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Q-ROF Fuzzy TOPSIS and VIKOR Methods for the Selection of Sustainable Private Health Insurance Policies

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Abstract: As a result of the inability of people to meet their demands in the face of increasing demands, people tend to have private health insurance in addition to the general health insurance offered as a public service. Due to the increasing trend of taking out private sustainable health insurance, the number of private sustainable health insurance plans in the health insurance market has increased significantly. Therefore, people may be confronted by a wide range of private health insurance plan options. However, there is limited information about how people analyze private health insurance policies to protect their health in terms of benefit payouts as a result of illness or accident. Thus, the objective of this study is to provide a model to aid people in evaluating various plans and selecting the most appropriate one to provide the best healthcare environment. In this study, a hybrid fuzzy Multiple Criteria Decision Making (MCDM) method is suggested for the selection of health insurance plans. Because of the variety of insurance firms and the uncertainties associated with the various coverages they provide, q-level fuzzy set-based decision-making techniques have been chosen. In this study, the problem of choosing private health insurance was handled by considering a case study of evaluations of five alternative insurance companies made by expert decision makers in line with the determined criteria. After assessments by expert decision makers, policy choices were compared using the Q-Rung Orthopair Fuzzy (Q-ROF) sets Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Q-ROF VIšeKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) methods. This is one of the first attempts to solve private health policy selection under imprecise information by applying Q-ROF TOPSIS and Q-ROF VIKOR methods. At the end of the case study, the experimental results are evaluated by sensitivity analysis to determine the robustness and reliability of the obtained results.

Keywords: multi-criteria decision making; fuzzy logic; Q-ROF TOPSIS; Q-ROF VIKOR; sustainable health insurance policy selection

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1. Introduction

Although it is impossible to date precisely when and where insurance started, the existence of human beings and the concept of insurance have always been intertwined. The necessary conditions for a person to feel safe have been shaped in different ways in the unique conditions of each age. Insurance is the main factor in the formation of capital accumulation. The way in today's world for people to take precautions against the elements that threaten their property and life safety is to share the risk of a certain period in return for a certain premium.

In accordance with the founding philosophy of the political system in Turkey, there is a social security system. The health needs of citizens are guaranteed by the state. The intensity of public services in the field of health and the inadequacy of service quality has created a suitable market environment for private sector representatives in this field. The high cost of health care services provided by the private sector has also been effective in the formation of insurance activities in this field. Private health insurance is insurance that undertakes the risk of covering the costs of examination, treatment, and medicine when going to a private health institution in case of any illness or injury due to an accident [1]. The number of health institutions providing private health services at various scales is increasing day by day. Additionally, these health institutions have created hospital brand chains, mostly in metropolitan areas.

Companies issuing private health insurance policies allow their insured to benefit from private health services in return for a premium, which is realized through the establishment of collective agreements with health care providers individually or with chains. In their preference, the insured considers private health institutions in terms of their validity, as well as the policy premiums. Private health insurance is divided into four sections: substitute, supportive, complimentary, and repetitive [1–14]. In this study, supportive health insurance is discussed.

Many criteria affect the choice of private health policy, such as the number of treatments it covers and its scope. Due to the uncertainties experienced in these decision-making processes, multi-criteria decision making methods have been preferred. TOPSIS and VIKOR methods, which are multi-criteria decision making methods, have been expanded due to uncertainties in the insurance sector being quite high, and these expansions have been based on Q-ROF Sets (Q-ROFS) cluster sets, as they will reduce uncertainty with a sharper distinction and allow decision makers to evaluate in a broader framework. Many academics concentrate on Q-ROF because of its capacity to handle uncertainty more efficiently and because Q-ROF Soft Set (Q-ROFSs) possess overall anticipation of the symmetry of trustworthy and inaccurate information in a greater space.

Atanassov [15], who developed the fuzzy set theory proposed by Zadeh [16], extended it to the Intuitionistic Fuzzy Set (IFS) by adding the non-membership degree to the fuzzy set theory. In the evaluations of decision makers, the condition that the sum of membership degrees and those without membership degrees ($\mu A(x) + vA(x) = 1$) cannot exceed 1 limits studies [17]. For this reason, Yager [18] developed the Pythagorean Fuzzy Sets (PFS) band with a recommended membership degree ($(\mu A(x))^2 + (vA(x))^2 \leq 1$). A Q-ROFSs is introduced with the condition ($(\mu A(x))^q + (vA(x))^q \leq 1$) [18,19]. Therefore, the Q-ROFSs appears as an IFS and PFS when $q = 1$ and $q = 2$, respectively. Researchers have successfully applied Yager's fuzzy set theory proposal in most areas with different addition methodologies. On the other hand, Khan et al. [20] presented Dombi aggregation operators for the PFS methodology developed by Yager in a sample decision-making problem. Khan et al. [21–23] presented a new model within the scope of a generalized IFS; Batool et al. [24] presented a new decision-making methodology for the Pythagorean probabilistic hesitant fuzzy set. Ashraf et al. [25,26] introduced the sine trigonometric operation laws and discussed the effectiveness of the sine trigonometric Pythagorean fuzzy clustering operators based on them in decision-making algorithms.

Since logarithmic operations offer better predictions than algebraic operations, Jin et al. [27] proposed the spherical fuzzy set (SFS), a new method based on logarithmic operations and logarithmic addition operators. Rafiq et al. [7] measured the similarities between SPFs based on the cosine function. Ashraf and Abdullah [26] and Ashraf et al. [28] presented SFSs because the areas of the PFS are limited and there is no independent grade assignment. Ashraf et al. [29] proved the effectiveness of the algorithm they developed with Dombi nom different aggregation operators in an SFS. Ashraf et al. [30] developed spherical Einstein aggregation operators. Narayanamoorthy et al. [31] used a Fermatean fuzzy set-based Fully Multiplicative Form (MULTIMOORA) analysis and Ratio Analysis-Based Multi-Objective Optimization and Removal Effects of Criteria (MEREC) hybrid method in the solar power plant site selection problem. Narayanamoorthy et al. [32] created a single-valued intuitive trapezoidal neutrophisophilic fuzzy set.

The proposed methodology's main objectives are to (1) investigate the evaluation process of selecting a private health insurance plan and (2) apply q-level fuzzy sets to decision support tools. The consistency of the results was compared by performing sensitivity analyses at different q-levels, and similar solutions were obtained. During the decision-making process, people face several challenges in terms of the selection of a private health insurance plan, such as examining the relationship between criteria and alternatives, modeling uncertainty, calculating importance weights for decision attributes, and evaluating various options. The proposed methodology addresses such challenges and improves the decision-making ability of private insurance customers. Therefore, the use of the proposed Q-Rung Orthopair Fuzzy TOPSIS and VIKOR methods to select the best private health insurance policy represents one of the first studies to combine two MCDM methods in this area. Additionally, the nature of the Q-Rung Orthopair Fuzzy method allows for a broader view when analyzing private insurance policies.

The rest of this study is presented as follows: In Section 2 of this study, studies using the multi-criteria method in the insurance sector and previous studies using Q-ROF TOPSIS and Q-ROF VIKOR methods are mentioned. In Section 3, the Q-ROF methodology and its application to VIKOR and TOPSIS are described. In Section 4, an explanation of the application made to select the policy is provided, and in the last chapter, Section 5, the results are discussed and the conclusion given.

2. Literature Review

When purchasing a private health policy in the insurance sector, it is important to choose the policy with the lowest cost and choose the most suitable policy for treatment coverage. When the literature is examined, there are many studies using MCDM methods in relation to both performance measurement and risk assessment of companies operating in the insurance sector. The literature review section that follows is divided into two parts. In the first part, MCDM methods in the insurance sector are discussed, and in the second part, studies prepared using Q-ROF TOPSIS and Q-ROF VIKOR methods are mentioned.

2.1. MCDM Methods in the Insurance Industry

Işık [33] proposed an integrated method to evaluate the financial performance of the Axa Company between 2011 and 2020 in his study. Weights were determined using an integrated use of subjective (Analytical Hierarchy Process, AHP) and objective (Criteria Importance Through Inter-criteria Correlation, CRITIC) methods. By including the WEDBA method in the model, which is not used much in the literature, he expressed the financial instability of the company between the specified years. Yücenur [34] used AHP–analytic network process (ANP)–VIKOR methods, while Tayyar and Dinçer [35] selected an automobile insurance policy by using TOPSIS and VIKOR methods. Mandic [36] proposed a model based on the AHP technique for motor vehicle insurance risk assessment. Alenjagh [37] integrated ANP with the preference ranking organization method for enrichment of evaluations (PROMETHEE) to assess the financial performance of insurance companies operating on the Tehran Stock Exchange.

Mishra et al. [38] discussed service quality in insurance companies by using the Tomada de Decisao Interativa Multicriterio (TODIM) method based on the Shapley function and deviation measure. Khan et al. [22] listed the purchase of private health insurance in different consumer groups, Wollmann et al. [39] ranked health insurance companies according to the determined criteria, and Azizi et al. [40] listed the factors affecting cost management in the field of insurance activity using the AHP method. Saeedpoor et al. [11] evaluated the service quality of insurance companies in Iran in the context of life insurance with SERVQUAL, Fuzzy AHP, and Fuzzy TOPSIS methods.

While Puelz [6] used the AHP method to select the best insurance company, Kahraman et al. [41] used Fuzzy AHP and Fuzzy TOPSIS methods to select health insurance options such as health savings accounts, flexible spending accounts, and health reimbursement arrangement. Yücenur and Demirel [42] found the most suitable alternative for a foreign investor in terms of local insurance companies in Turkey by using the extended VIKOR method. Sehhat et al. [12] evaluated seven insurance companies using AHP and TOPSIS. Mikhailov and Almulhim [43] used Fuzzy ANP to evaluate alternative group health insurance plans such as social security insurance, direct health insurance, private health insurance, and cooperative health insurance. Ecer and Pamucar [44] evaluated the health service performance of insurance companies in the pandemic situation with the MARCOS method. The criteria used in these studies and the purposes of the studies are briefly listed in Table 1.

Table 1. Criteria used in studies in the literature.

Author	Criteria Used	Purpose
Işık [17]	Premiums received, technical profit, financial assets, cash and cash equivalents, net profit/loss, paid capital, total assets, total liabilities, losses paid	Financial performance
Ecer and Pamucar [33]	Effectiveness, responsibility, network, age, payback period, premium Pprice	Determining the COVID-19 pandemic performance of insurance companies in terms of healthcare services
Mishra et al. [38]	Confidence, responsiveness, reliability, tangibles	Service quality in insurance companies
Yücenur [34]	Price, coverage content, after-sales service, distribution channel, organizational structure	Motor insurance policy
Tayyar and Dinçer [35]	Company factor, guarantees, policy price	Motor insurance policy
Kahraman et al. [41]	Eligibility, portability, catch-up contribution, ownership, funding, health plan arrangement, tax treatment, usability for non-medical expenses	Selection of the best health insurance option
Sehhat et al. [12]	Development, after-sales service, productivity, sales network, customer satisfaction, information technology, composition and growth	Ranking of insurance companies
Alenjagh [37]	Liquidity, leveraged, profitability, exchange, market	Financial performance
Saeedpoor et al. [11]	Tangibility, reliability, assurance, responsiveness, empathy	Service quality of insurance companies
Khan et al. [22]	Insurance awareness, brand, trust in insurance provider, purpose of buying HI, policy features and benefits, premium amount, payment options, customer service, claim settlement history	Ranking of private health's critical purchase factors
Mikhailov and Almulhim [43]	The insurance company's reputation, reliability of the insurance company, clarity of insurance policy terms, quality of the insurance company, efficiency of the health service providers network, health benefits, types of medical treatment, emergency expenses, availability of additional health benefits, financial benefits, period of insurance, geographical scope of coverage worldwide, flexibility of the insurance contract, accessibility of deductible insurance plan, premiums prices, availability of the health service providers, accessibility of the health service providers, specialized team availability, communication channels availability	Health insurance plan selection
Wolmann et al. [39]	Location, effectiveness, responsiveness, speed, price, coverage	Ranking of health insurance companies

Table 1. *Cont.*

Author	Criteria Used	Purpose
Mandic [36]	Vehicle price, number of penalty points, vehicle age, number of hours per day, week, and month spent driving, driver's age, vehicle purpose, price of vehicle spare parts, vehicle price implies the risk, geographic setting, size of place of residence, value of working hours in the service, infrastructure, state of traffic culture	Risk assessment model in motor vehicle insurance
Azizi et al. [40]	Human productivity, competition inflation rate, information technology, damage, coverage	To list the factors affecting cost management in the field of insurance activity
Yücenur and Demirel [42]	Price, profitability, portfolio structure, portfolio size, sales channel structure, brand equity, organizational quality, solvency ratio	Selection of an insurance company for a foreign investor
Puelz [6]	Net payment index, contractual flexibility, financial strength, cash value accumulation	Life insurance contract choice

2.2. Q-ROF TOPSIS and Q-ROF VIKOR Methods

Uncertainties in the insurance sector make it difficult for decision makers to make decisions. It was decided that fuzzy numbers would be used in this study since we could not make definite and clear decisions when we evaluated them in terms of different criteria.

Q-ROFS effectively fill the gaps in FS and IFS theory. After the advent of Q-ROFS, different types of approaches have been presented to improve searches with different aggregation operators and information measures [17]. The frequency of Q-ROFS methods and addition operators can be seen in Figure 1, which was created according to the literature reviewed.

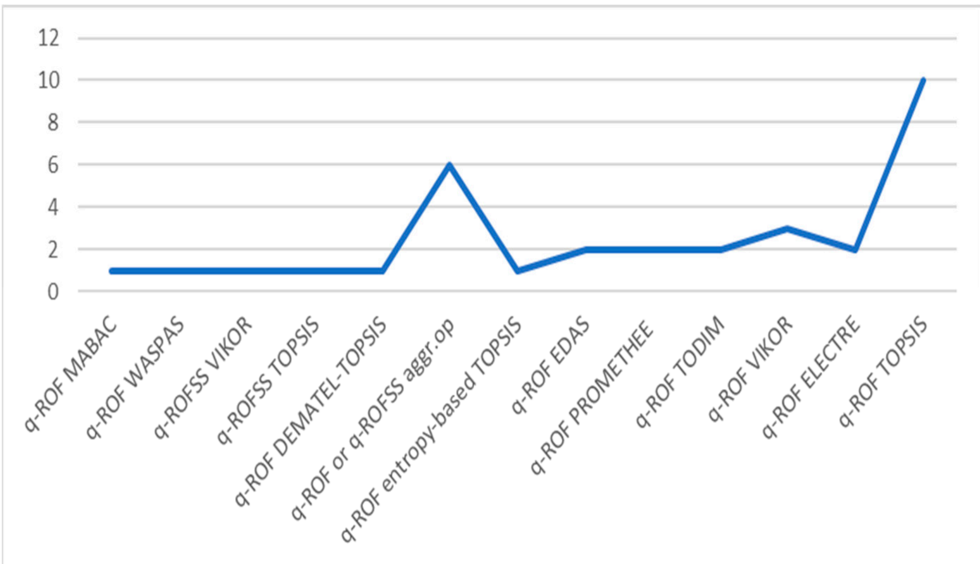


Figure 1. Frequency of use of the methods.

In the literature, various studies have been conducted for different purposes in different sectors using Q-ROF methods and operators. A summary of these studies is presented in Table 2. Even if other multi-criteria methods were used in the studies examined, only methods with Q-ROF content are indicated in the table. As Table 2 and Figure 1 show, Q-ROF TOPSIS is the most used method, and the most common practice is supplier selection. In this study, comparisons will be made using Q-ROF TOPSIS and Q-ROF VIKOR methods. The proposed model enhances existing multi-criteria decision making models by combining two distinct methods and fuzzy logic concepts in a generalized form. The hybrid model proposed seeks to solve general multi-criteria decision making issues. In this study, the private health insurance policy selection problem is adopted as a case scenario.

The membership degree of an element can be represented using a set of q-rung functions thanks to a fuzzy set extension known as q-rung fuzzy sets. Various fields, including decision making, pattern recognition, image processing, and control systems, have used q-rung fuzzy sets [45]. For instance, q-rung fuzzy sets were utilized in the creation of a fuzzy controller for a mobile robot with two wheels [46]. They have also been employed to categorize medical images [21]. In this paper, TODIM and VIKOR methods are extended with Q-Rung Orthopair Fuzzy sets to capture vague information precisely. The proposed approach is applied to a case study in the field of private health insurance policy, where decision making is often complicated by the presence of multiple criteria and conflicting objectives. The results show that the Q-Rung Orthopair Fuzzy TODIM and VIKOR methods are effective tools for handling imprecise information in decision-making processes. Moreover, the use of Q-rung Orthopair Fuzzy sets allows decision makers to consider both positive and negative aspects of the evaluated alternatives, leading to more comprehensive and accurate evaluations. Overall, this study highlights the potential of Q-Rung Orthopair Fuzzy sets as a valuable tool for decision making in complex and uncertain environments. Further research could explore their application in other fields and compare their performance with other existing methods.

Q-rung fuzzy logic models complex systems more effectively than conventional fuzzy logic systems. The extension of TOPSIS and VIKOR methods with q-rung fuzzy logic helps to improve decision-making processes. The private health insurance policy selection problem could be analyzed by group decision-making methods, as it was in the works [47–49].

Table 2. A brief summary of Q-ROF application in MCDM methods.

Author	Sector	Purpose	Q-ROF TOPSIS	Q-ROF ELEC-TRE	Q-ROF VIKOR	Q-ROF TODIM	Q-ROF PROMETHEE	Q-ROF EDAS	Q-ROF Entropy-Based TOPSIS	Q-ROF or Q-ROFSs	Q-ROF DEMATEL-TOPSIS	Q-ROFSS TOPSIS	Q-ROFSS VIKOR	Q-ROF WASPAS	Q-ROF MABAC
Taghipour et al. [13]	Call Center Organization	The factors that influence supplier selection for speech recognition	√												
Pınar et al. [5]	Turkish Company	Green supplier selection	√												
Doğu [50]	Medical	Ranking the length of stay in the hospital	√												
Pınar and Boran [4]	Construction	Supplier selection	√	√											
Pınar [3]	Third Party Logistics	Provider selection	√												
Tian et.al. [51]	Pork Supplier Companies	Green supplier selection	√			√									
Alkan and Kahraman [52]	COVID-19 Pandemic	Evaluation of government strategies	√			√	√	√	√						
Akram and Shumaiza [53]	Construction Project	Contractor selection	√	√	√		√			√					
Cheng et al. [54]	Manufacturing	Sustainability enterprise risk management	√		√										
Uslu et.al. [55]	Sustainable Healthcare Policy	Evaluating vaccine hesitancy criteria in the COVID-19 period									√				
Riaz et.al. [9]	Construction Company and Education	Supplier selection and university choice								√		√	√		
Riaz et al. [10]	Vendor of Baby Cribs	Green supplier selection								√					
Rani and Mishra [8]	Alternative Fuel Technology	Alternative fuel technology selection	√											√	
Li et al. [47]	Household Goods	Refrigerator selection						√		√					
Wang et.al. [56]	Construction	Construction project selection								√					√
Krishankumar et al. [57]	Construction	Green supplier selection			√					√					

3. Methodology

The selection of private health insurance is a fuzzy decision problem for decision makers when considered in terms of evaluation criteria. In this section, Q-ROFS theory is briefly discussed and the Q-ROF TOPSIS and Q-ROF VIKOR methods are then introduced. Q-rung fuzzy logic is a form of fuzzy logic that seeks to overcome some of the limitations of conventional fuzzy logic system. Q-rung fuzzy logic is founded on the concept of Q-Rung Orthopair Fuzzy sets, a generalization of fuzzy sets. Q-rung fuzzy logic has many benefits over other fuzzy logic systems, such as handling uncertainty and imprecision better than conventional fuzzy logic systems. It also handles non-monotonic reasoning better than traditional fuzzy logic systems. In addition, q-rung fuzzy logic models complex systems more effectively than conventional fuzzy logic systems. The extension of the TOPSIS and VIKOR methods with q-rung fuzzy logic helps to improve decision-making processes.

Summary of the q-rung information-based studies' weaknesses: There are parameters, such as risk parameters, whose values vary for various practical applications; consequently, their optimization is required. To effectively provide preferences and comprehend inferences, specialists must be trained in the preferred style.

3.1. Q-ROF TOPSIS Method

A flowchart of the Q-ROF TOPSIS method is illustrated in Figure 2.

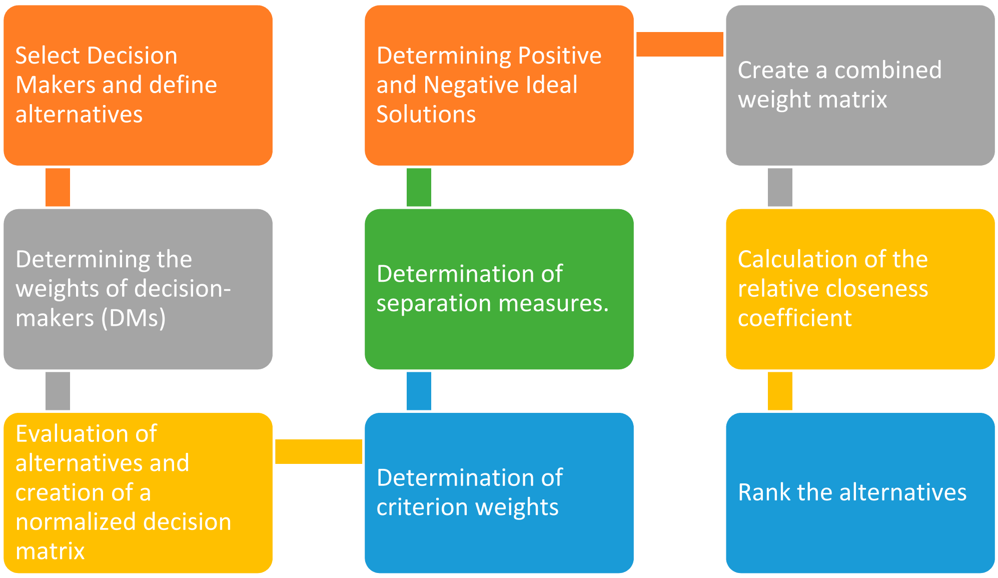


Figure 2. Flowchart of the Q-ROF TOPSIS method.

The Q-ROF TOPSIS method proposed by Pınar and Boran [4] consists of seven steps. X = $\{X_1, X_2, X_3, \ldots, X_n\}$ is a set of n criteria and A = $\{A_1, A_2, A_3, \ldots, A_m\}$ is a set of m alternatives. The algorithm's steps are explained below.

Step 1: *Determining the weights of decision makers (DMs).*

The weights of the decision makers determined by linguistic terms were converted into q-level fuzzy numbers according to the scale in Table 3.

Table 3. Linguistic terms.

Linguistic Terms	Abbreviations	Q-ROFN
Extremely High	EH	(0.95, 0.15)
Very High	VH	(0.85, 0.25)
High	H	(0.75, 0.35)
Medium High	MH	(0.65, 0.45)
Medium	M	(0.55, 0.55)
Medium Low	ML	(0.45, 0.65)
Low	L	(0.35, 0.75)
Very Low	VL	(0.25, 0.85)
Extremely Low	EL	(0.15, 0.95)

A Q-ROFN is indicated as

$$D_k = [\mu_k, v_k, \pi_k]$$

The score function of the final Q-ROF Number (Q-ROFN) is calculated using Equation (1) (Wang, 2018, [56]).

$$\lambda_k = \frac{\left(1 + \mu_k^q(x_i) - v_k^q(x_i)\right)}{\sum_{k=1}^{l}\left(1 + \mu_k^q(x_i) - v_k^q(x_i)\right)},$$

where

$$\sum_{k=1}^{l} \lambda_k = 1 \quad (1)$$

Step 2: *Evaluation of alternatives and creation of a normalized decision matrix.*

All alternative evaluations made by the DMs are converted into a Q-ROFN using Table 3. In Equation (2), it is supposed that $\alpha_k = \langle \mu_k(x), v_k(x)\rangle (k = 1,2,3, \ldots, l)$ is a group of Q-ROFN sets (Q-ROFNs) combined with DM weights (λ_k) using the Q-ROF weighted averaging (Q-ROFWA) operator proposed by Liu and Wang [49].

$$q - \text{ROFWA}(\alpha_1, \alpha_2, \ldots, \alpha_l) = \left\langle (1 - \prod_{k=1}^{l} (1 - \mu_k(x)^q)^{\lambda_k})^{\frac{1}{q}}, \prod_{k=1}^{l} v_k(x)^{\lambda_k} \right\rangle \quad (2)$$

The final state of the Q-ROF decision matrix is as shown in Equation (3).

$$R = \begin{bmatrix} \mu_1(x_1), v_{A1}(x_1), \pi_{A1}(x_1), \mu_{A1}(x_2), v_{A1}(x_2), \pi_{A1}(x_2) \ldots \mu_{A1}(x_n), v_{A1}(x_n), \pi_{A1}(x_n) \\ \mu_{A2}(x_1), v_{A1}(x_1), \pi_{A1}(x_1), \mu_{A2}(x_2), v_{A1}(x_2), \pi_{A1}(x_2) \ldots \mu_{A2}(x_n), v_{A1}(x_n), \pi_{A1}(x_n) \\ \vdots \ddots \vdots \\ \mu_{Am}(x_1), v_{Am}(x_1), \pi_{Am}(x_1), \mu_{Am}(x_2), v_{Am}(x_2), \pi_{Am}(x_2) \ldots \mu_{Am}(x_n), v_{Am}(x_n), \pi_{Am}(x_n) \end{bmatrix} \quad (3)$$

where $R = (r_{ij})$ and $((\mu_{Ai}(x_j), v_{Aj}(x_j), \pi_{Aj}(x_j))$, $(i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n)$.

Step 3: *Determination of criterion weights.*

In order to determine the importance (Wj) of the criteria, the linguistic terms evaluated by the DMs are converted into Q-ROFNs using Equation (4).

$$W_j = \frac{\sum_{k=1}^{l} \lambda_k \left(1 + \mu_k^q(x_j) - v_k^q(x_j)\right)}{\sum_{j=1}^{n} W_j \sum_{k=1}^{l} \lambda_k \left(1 + \mu_k^q(x_i) - v_k^q(x_i)\right)} \quad (4)$$

where $W = [w_1 + w_2 + w_3 + \ldots + w_j]$ and $w_j = (\mu_j, v_j, \pi_j)$, $(j = 1,2,3, \ldots, n)$.

Step 4: *Create a combined weight matrix.*

The aggregated weight matrix (R′) is created with the Equations (5)–(7) (Liu and Wang, 2018, [58]).

$$w_k \alpha_1 = \left((1 - (1 - \mu_1(x)^q)^{w_k})^{\frac{1}{q}}, v_1(x)^{w_k} \right) \quad (5)$$

$$\pi_{Ai}(x_j) = \left(1 - \mu^{q}_{Ai}(x_j) - v^{q}_{Ai}(x_j)\right)^{1/q}, \quad (6)$$

$$R' = \begin{bmatrix} \mu_{A1}w(x1), v_{A1}w(x1), \pi_{A1}w(x1), \mu_{A1}w(x_n), v_{A1}w(x_n), \pi_{A1}w(x_n) \\ \mu_{A2}w(x1), v_{A1}w(x1), \pi_{A1}w(x1), \mu_{A2}w(x_n), v_{A1}w(x_n), \pi_{A1}w(x_n) \\ \vdots \ddots \vdots \\ \mu_{Am}w(x1), v_{Am}w(x1), \pi_{Am}w(x1), \mu_{Am}w(x_n), v_{Am}w(x_n), \pi_{Am}w(x_n) \end{bmatrix} \quad (7)$$

$r'ij = (\mu'_{ij}, v'_{ij}, \pi'_{ij}) = (\mu_{Ai}\, w(x_j), v_{Ai}w(x_j), \pi_{Ai}w(x_j))$ is an element of the R′ matrix.

Step 5: *Determining positive and negative ideal solutions.*

The Q-ROF positive ideal solution (A^*) maximizes the benefit criteria while minimizing the cost criteria. On the other hand, the Q-ROF negative ideal solution (A^-) maximizes the benefit criteria while minimizing the cost criteria. A^* and A^- values are calculated with Equations (8)–(12).

$$A^* = \mu_{A*W}(x_j), v_{A*W}(x_j), \pi_{A*W}(x_j) \text{ and } A^- = \mu_{A-W}(x_j), v_{A-W}(x_j), \pi_{A-W}(x_j) \quad (8)$$

where

$$\mu_{A*W}(x_j) = ((\max_i \mu_{A_i}w(x_j)\ |j \in j_1), (\min_i \mu_{A_i}w(x_j)\Big|\ j \in j_2)) \quad (9)$$

$$v_{A*W}(x_j) = ((\min_i v_{A_i}w(x_j)\Big|\ j \in j_1), (\max_i v_{A_i}w(x_j)|\ j \in j_2)) \quad (10)$$

$$\mu_{A-W}(x_j) = ((\min_i \mu_{A_i}w(x_j)\ |j \in j_1), (\max_i \mu_{A_i}w(x_j)|\ j \in j_2)) \quad (11)$$

$$v_{A-W}(x_j) = ((\max_i v_{A_i}w(x_j)\,|\, j \in j_1), (\min_i v_{A_i}w(x_j)\Big|\ j \in j_2)) \quad (12)$$

Step 6: *Determination of separation measures.*

The distance measures suggested by Pınar and Boran [49] were calculated using Equations (13) and (14).

$$S_i^* = \sqrt[p]{\frac{1}{2n}\sum_{j=1}^{n}\left\{\begin{array}{l} \left|(1-k)(\mu_{A_i}w(x_j) - \mu_{A^*W}(x_j)) + k\left(\sqrt[q]{1-v^q_{Ai}w(x_j)} - \sqrt[q]{1-v^q_{A^*w}(x_j)}\right)\right|^p + \\ \left|(1-k)(v_{A_i}w(x_j) - v_{A^*W}(x_j)) + k\left(\sqrt[q]{1-\mu^q_{Ai}w(x_j)} - \sqrt[q]{1-\mu^q_{A^*W}(x_j)}\right)\right|^p \end{array}\right\}} \quad (13)$$

$$S_i^- = \sqrt[p]{\frac{1}{2n}\sum_{j=1}^{n}\left\{\begin{array}{l} \left|(1-k)(\mu_{A_i}w(x_j) - \mu_{A-W}(x_j)) + k\left(\sqrt[q]{1-v^q_{Ai}w(x_j)} - \sqrt[q]{1-v^q_{A-w}(x_j)}\right)\right|^p + \\ \left|(1-k)(v_{A_i}w(x_j) - v_{A-W}(x_j)) + k\left(\sqrt[q]{1-\mu^q_{Ai}w(x_j)} - \sqrt[q]{1-\mu^q_{A-W}(x_j)}\right)\right|^p \end{array}\right\}} \quad (14)$$

where $p = 1, 2, \ldots, n$ and $k = \frac{(\frac{1}{2}q^2 + \frac{3}{2}q - \frac{1}{3})}{(q^2+3q+1)}$, $k \in \left[\frac{1}{3}, \frac{1}{2}\right]$

Step 7. *Calculation of the relative closeness coefficient (Ci_*)*

Ci_* is calculated using Equation (15).

$$Ci_* = \frac{S_i^-}{S_i^+ = S_i^-} \text{ where } 0 \le C_{i*} \le 1 \quad (15)$$

3.2. Q-ROF VIKOR Method

A flowchart of the Q-ROF VIKOR method is illustrated in Figure 3.

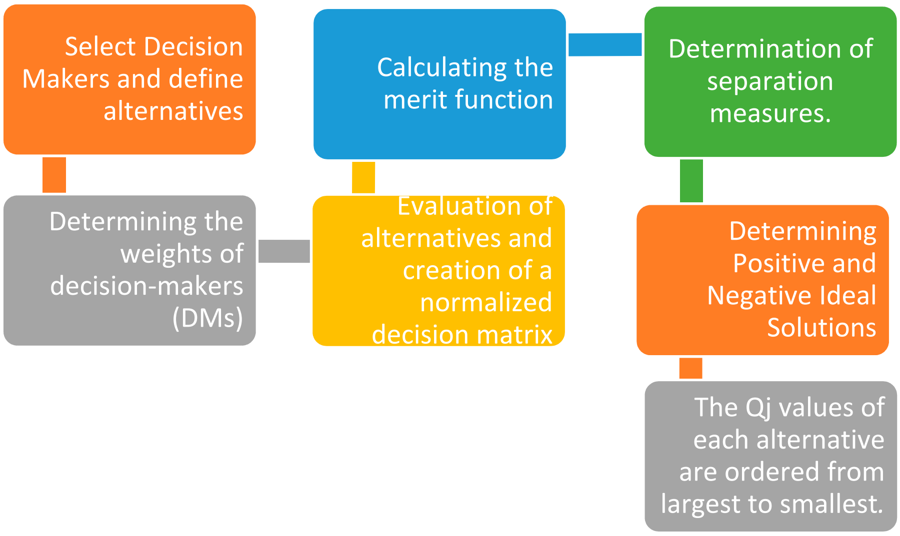


Figure 3. Flowchart of the Q-ROF VIKOR method.

The current Q-ROF VIKOR method proposed by Krishankumar et al. [57] was used. Below are the steps of this method.

Step 1: *The first four steps available in the Q-ROF VIKOR method are repeated in the same way to create the weighted decision matrix.*

Step 2: *Determining positive and negative ideal solutions.*

Benefit and cost criteria are determined and the positive ideal solution and negative ideal solution (PIS, NIS) are calculated using Equations (16) and (17).

$$Q^{PIS} = \underset{j\,\in\,benefit}{max}(M(Q_j)) \text{ or } \underset{j\,\in\,cost}{min}(M(Q_j)) \tag{16}$$

$$Q^{NIS} = \underset{j\,\in\,benefit}{min}(M(Q_j)) \text{or} \underset{j\,\in\,cost}{max}(M(Q_j)) \tag{17}$$

Step 3: *Determination of separation measures.*

With the help of Equations (18) and (19), the Si and R_i values of each alternative are calculated.

$$Si = \sum_{j=1}^{n} w_j \frac{d\,(Q_j\,,\,Q^{PIS})}{d\,(Q^{PIS},\,Q^{NIS})} \tag{18}$$

$$R_i = \underset{j\,\in\,n}{max}\left(w_j \frac{d\,(Q_j\,,\,Q^{PIS})}{d\,(Q^{PIS},\,Q^{NIS})} \right) \tag{19}$$

The Euclidean distance formula (Du [59]) in Equation (20) was used for the distances between Q-ROFNs.

$$\text{d}\,(Q_1,\,Q_2) = \sqrt{\left(\mu_1^q - \mu_2^q\right)^2 + \left(v_1^q - v_2^q\right)^2 + \left(\pi_1^q - \pi_2^q\right)^2} \tag{20}$$

w_j is the weight of the jth criteria, and the total number of criteria is n.

Step 4: *Calculating the merit function.*

The merit function Q_i^{mf} of each alternative is calculated using Equation (21).

$$Q_i^{mf} = v\left(\frac{Si - S^*}{S^- - S^*}\right) + 1 - v\left(\frac{Ri - R^*}{R^- - R^*}\right) \tag{21}$$

where $v \in [0, 1]$ is the strategy of the DMs. In this study, v is taken as 0.5.

$$S^- = max_i\,(S_i\,),\; S^* = min_{\,i}\,(S_i\,)$$

$$R^{-} = max_i\ (R_i\ ),\ R^{*} = min\ _i\ (R_i\ )$$

Step 5: *The Qj values of each alternative are ordered from largest to smallest.*

4. Case Study

This study addresses the health insurance selection problem for insurance purchased from five insurance companies operating in Turkey. Important criteria affecting health policy selection were determined by literature screening and expert assessments. The proposed model improves the current multi-criteria decision making models by combining two different methods and generalized fuzzy logic concepts. The proposed hybrid model aims to solve general multi-criteria decision making problems. The private health insurance policy selection problem is accepted as a case scenario in this research. Accordingly, five insurance companies were compared in terms of 10 criteria using Q-ROF TOPSIS and Q-ROF VIKOR methods. The specified criteria descriptions and sources of the criteria are provided in Table 4. All the determined criteria are benefit criteria.

Table 4. Criterion explanations.

No	Criteria	Research	Description
C_1	Premium Eligibility	Sehhat et al. [12] Yücenur and Demirel [42]	The level of compliance between policy coverage and the premium to be paid.
C_2	Company Brand Strength and Value	Azizi et al. [40] Saeedpoor et al. [11] Puelz [6]	The degree of trust the company has created in customers.
C_3	Contracted Hospital Chain	Azizi et al. [40] Sehhat et al. [12] Puelz [6]	The hospital chains where the services covered by the policy can be obtained differ depending on service quality.
C_4	Number of Inspections	Azizi et al. [40] Saeedpoor et al. [11]	The number of examinations that are conducted annually in outpatient treatment.
C_5	Efficiency in Emergencies	Sehhat et al. [12] Yücenur and Demirel [42] Puelz [6]	The success of fast transportation to the patient in any emergency and transfer to the nearest health institution.
C_6	Age Limit Acceptance	Azizi et al. [40] Mikhailov and Almulhim [43] Yücenur and Demirel [42]	Insurance companies have determined an age limit because they consider insuring those above a certain age risky within the scope of the regulation of private health policies.
C_7	Renewal Guarantee	Sehhat et al. [12] Saeedpoor et al. [11] Mikhailov and Almulhim [43]	When the health policy starts being used, expenses that spread over the years may occur in the continuation of treatment. Companies that want to avoid the high costs this may entail may refrain from renewing the policy. The renewal guarantee processes vary according to the number of policy renewals and the usage status of the insured.
C_8	Renewal Premium Eligibility	Azizi et al. [40] Saeedpoor et al. [11] Yücenur and Demirel [42]	Some companies apply additional fees for renewal policies in the following years due to the frequency of use of the policy by the insured or high expense items.
C_9	Private Physician Coverage	Azizi et al. [40] Mikhailov and Almulhim [43] Puelz [6]	Determination of whether it covers private doctor examination fees other than contracted health institutions.
C_{10}	Validity Abroad	Sehhat et al. [12] Yücenur and Demirel [42] Puelz [6]	The geographical scope of the insurance is whether it is valid in countries other than the Republic of Turkey.

Decision makers were chosen from private health insurance customers. The expertise of the decision makers has been determined based on the length of time they have been private health insurance customers, which is defined as follows:

DM_1 = EH (0.95, 0.15), DM_2 = MH (0.65, 0.45), and DM_3 = M (0.55, 0.55)

$$\lambda_{DM_1} = \frac{\left(1 + 0.95^3 - 0.15^3\right)/2}{(0.927 + 0.592 + 0.500)} = 0.4592$$

$$\lambda_{DM_2} = \frac{\left(1 + 0.65^3 - 0.25^3\right)/2}{(0.927 + 0.592 + 0.500)} = 0.2931$$

$$\lambda_{DM_3} = \frac{\left(1 + 0.55^3 - 0.55^3\right)/2}{(0.927 + 0.592 + 0.500)} = 0.2477$$

The linguistic terms of firm evaluations of the decision makers are given in Table 5. These linguistic terms were converted into Q-ROFNs using Table 3.

Table 5. Decision maker ratings of alternatives in linguistic terms.

	Insurance Company	DM_1	DM_2	DM_3	Criteria	Insurance Company	DM_1	DM_2	DM_3
C_1	A_1	VH	M	VL	C_6	A_1	MH	ML	M
	A_2	MH	EH	VH		A_2	M	L	ML
	A_3	H	H	H		A_3	VH	M	H
	A_4	VH	VH	MH		A_4	EH	MH	EH
	A_5	EH	M	MH		A_5	H	H	VH
C_2	A_1	VH	MH	MH	C_7	A_1	M	MH	MH
	A_2	M	M	MH		A_2	M	M	M
	A_3	H	H	M		A_3	M	MH	MH
	A_4	H	VH	MH		A_4	EH	VH	H
	A_5	EH	EH	H		A_5	EH	EH	H
C_3	A_1	H	VH	H	C_8	A_1	L	H	L
	A_2	H	H	EH		A_2	L	VH	ML
	A_3	MH	H	H		A_3	MH	MH	M
	A_4	H	M	H		A_4	ML	M	ML
	A_5	EH	EH	VH		A_5	EH	EH	VH
C_4	A_1	H	M	MH	C_9	A_1	VH	H	H
	A_2	M	ML	M		A_2	M	MH	L
	A_3	H	MH	H		A_3	MH	H	MH
	A_4	H	H	VH		A_4	MH	ML	EH
	A_5	H	VH	H		A_5	EH	VH	VH
C_5	A_1	MH	M	M	C_{10}	A_1	M	MH	H
	A_2	M	M	L		A_2	VH	MH	H
	A_3	M	M	MH		A_3	H	H	MH
	A_4	ML	L	M		A_4	H	H	M
	A_5	EH	VH	VH		A_5	EH	VH	EH

The Q-ROF matrix normalized using the Q-ROFWA operator in Equation (2) is shown in Table 6.

Table 6. Normalized decision matrix.

		C_1			C_2			C_3			C_4		
	A_1	0.731	0.427	0.810	0.770	0.344	0.795	0.786	0.317	0.784	0.683	0.425	0.845
	A_2	0.850	0.282	0.713	0.579	0.523	0.872	0.839	0.284	0.728	0.525	0.578	0.872
	A_3	0.750	0.350	0.812	0.716	0.391	0.831	0.710	0.393	0.834	0.726	0.377	0.826
	A_4	0.819	0.289	0.753	0.770	0.337	0.796	0.709	0.400	0.834	0.781	0.322	0.788
	A_5	0.863	0.288	0.694	0.928	0.185	0.580	0.935	0.170	0.562	0.786	0.317	0.784
		C_4			C_6			C_7			C_8		
	A_1	0.602	0.502	0.869	0.583	0.527	0.869	0.610	0.493	0.868	0.559	0.600	0.848
	A_2	0.516	0.594	0.868	0.484	0.628	0.862	0.550	0.550	0.874	0.651	0.525	0.834
R	A_3	0.579	0.523	0.872	0.775	0.342	0.791	0.610	0.493	0.868	0.629	0.473	0.864
	A_4	0.459	0.650	0.856	0.917	0.207	0.604	0.900	0.215	0.638	0.485	0.619	0.866
	A_5	0.911	0.198	0.618	0.781	0.322	0.788	0.928	0.185	0.580	0.935	0.170	0.562
		C_9			C_{10}								
	A_1	0.804	0.300	0.768	0.646	0.464	0.858						
	A_2	0.556	0.560	0.867	0.787	0.323	0.783						
	A_3	0.685	0.418	0.846	0.730	0.372	0.824						
	A_4	0.784	0.382	0.773	0.716	0.391	0.831						
	A_5	0.911	0.198	0.618	0.932	0.174	0.570						

The importance evaluations of the criteria made by the decision makers were converted into Q-ROFNs using Table 3, and the weights of the criteria were then determined using Equation (4), as shown in Table 7.

Table 7. Importance and weight of the criteria.

Weight of the DMs	DM_1		DM_2		DM_3		**Criterion Weight**
	0.4592	0.4592	0.2931	0.2931	0.2477	0.2477	
C_1	0.45	0.65	0.85	0.25	0.95	0.15	0.095
C_2	0.95	0.15	0.85	0.25	0.85	0.25	0.126
C_3	0.85	0.25	0.75	0.35	0.85	0.25	0.112
C_4	0.65	0.45	0.95	0.15	0.75	0.35	0.105
C_5	0.95	0.15	0.35	0.75	0.55	0.55	0.094
C_6	0.95	0.15	0.65	0.45	0.25	0.85	0.095
C_7	0.95	0.15	0.75	0.35	0.65	0.45	0.113
C_8	0.95	0.15	0.85	0.25	0.95	0.15	0.130
C_9	0.65	0.45	0.35	0.75	0.45	0.65	0.068
C_{10}	0.75	0.35	0.15	0.95	0.35	0.75	0.061

In Table 8, the weighted decision matrix is given by combining the criteria weights and the normalized decision matrix.

Table 8. Aggregated weighted decision matrix.

R′ =

	C_1			C_2			C_3			C_4		
A_1	0.359	0.922	0.554	0.420	0.874	0.636	0.416	0.879	0.629	0.340	0.914	0.581
A_2	0.443	0.886	0.601	0.299	0.922	0.575	0.457	0.868	0.630	0.253	0.944	0.522
A_3	0.371	0.905	0.593	0.382	0.889	0.623	0.365	0.900	0.605	0.366	0.903	0.599
A_4	0.418	0.888	0.609	0.420	0.872	0.640	0.364	0.902	0.602	0.403	0.888	0.616
A_5	0.454	0.888	0.591	0.567	0.809	0.661	0.558	0.819	0.651	0.407	0.887	0.617
	C_4			C_6			C_7			C_8		
A_1	0.284	0.937	0.536	0.275	0.941	0.527	0.306	0.923	0.570	0.291	0.936	0.539
A_2	0.240	0.952	0.497	0.225	0.957	0.483	0.273	0.934	0.547	0.345	0.919	0.566
A_3	0.272	0.941	0.527	0.387	0.903	0.590	0.306	0.923	0.570	0.332	0.907	0.601
A_4	0.212	0.960	0.471	0.507	0.861	0.614	0.517	0.840	0.646	0.250	0.939	0.538
A_5	0.499	0.859	0.624	0.391	0.898	0.600	0.550	0.826	0.647	0.584	0.794	0.670
	C_9			C_{10}								
A_1	0.365	0.921	0.553	0.266	0.954	0.482						
A_2	0.234	0.961	0.462	0.341	0.934	0.527						
A_3	0.296	0.942	0.515	0.309	0.942	0.514						
A_4	0.352	0.937	0.512	0.302	0.945	0.506						
A_5	0.450	0.896	0.575	0.458	0.899	0.562						

4.1. Insurance Company Selection with the Q-ROF TOPSIS Method

In this section, the steps of the Q-ROF TOPSIS method are indicated by considering the combined weighted decision matrix. The Q-ROF PIS and Q-ROF NIS values in Table 9 were calculated using Equations (8)–(12). The q-value is taken as 3.

Table 9. Positive and negative ideal solution values.

$A^* =$	C_1	0.454	0.886	0.609	$A^- =$	C_1	0.359	0.922	0.554
	C_2	0.567	0.809	0.661		C_2	0.299	0.922	0.575
	C_3	0.558	0.819	0.651		C_3	0.364	0.902	0.602
	C_4	0.407	0.887	0.617		C_4	0.253	0.944	0.522
	C_5	0.499	0.859	0.624		C_5	0.212	0.960	0.471
	C_6	0.507	0.861	0.614		C_6	0.225	0.957	0.483
	C_7	0.550	0.826	0.647		C_7	0.273	0.934	0.547
	C_8	0.584	0.794	0.670		C_8	0.250	0.939	0.538
	C_9	0.450	0.896	0.575		C_9	0.234	0.961	0.462
	C_{10}	0.458	0.899	0.562		C_{10}	0.266	0.954	0.482

Separation measures were calculated with the help of Equations (13) and (14). The closeness values to the ideal solution were then calculated, and the rankings of the alternatives are presented in Table 10.

Table 10. Proximity values and ranking of alternatives.

	S^*	S^-	Ci^*	*Rank*
A_1	0.099	0.034	0.254	4
A_2	0.112	0.021	0.156	5
A_3	0.093	0.040	0.300	3
A_4	0.075	0.059	0.439	2
A_5	0.006	0.127	0.953	1

The ranking of insurance companies according to the Ci^* results was calculated as follows: $A_5 > A_4 > A_3 > A_1 > A_2$. Therefore, the most appropriate alternative is accepted to be A_5, and the least appropriate alternative is determined to be A_2.

4.2. Insurance Company Selection with the Q-ROF VIKOR Method

In this part, the remaining steps of the Q-ROF VIKOR method are applied by considering the combined weighted decision matrix and criterion weights. The best and worst values of the criteria were calculated with the help of Equations (16) and (17) and are given in Table 11.

Table 11. Best and worst values of the criteria.

Criteria	Best Values			Worst Values		
C_1	0.862	0.288	0.693	0.730	0.426	0.810
C_2	0.927	0.185	0.580	0.579	0.523	0.871
C_3	0.935	0.170	0.562	0.709	0.399	0.833
C_4	0.786	0.317	0.783	0.525	0.577	0.871
C_5	0.910	0.197	0.618	0.459	0.650	0.851
C_6	0.916	0.209	0.604	0.483	0.627	0.868
C_7	0.927	0.185	0.580	0.550	0.550	0.873
C_8	0.935	0.170	0.562	0.484	0.618	0.861
C_9	0.910	0.197	0.618	0.555	0.559	0.867
C_{10}	0.931	0.174	0.570	0.645	0.463	0.857

Si^-, Si^+, Ri^-, and Ri^+ values are shown in Table 12.

Table 12. Values of Si and Ri.

Si^-	Si^+	Ri^-	Ri^+
0.804	0.046	0.130	0.046

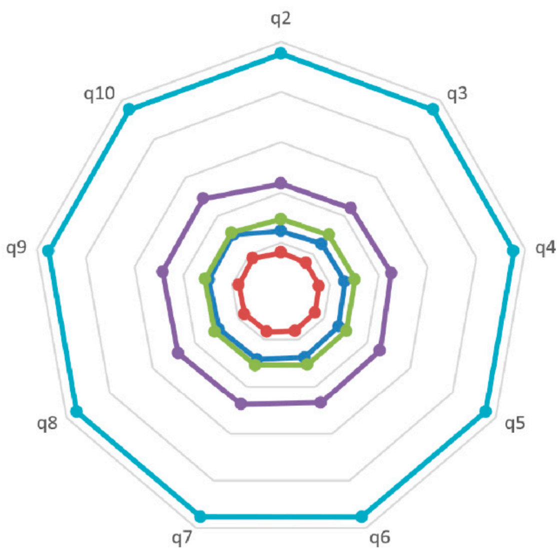
Si, Ri, and Qi values were calculated using Equations (18)–(21) and are indicated in Table 13.

Table 13. Values of *Si*, *Ri*, and *Qi*.

Alternatives	*Si*	*Ri*	*Qi (v = 0.5)*	*Rank*
A_1	0.7852	0.1192	0.9209	4
A_2	0.8042	0.1257	0.9723	5
A_3	0.7744	0.1122	0.8723	3
A_4	0.5506	0.1304	0.8326	2
A_5	0.0465	0.0465	0.0000	1

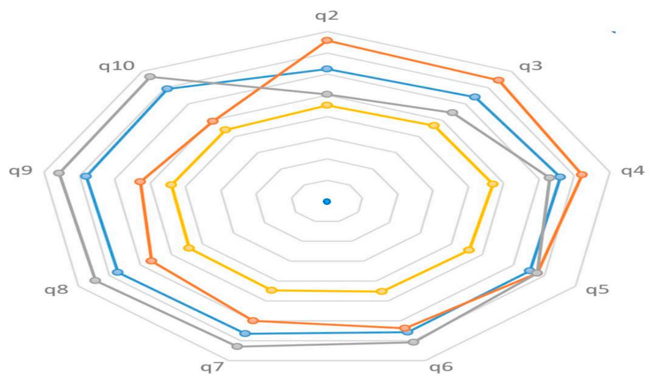
The ranking of insurance companies according to the *Qi* results is as follows: $A_5 > A_4 > A_3 > A_1 > A_2$. Therefore, the most appropriate alternative is accepted to be A_5, and the least appropriate alternative is determined to be A_2. The results are the same as with the Q-ROF TOPSIS method.

To show the consistency of the results and to show the stability and reliability of the q-value, the changes in the model were followed by resolution at different q-levels (2–10) in both methods. Parameter analysis of the Q-ROF TOPSIS method is given in Figure 4, and analysis of the Q-ROF VIKOR method is given in Figure 5.



	q2	q3	q4	q5	q6	q7	q8	q9	q10
A5	0.9529	0.9530	0.9529	0.9528	0.9528	0.9528	0.9528	0.9529	0.9529
A4	0.4344	0.4392	0.4515	0.4610	0.4689	0.4754	0.4808	0.4854	0.4894
A3	0.2939	0.3000	0.3023	0.3044	0.3065	0.3083	0.3099	0.3112	0.3123
A2	0.1601	0.1563	0.1555	0.1576	0.1615	0.1658	0.1701	0.1742	0.1781
A1	0.2460	0.2544	0.2610	0.2682	0.2759	0.2830	0.2897	0.2957	0.3011

Figure 4. Q-value analysis for Q-ROF TOPSIS.



	q2	q3	q4	q5	q6	q7	q8	q9	q10
A5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A4	0.8266	0.8326	0.8350	0.8292	0.8258	0.8235	0.8218	0.8204	0.8193
A3	0.8523	0.8723	0.9153	0.9381	0.9536	0.9647	0.9728	0.9790	0.9837
A2	0.9795	0.9723	0.9612	0.9380	0.9183	0.8998	0.8818	0.8641	0.8466
A1	0.9116	0.9209	0.9301	0.9273	0.9284	0.9316	0.9359	0.9406	0.9454

Figure 5. Q-value analysis for Q-ROF VIKOR.

Figure 4 illustrates that Q-ROF TOPSIS is less sensitive than Q-ROF VIKOR to changes in q-values. The order of the alternative is almost the same when the q-value approaches 10. On the other hand, Q-ROF VIKOR is more sensitive because the rank of the alternatives shows more changes. However, A_5 is robust to any change in q-values in both the Q-ROF TOPSIS and Q-ROF VIKOR method. Figures 4 and 5 indicate that A5 is a dependable option regardless of the decision maker's preference for various q-values. It is essential to note that both the Q-ROF TOPSIS and Q-ROF VIKOR method are effective in addressing multi-criteria decision making problems, but their sensitivity to changes in q-values differs. The Q-ROF TOPSIS method is more stable and less sensitive to q-value changes than the Q-ROF VIKOR method, which is more dynamic and sensitive to q-value changes. The choice between these two methods ultimately depends on the decision maker's particular requirements and the nature of the decision problem at hand. Regardless of the chosen method, it is evident that A5 is a viable alternative that should be thoroughly considered by any decision maker seeking to make an informed and effective selection.

When companies are evaluated in terms of some criteria, although there are not great differences between them, the most effective criteria in terms of people's preferences are the number of examinations, brand strength, and premium suitability. According to the results of both methods, it was shown that the A5 company, which is in first place, is a well-established company in the local market and is more reliable in the eyes of people.

5. Conclusions and Future Studies

Due to the emergence of new elements that threaten human health with each passing day, public health institutions are not sufficient for the increasing population, and with the desire to receive faster service, people may turn to private health institutions. Because of the extremely high expenses in private health facilities, demand for private health insurance is growing by the day. During any treatment, private healthcare provides both better service and the opportunity to meet treatment expenses without difficulty. Multiple factors affect the policy selection decision. Among these factors, the most important 10 criteria were determined, namely premium eligibility, company brand strength and value, the contracted hospital chain, the number of inspections, efficiency in emergencies, age limit acceptance, renewal guarantees, renewal premium eligibility, private physician coverage, and validity abroad.

However, crisp numbers are not always useful to define a situation. Under such uncertain situations, the Q-ROF method allows us to make clearer decisions. Due to the uncertainties affecting policy selection, Q-ROF-based clusters were used in this study to make the clearest decision. Five alternative insurance companies were evaluated using the

Q-ROF TOPSIS and Q-ROF VIKOR methods through comparison surveys completed by three decision makers working in the sector. In the Q-ROF TOPSIS method, a new distance measure proposed by Pınar and Boran [4] was used; the Euclidean distance measure formula proposed by Du [59] was used in the Q-ROF VIKOR method. The reason for using both distance measures was to investigate whether different distance measures affect the results. However, since the results were similar in both methods, it was concluded that the concept of distance measure was not very decisive. Additionally, the ranking between q-values provided by parameter analysis does not change at all in the Q-ROF TOPSIS method, while only the last three alternatives change slightly in the Q-ROF VIKOR method. In all analyses of both methods, the best alternatives are A_5 and A_4.

This study evaluates private health insurance plans by applying q-level fuzzy sets to decision support tools. In addition, the consistency of the results is compared by performing sensitivity analyses at different q-levels. Thus, the proposed method provides a broad perspective on the evaluation process. In this way, the proposed methodology helps customers to overcome challenges such as examining the relationship between criteria and the alternatives of private insurance plans, modeling uncertainty by calculating importance weights for decision attributes, and evaluating various options. Therefore, this study, which aims to determine the priorities of the insured in the Turkish insurance market when determining their health insurance product preferences, sets an example in terms of the criteria that both local and global companies entering the market should consider. In terms of customers, it contributes towards understanding what needs to be considered when purchasing a policy. On the other hand, the disadvantageous part of the study is the possibility that the expert decision makers who made the survey evaluations could not evaluate local companies objectively. For this reason, in future studies, expert decision makers should not only consist of local people but should also be part of a different heterogeneous structure.

In future studies, heuristic and classical methods will be compared and different distance operators will be used to demonstrate the effectiveness of Q-ROF methods more clearly. More consistent results will be achieved by increasing the number of criteria and the number of companies. In addition, the differences between outpatient and inpatient policies and the types of outpatient clinics that the policies do not cover can be mentioned by going deeply into the coverage of different policies. The proposed model is not limited to the health insurance market. It can deal with uncertainty in other areas to investigate the concept of dependency, examine the importance of each member of a design-making group, evaluate criteria weights, and rank accessible options accordingly. Additionally, the selection problem of private health insurance policies is a group decision-making problem. As a future research direction, the private health insurance policy selection problem will be analyzed in relation to group decision-making methods.

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Abbreviations

Q-ROF	Q-Rung Orthopair Fuzzy
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
VIKOR	VIšeKriterijumska Optimizacija I Kompromisno Resenje
Q-ROFS	Q-ROF Sets
Q-ROFSs	Q-ROF Soft Set
IFS	Intuitionistic Fuzzy Set
PFS	Pythagorean Fuzzy Sets
SFS	spherical Fuzzy Set
MULTIMOORA	Fully Multiplicative Form
MEREC	Ratio Analysis-Based Multi-Objective Optimization and Removal Effects of Criteria
AHP	Analytical Hierarchy Process
CRITIC	Criteria Importance Through Inter-criteria Correlation
WEDBA	Weighted Euclidean Distance-Based Approach
ANP	analytic network process
PROMETHEE	preference ranking organization method for enrichment of evaluations
TODIM	Tomada de Decisao Interativa Multicriterio
MABAC	Multi-Attributive Border Approximation Area Comparison
WASPAS	Weighted Aggregated Sum Product Assessment
DEMATEL	The Decision-Making Trial and Evaluation Laboratory
EDAS	Evaluation based on Distance from Average Solution
ELECTRE	Elimination and Choice Translating Reality English
Q-ROFN	Q-ROF Number
Q-ROFNs	Q-ROFN sets
MCDM	Multiple Criteria Decision Making
Q-ROFWA	Q-ROF weighted averaging
DM	decision makers
PIS	positive ideal solution
NIS	negative ideal solution

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