtained must be immediately delivered to and used by the customer.

There are two criteria in the second rank order of importance: "C1.2. Delivery Time and Request" and "C3.5. Availability of order information." It would be appropriate to simultaneously evaluate the "Delivery Time and Request" with the delivery time. Eren and Gür [77] define timeliness as the organization's response time to requests, the flow of information, and the speed with which post-delivery support is provided. Timeliness is a crucial factor in supply chains. For customers, the responsiveness of suppliers to business

TABLE 4. Details about experts.

Expert	Experience (years)	Job	Position
E1	15	Logistics operations	Logistics Specialist
E2	11	Logistics operations	Logistics Specialist
E3	16	Academician	Logistics Specialist
E4	10	Logistics manager	Operation management
E5	15	IT manager	IT process management
E6	15	Logistics operations	Shift superintendent
E7	10	Food engineering	Quality assurance specialist
E8	11	Food engineering	Quality assurance specialist
E9	15	Logistician	Quality assurance specialist
E10	12	Human resources	Human resources specialist

needs is an important criterion. The return speed is also a factor since business plans are modelled based on demand performance. The timeliness of the fulfilment of the order according to the returns sent should not affect the planning either. A smooth supply chain must be ensured by minimizing deviations from the specified delivery times for contractors and, thus, for customers. "Availability of Order Information" means complete and accurate preservation and storage of orders and information received.

After applying Eq. (17), the integrated IV-q-ROF decision matrix was constructed, as seen in Table 8.

The weighted normalized IV-q-ROF decision matrix was obtained by conducting normalization and weighting procedures, as seen in Appendix B. On the other hand, the score matrix is given in Table 9.

As seen in Table 9, the best option is A1. Also, the ranking order of the alternatives is A1≻, A2 ≻, A3≻, and A4. Using the factors influencing the quality of logistics services, it was found that the most crucial alternative when choosing the best technology adoption model is the "technology acceptance model." This model shows that perceived compatibility benefits both attitudes toward technology use and perceived usefulness. It is assumed that a system with high compatibility effectively facilitates user transaction processes and improves efficiency [78].

A. COMPARATIVE SENSITIVITY ANALYSIS

Sensitivity analysis is the process of resolving a decision problem by changing the model or parameter inputs. The decision maker may identify which parameter, data, and component are critical or essential to the solution using sensitivity analysis [79]. Furthermore, it is feasible to conduct significant tests, including validity and reliability assessments of the employed methodology, thanks to the input modifications included under the sensitivity analysis umbrella. Among these tests, changing the weight coefficients of the criteria, adding new alternatives to the model, eliminating existing alternatives, changing the values of particular coefficients, and comparing the results obtained via different methods are frequently used. In this subsection, four separate tests will be performed to assess the validity and reliability of the results acquired using the proposed methodology. In this context, the results of criterion weight modifications will be examined first. To investigate the consequences of changes in criterion weights, an approach in which each criterion takes the weight values of other criteria was adopted [51]. As a result, S1-S29 scenarios were produced. In addition, the criteria weight values produced using the equal weights, CRITIC [43], and RANCOM [80]

TABLE 5. Linguistic assessments of criteria by experts.

	C1.1	C1.2	C1.3	C1.4	C1.5	C1.6
E1	MI	HI	HI	VHI	MI	MI
E2	HI	VHI	VHI	VHI	HI	HI
E3	HI	VHI	VHI	VHI	LI	LI
E4	HI	VHI	VHI	VHI	MHI	VLI
E5	HI	VHI	VHI	VHI	VHI	VHI
E6	VHI	VHI	VHI	VHI	VHI	VHI
E7	VHI	VHI	HI	VHI	VHI	VHI
E8	VHI	VHI	HI	HI	VHI	VHI
E9	HI	VHI	VHI	VHI	VHI	VHI
E10	HI	VHI	HI	HI	MI	MI
	C2.1	C2.2	C2.3	C2.4	C2.5	C2.6
E1	VHI	HI	HI	HI	HI	HI
E2	VHI	HI	HI	HI	VHI	VHI
E3	VHI	HI	HI	HI	VHI	VHI
E4	VHI	VHI	VHI	VHI	VHI	VHI
E5	VHI	VHI	HI	MHI	MI	MLI
E6	VHI	VHI	VHI	VHI	VHI	VHI
E7	VHI	VHI	VHI	VHI	VHI	VHI
E8	VHI	VHI	MI	HI	VHI	VHI
E9	VHI	VHI	VHI	VHI	VHI	VHI
E10	VHI	HI	HI	HI	HI	HI
	C3.1	C3.2	C3.3	C3.4	C3.5	C3.6
E1	HI	MI	MHI	VHI	VHI	MI
E2	VHI	HI	HI	VHI	VHI	VLI
E3	VHI	HI	HI	VHI	VHI	VLI
E4	MHI	HI	VHI	VHI	VHI	VHI
E5	LI	VLI	ELI	VHI	VHI	HI
E6	VHI	VHI	VHI	VHI	VHI	HI
E7	VHI	HI	HI	VHI	VHI	HI
E8	VHI	VHI	MI	VHI	VHI	HI
E9	VHI	HI	HI	VHI	VHI	VHI
E10	MI	MI	MI	MI	HI	HI

TABLE 5. ***(Continued.)*** **Linguistic assessments of criteria by experts.**

	C4.1	C4.2	C4.3	C4.4	C4.5	C4.6
E1	HI	VHI	HI	HI	HI	MI
E2	VHI	VHI	HI	HI	HI	HI
E3	VHI	VHI	HI	HI	HI	HI
E4	VHI	VHI	HI	VHI	VHI	VHI
E5	MHI	MI	MLI	LI	VLI	ELI
E6	VHI	VHI	VHI	VHI	VHI	VHI
E7	VHI	VHI	VHI	VHI	HI	VHI
E8	VHI	VHI	VHI	VHI	VHI	VHI
E9	HI	HI	VHI	VHI	HI	HI
E10	VHI	HI	VHI	VHI	HI	HI
	C5.1	C5.2	C5.3	C5.4	C5.5	C5.6
E1	VHI	HI	HI	VHI	HI	MI
E2	VHI	HI	HI	HI	HI	HI
E3	VHI	HI	HI	HI	HI	HI
E4	HI	VHI	VHI	VHI	VHI	VHI
E5	VHI	VHI	HI	MHI	MI	MLI
E6	VHI	VHI	VHI	VHI	VHI	VHI
E7	HI	VHI	VHI	VHI	VHI	VHI
E8	HI	HI	VHI	VHI	VHI	VHI
E9	MI	VHI	VHI	MI	MI	VHI
E10	HI	MI	MI	MI	MI	MI

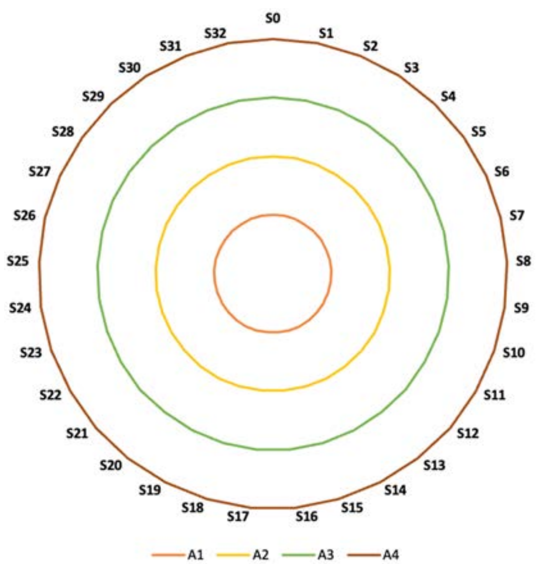

FIGURE 2. **The effects of criterion weight change.**

methods were included in the analysis as distinct scenarios. Thus, sensitivity analysis was conducted using 32 distinct criterion weighting scenarios. Figure 2 shows the obtained results.

TABLE 6. **Weight coefficients of criteria.**

	a_j^L	a_j^U	b_j^L	b_j^U	Score	w_j	Rank
C1.1	0.7253	0.7768	0.2796	0.3310	0.6981	0.0325	21
C1.2	0.7923	0.8426	0.2083	0.2586	0.7673	0.0357	2
C1.3	0.7665	0.8175	0.2352	0.2860	0.7401	0.0345	9
C1.4	0.7841	0.8347	0.2169	0.2674	0.7586	0.0353	5
C1.5	0.7148	0.7682	0.3039	0.3583	0.6861	0.0319	26
C1.6	0.7048	0.7585	0.3257	0.3819	0.6741	0.0314	27
C2.1	0.8000	0.8500	0.2000	0.2500	0.7756	0.0361	1
C2.2	0.7665	0.8175	0.2352	0.2860	0.7401	0.0345	9
C2.3	0.7366	0.7883	0.2685	0.3201	0.7094	0.0330	18
C2.4	0.7406	0.7921	0.2625	0.3137	0.7136	0.0332	17
C2.5	0.7669	0.8184	0.2377	0.2893	0.7404	0.0345	7
C2.6	0.7647	0.8164	0.2421	0.2942	0.7379	0.0344	11
C3.1	0.7376	0.7904	0.2773	0.3312	0.7094	0.0330	19
C3.2	0.6817	0.7337	0.3380	0.3914	0.6533	0.0304	28
C3.3	0.6725	0.7245	0.3519	0.4059	0.6435	0.0300	30
C3.4	0.7844	0.8355	0.2192	0.2705	0.7589	0.0353	4
C3.5	0.7923	0.8426	0.2083	0.2586	0.7673	0.0357	2
C3.6	0.6755	0.7273	0.3542	0.4088	0.6451	0.0300	29
C4.1	0.7702	0.8215	0.2325	0.2836	0.7440	0.0346	6
C4.2	0.7669	0.8184	0.2377	0.2893	0.7404	0.0345	7
C4.3	0.7449	0.7968	0.2625	0.3147	0.7175	0.0334	16
C4.4	0.7538	0.8057	0.2560	0.3087	0.7263	0.0338	12
C4.5	0.7204	0.7719	0.2930	0.3458	0.6918	0.0322	23
C4.6	0.7205	0.7727	0.2996	0.3537	0.6911	0.0322	24
C5.1	0.7473	0.7990	0.2578	0.3095	0.7202	0.0335	13
C5.2	0.7473	0.7990	0.2578	0.3095	0.7202	0.0335	13
C5.3	0.7473	0.7990	0.2578	0.3095	0.7202	0.0335	13
C5.4	0.7304	0.7831	0.2792	0.3320	0.7029	0.0327	20
C5.5	0.7142	0.7669	0.2973	0.3504	0.6865	0.0320	25
C5.6	0.7235	0.7766	0.2908	0.3445	0.6954	0.0324	22

As seen in Figure 1, criterion weight changes did not change the ranking orders of the alternatives. In this context, the solutions obtained for the studied problem are stable. The effects of different q-parameter values on the solutions will be investigated. It is assumed that the decision-maker can select a different q value in q-ROFS based on their preferences. At this point, it was stated that an optimistic outlook is indicated by a q number between 2 and 5, but a pessimistic outlook is indicated by a value greater than 5. Also, the q-ROFWAA operator gives more consistent results than the q-ROFWGA operator when q values are increased [39]. In addition, q values between 1 and 10 are ideal for practical applications because they cover 99% of the unit squares [81]. Examining the q-parameter changes in the solutions is essential within the context of this knowledge.

TABLE 7. Linguistic assessments of alternatives by experts.

		C1.1	C1.2	C1.3	C1.4	C1.5	C1.6	C2.1	C2.2	C2.3	C2.4
E1	A1	H	H	H	H	VL	VL	H	H	VH	VH
	A2	H	H	H	H	H	H	H	H	H	EH
	A3	VH	VH	H	H	H	M	MH	H	H	VH
	A4	MH	H	H	H	ML	L	H	H	H	MH
E2	A1	EH	VH	EH	EH	H	H	EH	VH	VH	EH
	A2	VH	VH	EH	EH	H	H	VH	H	H	EH
	A3	EH	VH	EH	EH	H	H	VH	H	H	EH
	A4	EH	VH	EH	EH	H	H	VH	VL	H	EH
E3	A1	EH	VH	EH	EH	VL	VL	EH	VH	VH	EH
	A2	VH	VH	EH	EH	VL	VL	VH	H	H	EH
	A3	EH	VH	EH	EH	VL	VL	VH	H	H	EH
	A4	EH	VH	EH	H	VL	H	VH	VL	H	EH
E4	A1	EH	EH	EH	EH	EH	MH	EH	EH	H	VH
	A2	VH	VH	EH	H	MH	MH	EH	EH	VH	EH
	A3	EH	H	EH	VH	H	MH	EH	VH	VH	EH
	A4	EH	H	EH	EH	MH	MH	EH	H	VH	EH
E5	A1	VH	EH	VH	H	MH	M	ML	L	VL	EL
	A2	VH	EH	VH	H	MH	M	ML	L	VL	EL
	A3	VH	EH	VH	H	MH	M	ML	L	VL	EL
	A4	VH	EH	VH	H	MH	M	ML	L	VL	EL
E6	A1	EH	EH	EH	EH	EH	EH	.EH	EH	EH	EH
	A2	EH	EH	EH	EH	EH	EH	.EH	EH	EH	EH
	A3	EH	EH	EH	EH	EH	EH	.EH	EH	EH	EH
	A4	EH	EH	EH	EH	EH	EH	.EH	EH	EH	EH
E7	A1	VH	VH	H	H	H	H	VH	VH	VH	H
	A2	H	H	H	VH	VH	H	VH	H	EH	H
	A3	VH	H	VH	H	VH	VH	H	H	VH	VH
	A4	H	MH	H	VH	H	VH	VH	H	VH	H
E8	A1	EH	EH	EH	M	EH	EH	H	EH	EH	M
	A2	VH	M	ML	ML	VH	EH	M	M	EH	M
	A3	VH	VH	M	ML	VH	EH	ML	VH	VH	ML
	A4	EH	VH	ML	M	EH	EH	ML	ML	VH	M
E9	A1	VH	VH	VH	VH	H	H	H	VH	H	H
	A2	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH
	A3	H	H	H	H	H	H	H	H	H	H
	A4	H	H	H	H	H	H	H	H	H	H
E10	A1	H	M	ML	H	H	H	H	M	M	M
	A2	H	H	H	MH	H	H	H	H	M	M
	A3	H	M	ML	MH	M	M	M	M	M	H
	A4	M	M	ML	H	H	H	H	H	MH	H

TABLE 7. *(Continued.)* **Linguistic assessments of alternatives by experts.**

		C2.5	C2.6	C3.1	C3.2	C3.3	C3.4	C3.5	C3.6	C4.1	C4.2
E1	A1	VH	MH	MH	H	MH	MH	H	H	H	H
	A2	H	H	MH	M	MH	H	H	VH	H	M
	A3	MH	MH	L	L	MH	MH	EH	H	H	H
	A4	VH	MH	MH	M	H	VH	H	H	M	MH
E2	A1	VH	EH	VH	H	EH	EH	EH	H	EH	EH
	A2	VH	EH	VH	H	EH	EH	EH	H	H	EH
	A3	VH	EH	VH	H	EH	EH	EH	VH	H	EH
	A4	VH	EH	H	VL	EH	EH	EH	H	H	EH
E3	A1	VH	EH	VL	H	EH	EH	EH	H	EH	EH
	A2	VH	EH	VL	H	EH	EH	EH	H	H	EH
	A3	VH	EH	VL	H	EH	EH	EH	VH	H	H
	A4	VH	EH	VL	VL	EH	EH	EH	H	H	VH
E4	A1	EH	EH	H	MH	EH	EH	EH	MH	EH	EH
	A2	VH	EH	H	MH	VH	EH	EH	MH	EH	EH
	A3	VH	EH	H	MH	H	EH	EH	H	VH	EH
	A4	VH	EH	H	MH	EH	EH	EH	H	VH	EH
E5	A1	EH	VH	H	MH	M	ML	L	VL	EL	EL
	A2	EH	VH	H	MH	M	ML	L	VL	EL	EL
	A3	EH	VH	H	MH	M	ML	L	VL	EL	EL
	A4	EH	VH	H	MH	M	ML	L	VL	EL	EL
E6	A1	EH	EH	EH	EH	EH	EH	EH	EH	EH	EH
	A2	EH	EH	EH	EH	EH	EH	EH	EH	EH	EH
	A3	EH	EH	EH	EH	EH	EH	EH	EH	EH	EH
	A4	EH	EH	EH	EH	EH	EH	EH	EH	EH	EH
E7	A1	MH	EH	H	VH	H	VH	VH	VH	H	H
	A2	H	EH	H	VH	VH	EH	EH	EH	H	VH
	A3	H	EH	VH	VH	VH	VH	VH	H	VH	MH
	A4	H	VH	H	VH	H	MH	VH	VH	H	VH
E8	A1	EH	VH	EH	EH	M	VH	EH	VH	EH	VH
	A2	EH	VH	EH	VH	M	H	VH	H	EH	VH
	A3	EH	VH	EH	VH	M	H	VH	H	EH	VH
	A4	EH	VH	EH	VH	ML	H	VH	H	EH	VH
E9	A1	H	H	H	H	H	EH	H	H	M	H
	A2	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH
	A3	H	H	ML	M	M	ML	ML	M	M	M
	A4	H	H	ML	M	M	ML	ML	H	M	M
E10	A1	ML	ML	H	H	H	H	H	M	M	M
	A2	ML	ML	H	H	H	H	M	M	H	H
	A3	VH	M	L	L	L	L	H	H	VH	H
	A4	H	H	H	ML	L	L	L	L	H	H

Figure 3 depicts changes in criterion weighting coefficients and utility index values in this context.

Figure 3 shows that as the q parameter value increases, the weight coefficients of the criteria converge to each other, with a value of 0.3333. However, it was found that the rank order

TABLE 7. ***(Continued.)*** **Linguistic assessments of alternatives by experts.**

		C4.3	C4.4	C4.5	C4.6	C5.1	C5.2	C5.3	C5.4	C5.5	C5.6
E1	A1	H	MH	H	VH	VH	VH	H	H	M	M
	A2	M	VH	H	VH	VH	MH	H	H	H	M
	A3	VH	MH	EH	MH	H	H	H	MH	H	H
	A4	MH	H	H	H	M	MH	M	H	H	H
E2	A1	H	EH	H	VH	EH	EH	EH	H	H	EH
	A2	H	VH	H	VH	EH	EH	H	H	H	EH
	A3	H	H	H	H	VH	EH	H	H	H	EH
	A4	H	H	H	H	VH	EH	H	H	H	EH
E3	A1	H	EH	H	VH	EH	EH	H	H	H	EH
	A2	H	VH	H	VH	EH	EH	H	H	H	EH
	A3	H	H	MH	H	H	H	H	H	MH	L
	A4	H	H	H	H	H	M	H	L	MH	M
E4	A1	H	EH	VH	VH	MH	EH	EH	MH	EH	EH
	A2	MH	EH	VH	H	MH	EH	EH	H	EH	EH
	A3	MH	EH	H	H	MH	EH	EH	VH	EH	EH
	A4	MH	EH	VH	H	MH	EH	EH	MH	EH	EH
E5	A1	EL	EH	VH	H	MH	M	ML	L	VL	EL
	A2	EL	EH	VH	H	MH	M	ML	L	VL	EL
	A3	EL	EH	VH	H	MH	M	ML	L	VL	EL
	A4	EL	EH	VH	H	MH	M	ML	L	VL	EL
E6	A1	EH	EH	EH	EH	EH	EH	EH	EH	EH	EH
	A2	EH	EH	EH	EH	EH	EH	EH	EH	EH	EH
	A3	EH	EH	EH	EH	EH	EH	EH	EH	EH	EH
	A4	EH	EH	EH	EH	EH	EH	EH	EH	EH	EH
E7	A1	H	MH	MH	H	H	MH	H	MH	M	H
	A2	VH	H	H	H	VH	MH	H	MH	MH	H
	A3	VH	H	H	VH	VH	H	H	VH	MH	VH
	A4	H	MH	H	H	H	VH	VH	VH	H	H
E8	A1	EH	H	H	M	M	EH	EH	H	H	EH
	A2	EH	M	VH	ML	M	EH	EH	H	H	EH
	A3	EH	ML	VH	M	M	EH	EH	H	H	EH
	A4	EH	VH	VH	ML	M	EH	EH	H	H	EH
E9	A1	H	VH	H	VH	M	M	H	M	H	EH
	A2	VH	VH	VH	VH	VH	H	VH	VH	VH	VH
	A3	M	M	M	M	M	M	M	M	M	M
	A4	M	M	M	M	M	M	M	M	M	M
E10	A1	M	M	M	M	H	H	H	H	H	H
	A2	ML	ML	MH	H	H	H	M	M	M	M
	A3	H	H	H	M	M	MH	H	H	H	M
	A4	H	H	H	H	M	MH	M	M	H	H

TABLE 8. **The integrated IV-Q-ROF decision matrix.**

	C1.1				C1.2				C1.3			
	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U
A1	0.85	0.91	0.15	0.21	0.83	0.89	0.17	0.23	0.84	0.90	0.17	0.23
A2	0.79	0.85	0.21	0.26	0.79	0.85	0.22	0.27	0.82	0.88	0.19	0.25
A3	0.84	0.90	0.16	0.22	0.79	0.85	0.22	0.27	0.81	0.87	0.20	0.26
A4	0.83	0.89	0.18	0.24	0.78	0.84	0.23	0.29	0.80	0.87	0.21	0.27
x_{0j}	0.85	0.91	0.15	0.21	0.83	0.89	0.17	0.23	0.84	0.90	0.17	0.23
	C1.4				C1.5				C1.6			
	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U
A1	0.81	0.88	0.20	0.25	0.76	0.83	0.27	0.33	0.72	0.79	0.32	0.38
A2	0.79	0.85	0.22	0.28	0.74	0.80	0.28	0.33	0.75	0.81	0.28	0.33
A3	0.79	0.85	0.23	0.29	0.73	0.78	0.30	0.35	0.73	0.79	0.31	0.37
A4	0.79	0.85	0.22	0.27	0.73	0.79	0.30	0.36	0.75	0.81	0.27	0.33
x_{0j}	0.81	0.88	0.20	0.25	0.73	0.78	0.30	0.36	0.75	0.81	0.27	0.33
	C2.1				C2.2				C2.3			
	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U
A1	0.81	0.87	0.20	0.26	0.80	0.87	0.21	0.27	0.78	0.84	0.24	0.30
A2	0.78	0.84	0.23	0.29	0.75	0.82	0.26	0.32	0.79	0.85	0.23	0.29
A3	0.75	0.81	0.28	0.34	0.73	0.79	0.28	0.34	0.74	0.80	0.28	0.33
A4	0.77	0.83	0.24	0.30	0.67	0.73	0.38	0.44	0.75	0.80	0.27	0.33
x_{0j}	0.81	0.87	0.20	0.26	0.80	0.87	0.21	0.27	0.79	0.85	0.23	0.29
	C2.4				C2.5				C2.6			
	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U
A1	0.78	0.84	0.25	0.31	0.82	0.88	0.19	0.25	0.83	0.89	0.18	0.23
A2	0.82	0.88	0.21	0.27	0.81	0.87	0.20	0.25	0.84	0.90	0.16	0.22
A3	0.81	0.87	0.21	0.27	0.82	0.87	0.19	0.24	0.84	0.90	0.17	0.23
A4	0.79	0.86	0.23	0.30	0.82	0.88	0.18	0.24	0.83	0.89	0.18	0.23
x_{0j}	0.82	0.88	0.21	0.27	0.82	0.88	0.18	0.24	0.84	0.90	0.16	0.22
	C3.1				C3.2				C3.3			
	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U
A1	0.76	0.82	0.26	0.32	0.76	0.82	0.24	0.30	0.80	0.86	0.22	0.28
A2	0.77	0.83	0.25	0.31	0.75	0.80	0.27	0.32	0.80	0.86	0.22	0.28
A3	0.73	0.80	0.31	0.37	0.70	0.76	0.33	0.39	0.76	0.83	0.27	0.33
A4	0.73	0.80	0.29	0.35	0.67	0.73	0.38	0.44	0.78	0.85	0.25	0.31
x_{0j}	0.73	0.80	0.31	0.37	0.76	0.82	0.24	0.30	0.80	0.86	0.22	0.28
	C3.4				C3.5				C3.6			
	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U
A1	0.83	0.89	0.18	0.23	0.83	0.89	0.18	0.24	0.73	0.78	0.30	0.35
A2	0.83	0.89	0.18	0.24	0.83	0.89	0.18	0.24	0.76	0.82	0.27	0.32
A3	0.79	0.86	0.24	0.30	0.83	0.89	0.19	0.25	0.73	0.79	0.29	0.34
A4	0.79	0.86	0.24	0.30	0.80	0.87	0.23	0.29	0.72	0.77	0.31	0.37
x_{0j}	0.83	0.89	0.18	0.23	0.83	0.89	0.18	0.24	0.76	0.82	0.27	0.32

change occurred for $q = 67$ for the first time when the utility index values of the alternatives were examined. In modelling uncertainty, $q = 1$ is used for intuitive fuzzy sets, and $q = 2$ is employed for Pythagorean fuzzy sets [82]. The value of the q parameter can be objectively determined to reflect decision-makers preferences or judgments about the problem effectively. A decision can be reached by assessing the

TABLE 8. ***(Continued.)*** **The integrated IV-Q-ROF decision matrix.**

	C4.1				C4.2				C4.3			
	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U
A1	0.81	0.88	0.21	0.28	0.80	0.87	0.22	0.28	0.74	0.80	0.28	0.34
A2	0.79	0.85	0.23	0.29	0.82	0.88	0.20	0.26	0.74	0.81	0.29	0.35
A3	0.77	0.83	0.25	0.31	0.78	0.84	0.25	0.31	0.76	0.82	0.27	0.33
A4	0.74	0.81	0.29	0.35	0.79	0.85	0.23	0.29	0.73	0.79	0.30	0.36
x_{0j}	0.81	0.88	0.21	0.28	0.82	0.88	0.20	0.26	0.76	0.82	0.27	0.33
	C4.4				C4.5				C4.6			
	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U
A1	0.83	0.89	0.19	0.24	0.74	0.80	0.27	0.32	0.77	0.82	0.24	0.30
A2	0.81	0.87	0.21	0.26	0.77	0.83	0.24	0.29	0.76	0.82	0.24	0.30
A3	0.77	0.83	0.25	0.31	0.77	0.83	0.24	0.30	0.71	0.77	0.31	0.37
A4	0.79	0.85	0.22	0.28	0.76	0.81	0.25	0.30	0.71	0.77	0.30	0.36
x_{0j}	0.83	0.89	0.19	0.24	0.77	0.83	0.24	0.29	0.77	0.82	0.24	0.30
	C5.1				C5.2				C5.3			
	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U
A1	0.77	0.84	0.24	0.30	0.82	0.89	0.19	0.25	0.81	0.87	0.21	0.27
A2	0.80	0.86	0.21	0.27	0.82	0.88	0.19	0.25	0.78	0.85	0.23	0.29
A3	0.71	0.77	0.31	0.36	0.80	0.86	0.22	0.28	0.77	0.84	0.24	0.30
A4	0.69	0.75	0.34	0.39	0.79	0.86	0.23	0.29	0.77	0.83	0.26	0.32
x_{0j}	0.69	0.75	0.34	0.39	0.82	0.89	0.19	0.25	0.81	0.87	0.21	0.27
	C5.4				C5.5				C5.6			
	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U	a_{ij}^L	a_{ij}^U	b_{ij}^L	b_{ij}^U
A1	0.69	0.75	0.33	0.38	0.73	0.80	0.29	0.35	0.84	0.90	0.18	0.24
A2	0.71	0.77	0.30	0.36	0.75	0.81	0.28	0.33	0.82	0.88	0.21	0.27
A3	0.73	0.78	0.29	0.35	0.73	0.79	0.30	0.36	0.79	0.85	0.25	0.31
A4	0.68	0.74	0.35	0.41	0.74	0.80	0.29	0.35	0.79	0.85	0.24	0.30
x_{0j}	0.73	0.78	0.29	0.35	0.75	0.81	0.28	0.33	0.84	0.90	0.18	0.24

data's processability and implications for the solution while accounting for various q values. In general, it is assumed that $q \geq 3$ is adequate to eliminate the different issues observed with $q = 1$ and $q = 2$ [42], [44], [51]. According to this framework, the solutions for the studied problem are reliable and valid. Figure 3 shows that the proposed methodology gives consistent results for the studied problem.

The existence of the rank reversal problem will be examined in the second stage, and a comparison of the findings obtained by the proposed methodology and similar methodologies will be carried out in the third stage. To determine whether the rank reversal problem exists in this context, the results of removing existing alternatives from the problem will be examined first. The results in this scenario are shown in Table 10.

The findings in Table 10 show that the proposed methodology does not lead to a rank reversal problem. In this context, the results of the proposed methodology were reliable and valid. Second, the results of the proposed

TABLE 9. **The score matrix and IV-Q-ROF-ARAS results.**

	C1.1	C1.2	C1.3	C1.4	C1.5	C1.6	C2.1	C2.2	C2.3	C2.4	C2.5
A1	0.1	0.1	0.1	0.09	0.01	0.06	0.09	0.08	0.07	0.07	0.09
A2	0.08	0.09	0.09	0.08	0.01	0.06	0.08	0.07	0.08	0.08	0.09
A3	0.09	0.09	0.09	0.08	0.01	0.06	0.07	0.07	0.07	0.08	0.09
A4	0.09	0.08	0.08	0.08	0.01	0.06	0.08	0.05	0.07	0.08	0.09
x_{0j}	0.1	0.1	0.1	0.09	0.01	0.06	0.09	0.08	0.08	0.08	0.09
	C2.6	C3.1	C3.2	C3.3	C3.4	C3.5	C3.6	C4.1	C4.2	C4.3	C4.4
A1	0.09	0.01	0.07	0.07	0.1	0.1	0.06	0.08	0.08	0.07	0.09
A2	0.1	0.01	0.06	0.07	0.1	0.1	0.06	0.08	0.09	0.07	0.08
A3	0.09	0.01	0.05	0.06	0.08	0.09	0.06	0.07	0.07	0.07	0.07
A4	0.09	0.01	0.05	0.07	0.08	0.08	0.05	0.07	0.08	0.06	0.08
x_{0j}	0.1	0.01	0.07	0.07	0.1	0.1	0.06	0.08	0.09	0.07	0.09
	C4.5	C4.6	C5.1	C5.2	C5.3	C5.4	C5.5	C5.6	ϱ_i	ζ_i	Rank
A1	0.07	0.07	0.01	0.09	0.08	0.06	0.06	0.09	2.2	0.97	1
A2	0.07	0.07	0.01	0.09	0.08	0.06	0.06	0.08	2.14	0.95	2
A3	0.07	0.06	0.02	0.08	0.07	0.06	0.06	0.07	2.03	0.9	3
A4	0.07	0.06	0.02	0.08	0.07	0.05	0.06	0.07	1.98	0.88	4
x_{0j}	0.07	0.07	0.02	0.09	0.08	0.06	0.06	0.09	2.26		

TABLE 10. **Testing rank reversal problems.**

	Original	Excluding A1 & A2	Excluding A1 & A3	Excluding A1 & A4
A1	1	-	-	-
A2	2	-	1	1
A3	3	1	-	2
A4	4	2	2	-
	Original	Excluding A2 & A3	Excluding A2 & A4	Excluding A3 & A4
A1	1	1	1	1
A2	2	-	-	2
A3	3	-	2	-
A4	4	2	-	-

TABLE 11. **Comparison of results obtained via different methods.**

	IV-q-ROF-ARAS	IV-q-ROF-TOPSIS	IV-q-ROF-CODAS
A1	1	1	1
A2	2	2	2
A3	3	3	4
A4	4	4	3

methodology will be compared with those of two previously published methods, IV-q-ROF-TOPSIS [52] and IV-q-ROF-CODAS [83]. Table 11 shows the findings obtained via these methods.

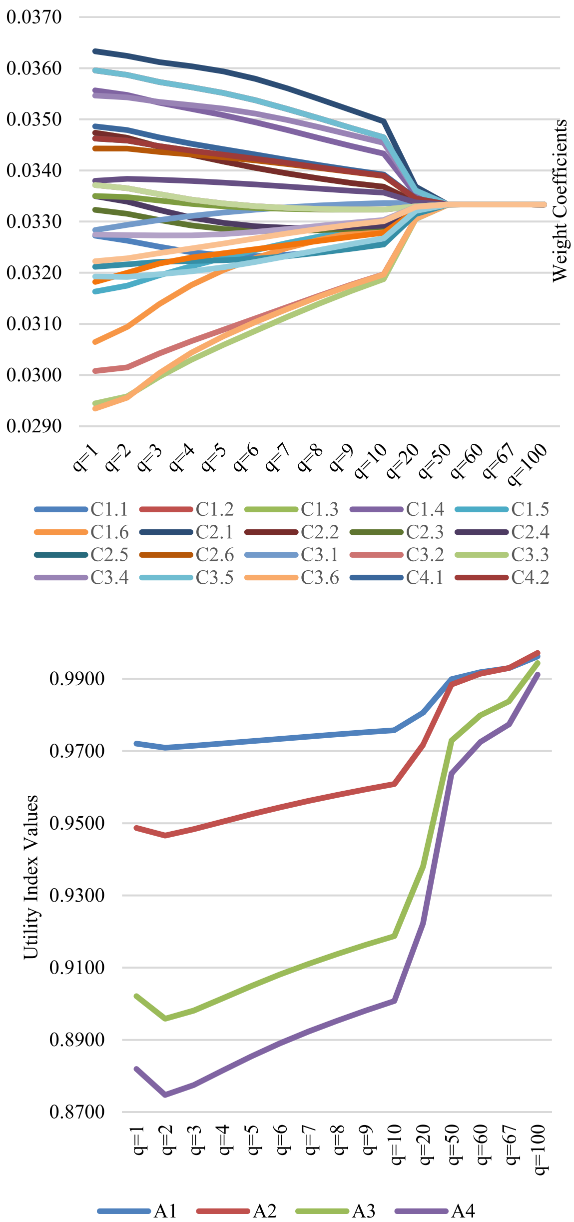

FIGURE 3. **The effects of q-parameter value change.**

Table 11's results show that the A1 alternative was at the top of the three rankings. The ranking orders generated by IV-q-ROF-ARAS and IV-q-ROF-TOPSIS were identical. In this context, it is clear that the results of the proposed methodology are reliable and valid.

V. DISCUSSION

Providing logistics services, one of the key factors affecting how customers perceive the quality of a product, is a crucial component of marketing when considering logistics as a service sector. This situation reveals the importance of considering logistics and marketing together. The logistics and marketing departments must work together to ensure that logistics excellence gives companies a competitive advantage [62]. Meeting customers' expectations and receiving positive feedback about the service they receive can be considered indicators of logistics service quality. Thus, logistics service quality is increasingly important for customers and companies [65].

In this context, the study's results should be reviewed and discussed. The comparison of the findings with the literature reveals the similarities and differences of this study. Table 6 lists the main final weights of the criteria affecting the quality of logistics service for the beneficiary companies of the 3PL service.

"Reliability, regularity, flexibility, and service usability" was identified as the most crucial criterion. The result obtained supports the research of Beniusiene and Petukiene [84], Wang [85], Korucuk [1], Huma et al. [33], and Michalski and Montes-Botella [34]. The logistics service quality, which includes all stages of the supply chain, contributes to gaining a competitive advantage and improving customer satisfaction by increasing the effectiveness of marketing measures. Therefore, the service obtained through implementing these processes must be reliable, smooth, and usable. At the same time, it is essential to keep up with the changing market conditions and to offer a service at the highest level flexibly.

The importance level of the "Delivery time and request" and "availability of ordering information" criteria was ranked second. The result for the factor "delivery time and demand" is consistent with the research of Cui et al. [86], Jiang et al. [87], and Bahamdain et al. [88]. 3PL companies that provide services must respond to delivery times and demand, respond to their customers' requests and needs, and solve problems. It is essential to run the process at the most desirable level, especially regarding order fulfilment speed, order confirmation cycle, and error handling rates associated with the delivery and requested times. Delivery times and demand are the critical frameworks for customer value creation.

The result for the "availability of ordering information" factor is consistent with research by Thai et al. [3] and Vu et al. [89]. The order cycle, one of the fundamental elements of the logistic system, has a decisive impact on the efficiency and costs of the entire process. It is known that every wrong operation in order to obtain information affects the whole process. This can result in the loss of a dissatisfied customer. Proper and secure storage of order information, especially when using technology and software, is essential to the process and beyond. It also contributes to the efficiency and effectiveness of order management and feedback.

Employing the weights associated with the factors used in the quality of logistics services at the level of the companies receiving the 3PL service, the models used to adopt the perfect technology were selected. The "A1. technology acceptance model" was the most ideal choice. The result agrees with the studies by Lu et al. [90], Muk and Chung [91], Purwanto et al. [92], and Aydın and Taşdelen [93]. It was stated that this model affects attitudes towards phenomena that shape perceived ease of use and intention. Besides, it was claimed that this model directly impacts the perceived ease of use.

On the other hand, it was also concluded that behavioural intention affects actual behaviour [94]. In other words, various studies have been conducted with the subjective goal of understanding the business adoption of information technology. However, the limitation of the research results to the problems of a specific company prevented the conclusion of general validity. The adaptability of this model to the acceptance behaviour of all technologies has closed the gap in the literature as a universal model. One of the most important reasons for the widespread use of the technology acceptance model is that it is simple and easy to understand [95].

VI. CONCLUSION

In a marketing environment where the demands and needs of customers are changing every day, the efficiency of quality practices for logistics services and the integration of technologies have become significant challenges for companies. One way that businesses can maintain their existence and increase customer satisfaction through sustainable strategies is through the efficacy and efficiency of logistics service quality procedures. In this context, the study is based on selecting the model that will be used to implement the ideal technology by determining the weight of the factors affecting the quality of logistics services in companies receiving 3PL services in Istanbul. An extensive literature review found very few studies on the factors affecting logistics service quality in companies receiving 3PL services and the selection of models used to adopt the ideal technology.

This study provides an outlook on future research and offers the opportunity to compare it with other studies. Due to the MCDA methods used in the study, the study stands out from other studies and is intended to fill a gap in the literature about the industry and the subject. On the other hand, the study helps to evaluate the quality practices for logistics services, which play a quantitative and guiding role in companies receiving 3PL services, enabling the company to effectively raise the quality control requirements of logistics services to a high level.

On the other hand, the study also contains various ambiguities and contradictions between policymakers and practitioners. Therefore, this situation allows us to assess the practical prospects for logistics service quality in the companies benefiting from 3PL services. At this point, the findings guide avoiding potential problems when implementing logistics service quality and selecting a technological model.

However, due to the improvement in the quality of logistics services, the intensity of economic activity is increasing. Adopting the technology model is essential to avoid deterioration in transaction quality and loss of customers. Therefore, companies must continually monitor and measure how customers rate the quality of their logistics services. It guarantees the maintenance and improvement of its market position regarding the quality of logistics services and the compatibility of technology models. In this context, companies need to understand customers' requirements proactively, provide satisfactory answers to customers' needs, gain their trust by satisfying customers the first time, and continually improve their systems to retain customers. The issues addressed depend on efficiency in terms of the quality of logistics services and the integration of technological models.

This study provides specific findings to reveal the determinants of logistics service quality in companies. It contains a variety of theoretical contributions to the relevant literature. In addition, since the quality of logistics services is assessed based on customer perception, this will guide professionals working in this area to improve the quality of logistics services and ensure efficiency when choosing a technology model. Customer satisfaction is the key to the company's survival in the market. Messenger attaches importance to the quality of logistics services. In this way, long-term business relationships can be built, and customer loyalty can be ensured. For this reason, where competition is rapidly intensifying, it is essential to understand companies' assessments of the quality of logistics services, select a technological model, and allocate the resources necessary to fulfil customers' orders and solutions.

In this study, we first tried to list the factors that can influence the quality of logistics services and then determine to what extent they influence the choice of technology model. First, the results of the field research carried out by the research objective were evaluated. Conclusions are then drawn regarding the contribution of this research to the relevant literature and practitioners. Finally, the study's limitations are noted, and suggestions for future academic research are provided.

A. PRACTICAL AND MANAGERIAL IMPLICATIONS

This study evaluated the connections and influences of factors affecting logistics service quality in businesses receiving 3PL services. In addition, the best technology adoption model was investigated. In the field of quality improvement of logistics services, it is part of research on technology acceptance patterns in companies receiving 3PL services and ways to achieve critical components in their usage at the desired level. This study, which takes logistics service quality practices as a starting point for companies receiving 3PL services and is based on theories about technology acceptance patterns, provides a wealth of information for business leaders and stakeholders. The methods of integrating the logistics service quality resources between supply and demand and the adoption models of the technologies explore the mechanism of action and allow an evaluation of complete transparency. In other words, it contributes to the relevant literature system and enriches the theory of evaluating the logistics service quality of the received 3PL service.

As another contribution to the study, it provides an opportunity to evaluate the factors affecting the logistics service quality. It also leads to a basic model for selecting the optimal alternative for a given decision problem. In other words, it provides a reasonable and healthy outcome environment, considering similar and different aspects of the decision problem. The study not only focuses on an isolated and unique relationship in the quality of logistics services but also considers the entire logistics service system from a broad perspective and allows optimization of the logistics service system. Decision-makers and stakeholders can use the proposed model based on customer satisfaction. It also allows companies to plan a new road route that activates the supply chain. Thus, it makes a positive contribution to relevant decision problems by presenting a set of new or more appropriate criteria. At the same time, another contribution of the study is the motivation of the authors to conduct future research on this topic in various areas and industries.

B. LIMITATIONS AND FUTURE RESEARCH

This study, like many others, has limitations. The first is a lack of available data to compare. At the same time, the restricted number of panellists and the use of the structured form approach as a data collection tool are limitations. Other constraints include time, control, and a limited budget. Another constraint is the region and sector in which the study is carried out.

Another limitation of the study is the attention paid to selecting the model to use when adopting the ideal technology for logistics service quality factors and the need for adequate research on other service quality studies and practices at the logistics service level. In other words, if the study in question is subjective in certain respects, that is a fact and another reason for the qualification.

The study has important implications for the future. Entrepreneurs and those interested in the topic can evaluate the adoption of technology models in logistics service quality and transfer the discussed issues to a scientific framework. Furthermore, future studies will examine relevant research results to allow comparisons between different decision-making environments. Future studies can evaluate the current situation using various analyses and statistical methods. In addition, the research methodology and methods can be applied to diverse and complex decision-making problems in other industries.

APPENDIX A
THE CORRESPONDING IV-Q-ROFNS FOR THE LINGUISTIC ASSESSMENTS OF CRITERIA BY EXPERTS

The table is presented in a separate file titled Appendix A.

APPENDIX B
THE CORRESPONDING IV-Q-ROFNS OF THE LINGUISTIC TERMS RELATED TO ALTERNATIVES

The table is presented in a separate file titled Appendix B.

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SELÇUK KORUCUK received the B.S. degree in business administration from Inonu University, the M.S. degree in business administration from Gumushane University, and the Ph.D. degree in business administration from Ataturk University. He is currently an Associate Professor of operations management with Giresun University, Turkey. He teaches courses in operations management and operations research. He has published more than 50 journals in the related operations management and sustainability fields. His research interests include process management, logistics, fuzzy logic, and decision-making.

AHMET AYTEKİN received the M.S. and Ph.D. degrees in quantitative methods from Anadolu University, Eskişehir, Turkey. He is currently an Associate Professor with the Department of Business and Administration, Artvin Çoruh University, Hopa, Artvin, Turkey. His research interests include decision analysis, MCDA/MCDM, fuzzy MCDA/MCDM, data analysis, sustainability, environmental sustainability, performance analysis, applied multivariate statistics, supply chain management, logistics, and structural equation modeling.

SARBAST MOSLEM received the Ph.D. degree in transportation engineering from Budapest University of Technology and Economics, in 2020. He is currently a Postdoctoral Research Fellow with the School of Architecture Planning and Environmental Policy, University College Dublin. He has been involved in several research projects on national and international levels. He worked on several EU projects. He is a Coordinator and a Principal Investigator of the VOTE-TRA Project, funded by the Science Foundation Ireland. He is the author or coauthor of several conference papers and journal articles. His research interests include transport engineering and planning, logistics, supply chain management, soft computing, decision policy, fuzzy set theory, sustainability, and citizen science.