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An integrated stochastic fuzzy MCDM approach to the balanced scorecard-based service evaluation☆

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Highlights

- The model includes fuzzy ANP, Monte Carlo Simulation, fuzzy TOPSIS, and fuzzy VIKOR.
- Comparative analysis is coherent for ranking the alternatives and the stochastic values.
- Foreign banks have lower performance in comparison with state and private banks.
- New service development process increases the competitive power.

Abstract

The purpose of the study is to analyse the balanced scorecard (BSC)-based evaluation of the new service development (NSD) in Turkish banking sector. The proposed model includes fuzzy ANP (FANP), Monte Carlo Simulation, fuzzy TOPSIS (FTOPSIS), and fuzzy VIKOR (FVIKOR) respectively. FANP has been used for weighting the criteria, Monte Carlo Simulation has been applied to provide the stochastic values of BSC-based dimensions of NSD in banking sector. FTOPSIS and FVIKOR have been considered to rank the banks by their dimension performances. The novelty of the study is to provide an integrated model including FANP, FTOPSIS, FVIKOR, and Monte Carlo Simulation respectively. Additionally, BSC-based analysis of NSD has been applied for evaluating Turkish banking sector. The results demonstrate that the comparative analysis is coherent for ranking the alternatives and the stochastic values facilitate to obtain the immense expert evaluations under the fuzzy environment. It is identified that the performance of the foreign banks is lower than private and state banks. Hence, it can be said that especially foreign banks should develop new services to attract the attention of their customers. Within this framework, customer expectations should be defined by conducting a detailed analysis. As a result, it can be possible to increase comparative advantage in comparison with the other banks.

Keywords: Balanced scorecard; New service development; Turkey; Banking; Monte Carlo simulation; Fuzzy sets

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1. Introduction

By the globalization, the use of knowledge makes the multinational firms efficient and it eases to monitor the competitive policies in determining strategy includes versatile information for the production and service sector. Due to the effective use of information, the companies have some opportunities to determine the adequacy of the service and products in the commercialization process. Accordingly, knowledge-based system which is called the new economy has allowed the globalized firms to use the multifaced data obtained from the customers and other participants by the beginning of the 1990s.

Moreover, ease of reaching the information and communication technologies with the new economy has enhanced the importance of analysing the existing internal and external environmental data in the incremental and radical innovation and development process. In the increasing competitive environment, the product development processes have begun to host the service development processes by the 1980s. Thus, the new economic process to emphasize a sustainable progress for each stage of the NSD process from the design to the commercialization in the interactive way.

Similarly, multidimensional assessment of innovative strategies and decisions on the NSD in the service industry is a novel issue in the competitive market environment. The critical success factors of innovative service thinking are defined in the strategy and knowledge management, process formulation [3]. Several factors such as strategy, formalized development process, integrated development teams, and customer interaction are highly related to examine the key strategic factors in developing new services [28].

Nowadays, some research interests arise to gain the advantages of the globalized service quality improvement. Organizational competency is one of the prominent issues in the NSD. Interaction in the organizational team increases the expertise for the service improvement [78]. Thus, innovative thoughts are highly valuable by considering functional teams, and learning orientation processes. Additionally, the internal and external integration practises bring the achievement on the new service applications, despite some costs in the idea generation stage [35] and interventional culture is an influential factor in the development of new services within the learning culture [76]. Another important debate in the service development is customer-oriented innovation policies. The active role of customers at each stage contributes to creating the service innovation [15] with social networks [73], learning alignment [79], harmony between client and directly related personnel in the NSD.

Because of the recent interests in the NSD, the dynamic innovation policies towards the service development process, especially the suitability of NSD process, are more closely used in the multidimensional perspective defining the internal and external factors of competitive business environment for the new economic requirements. Consequently, the NSD process needs to be redesigned by considering BSC approach to include the customer, financial outcomes, organizational factors, and learning and growth factors concurrently [44,45,77]. Accordingly, BSC-based performance measurement is one of unique technique that provides the multifaceted perspectives for the service and quality improvement in the fierce competitive conditions. Multi Criteria Decision Making (MCDM) is frequently used for evaluating the complex real-world problems. Especially, stochastic modelling provides several extensions in the sophisticated decision-making process [53,80,100]. However, the stochastic extensions to MCDM are extremely limited under the fuzzy environment [41,83,98].

This study proposes a novel approach to stochastic fuzzy decision-making process with the integrated modelling. For this purpose, the FANP have been applied for weighting the criteria, the FVIKOR and TOPSIS have been used for ranking the banks. Accordingly, Monte Carlo simulation has been adapted to the hybrid fuzzy decision-making process for providing the stochastic values of the BSC-based dimensions for the NSD competencies in Turkish banking sector. Hence, using simulation approach gives opportunity to increase the number of decision makers (DM) stochastically. In this study, FANP is preferred instead of fuzzy AHP because it considers the conditions under the assumption of innerdependency of the factors. Also, the main reason of choosing FVIKOR and FTOPSIS is that they are coherent and frequently used approaches. Additionally, with the help of Monte Carlo analysis, high numbers of expert opinions can be taken into the consideration with stochastic data.

Hence, it can be said that this study has many novelties. First of all, it is the first study in which FANP, FVIKOR and FTOPSIS approaches are considered with simulation methodology. In addition to this issue, Monte Carlo simulation technique is firstly considered in order to calculate the stochastic values for the dimensions. Moreover, this new model is taken into the consideration firstly for the banking sector. As a result, it is obvious that the results provide significant opportunities for both researchers and experts with respect to the strategy development in new service generation process. Thus, this study is intended to contribute to the literature.

In this study, five different sections are stated. In this introduction section, general information about the concept is given. The second section presents the current literature and research interest in the NSD. The following section discusses methodology of the stochastic hybrid fuzzy decision-making approach. Additionally, the fourth section provides the model construction and analysis results. Finally, the last section highlights the results and recommendations of the study.

2. Literature review

There is limited debate on the service improvement of the banking sector in the literature. Drew [25] emphasizes the barriers to rapid innovation and increasing factors of the new product development in the financial sector. Yanikkaya et al. [95] discuss the role of new product and alternative channel development for the profitability of Islamic banks by comparing the conventional banking system. Garrone and Colombo [30] define the needs for driving the development of innovative services in the multimedia home banking by considering the differences in socioeconomic conditions of the customers.

Papathanassiou [64] highlights the importance of developing customized services in the financial sector with the competitive costs due to the mass-produced goods. Weir et al. [93] examine the role of the designs for increasing the performance of new electronic banking services. Yip and Bocken [96] define the sustainable business models and innovations of the banking sector with the customer receptiveness. Channon [10] highlights the strategy role of innovations based on information technologies in the retail financial services.

In the current literature of NSD, it is understood that some studies are related to the organizational factors. For example, Storey and Perks [78] and Limpibunterng and Johri [50] focused on the NSD process of the companies in different industries. They mainly underlined that communication quality in the organization mainly affects the success of NSD. In addition to them, Homburg and Kuehnl [35] identified the significance of interaction and network in the organization in this framework. Moreover, Storey and Hughes [76] and Tajeddini [79] explained that learning and network are important items that affect the performance of NSD.

On the other hand, some researchers also underlined the importance of customer satisfaction in the success of NSD. For instance, Cheng et al. [15] aimed to analyse the main indicators of NSD process. For this purpose, a survey analysis was conducted with 179 different people in Taiwan. It is concluded that customer involvement is the most important factor to increase the performance of NSD. Additionally, Sigala [73] determined that customer expectation should be taken into consideration to be successful for the new services. Furthermore, Tajeddini [79] also emphasized some other items related to the customer, such as feedback and orientation.

Some other studies in the literature also aimed to evaluate the performance of NSD process. As an example, Gremyr et al. [33] aimed to evaluate NSD process for manufacturing firms by making interviews with 16 different companies. Similarly, Kuester et al. [47] measured the performance of NSD by using cluster analysis. Angelopoulos et al. [3] focused on NSD in e-government system. Storey and Perks [78], Jaw et al. [42], Edvardsson et al. [27] and Storey and Kelly [77] are other studies which tried to evaluate the performance of NSD process for different companies.

Moreover, it is seen that some researchers made a study to improve different stages in NSD process. For example, Alam [1] tried to identify the ways to improve NSD process in India's financial services. By making surveys with 148 multinational service companies, it is defined that companies should mainly give importance to the design of the new services. Limpibunterng and Johri [50] and Stevens and Dimitriadis [75] also focused on this topic and reached a conclusion that initiation and testing processes should be mainly taken into consideration by the companies to become successful in NSD process.

In addition to them, some researchers also gave importance to the appropriateness of the strategies in NSDD process. Within this framework, Edvardsson et al. [28] and Storey and Hughes [76] identified that benchmarking plays a very significant role to create a suitable strategy for the companies. Parallel to this study, Veflen Olsen and Sallis [88] and Van Riel and Lievens [87] also underlined the significance of the cooperation in this process. Additionally, Liu [52] concluded that the level of the competition should be considered to generate more appropriate strategies.

The current literature on NSD is summarized in Table 1. According to the research interests in NSD, it is possible to divide the basic research areas into the basic areas as “Organization”, “Customer”, “Success”, “Process and Strategy”. It is also seen that the literature research on the subject are generally on “Success” and “Organization”.

Table 1
Research interests in NSD.

Research fields	Key discussions	Studies
Organization	Learning Interaction Formalization Network Communication	Storey and Perks [78], Homburg and Kuehnl [35], Storey and Hughes [76], Tajeddini [79], Limpibunterng and Johri [50]
Customer	Involvement Expectation Feedback Orientation	Cheng et al. [15], Sigala [73], Tajeddini [79]
Success	Measurement Performance Innovation Competency	Storey and Perks [78], Gremyr et al. [33], Kuester et al. [47], Angelopoulos et al. [3], Jaw et al. [42], Edvardsson et al. [27], Storey and Kelly [77]
Process	Initiation Generation Screening Testing Design	Alam [1], Limpibunterng and Johri [50], Stevens and Dimitriadis [75]
Strategy	Approach Benchmarking Competition Review Cooperation	Edvardsson et al. [28], Storey and Hughes [76], Liu [52], Veflen Olsen and Sallis [88], Van Riel and Lievens [87]

While considering the studies in Table 1, it is understood that NSD process plays a crucial role for the sustainability of the companies. The main reason behind this situation is that with a successful NSD process, companies can have a competitive advantage in comparison with their rivals [33]. Therefore, it is obvious that companies should take necessary actions to improve all stage in NSD process, such as initiation, strategy generation, designing, testing and feedback. Hence, a qualified evaluation should be performed to understand the competencies of the companies in NSD process [27].

Because a comprehensive analysis could be possible by examining the compliance of each new service dimension defined as organization, customer, performance, process and strategies integrally, it is understood that BSC approach is very appropriate for this evaluation [22]. The main reason is that this methodology considers both financial and nonfinancial issues, such as customer, internal process and learning and growth. As seen in the literature review, the theoretical novelty of this study is to construct a new area for the integrated BSC-based evaluation of NSD competencies in banking sector due to the lack of banking and finance literature.

3. Methodology

The aim of the study is to evaluate NSD capacity of Turkish deposit banks. For this purpose, criteria are weighted by FANP approach. On the other side, Monte Carlo simulation method is applied to provide stochastic values of the dimensions. Additionally, FTOPSIS and FVIKOR methods are considered to rank different banks according to their performances. These issues give information that a stochastic approach to fuzzy MCDM is used in order to reach this objective. With the help of simulation approach, it gives opportunity to increase the number of DM stochastically. Otherwise, it is very difficult to work with high number of DM. Therefore, it can be said that more consistent results can be obtained in decision making under uncertainty. Within this framework, in this section, firstly, necessary information is given regarding the stochastic approach to the MCDM. After that, FANP, FVIKOR and FTOPSIS approaches are explained.

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3.1. Stochastic approach to the multi-criteria decision-making model

A mathematical modelling to obtain the optimal solution for an objective under the determined constraints is available by considering the optimization techniques. The models including at least one random variable are defined as stochastic approach. Stochastic approach is also called the probabilistic process that presents the mathematical modelling varies randomly in the timeline. The optimal solution of a stochastic model could be defined with Monte Carlo simulation. In this circumstance, the Monte Carlo method is one of wide used technique to approximate the deterministic optimization problem using random numbers, firstly used in the 1940s by John Neumann, Edward Teller and Stanislaw Ulam. The method essentially aims to the numerical outputs by repeating random sampling to be a broad basis of computational algorithms. The method is principally defined by the transformation of the independent values of α in the interval (0,1).

$$P\left\{\xi = x_k\right\} = p_k,\ k = 0, 1, \ldots, \tag{1}$$

$$\sum_{k=0}^{m-1} P_k \leq \alpha < \sum_{k=0}^{m} P_k \tag{2}$$

where α is a random number, and m is the part of a computer logarithm following the decimal point.

Accordingly, MCDM is one of widely used technique in the complex problem of the real-world applications. Several extensions of the decision modelling using stochastic approach are generated to make a decision more accurately in the sophisticated decision-making process for computer development project [29], biopharmaceutical manufacturing [31], kanban allocations [2], disaster management [66], airline evaluation [32], bank branches [82], biomass crop [17], flood control operation [102], electricity market [48]. Furthermore, the novel studies with the stochastic data in the MCDM process could be a well-suited choice, to provide a larger dataset and to test the consistency of the analysis in case of the most complex conditions and consensus problems among the DM, such as stochastic dominance degree [53], conditional value at risk [60], exploratory modelling and analysis [61].

However, the stochastic extensions to MCDM are extremely limited under the fuzzy environment so that Zarghami and Szidarovszky [98] introduce the fuzzy and stochastic approaches to the revised OWA operator. Torfi et al. [83] construct a two phase heuristic simulated method with the fuzzy least-squares. Jato-Espino et al. [41] present a multi-criteria approach based on the integrated value model by using stochastic simulations. In the literature, stochastic fuzzy MCDM approach was preferred by many different researchers especially in the last decade. For instance, Tavakoli et al. [81], Wang and Huang [91], Zarghami and Szidarovszky [98], Zeng et al. [99] and Zhang et al. [101] considered this approach to find solutions on environmental problems. On the other side, Das et al. [18], Promentilla et al. [65] and Hu et al. [37] used stochastic fuzzy MCDM in their studies for energy industry. In addition to them, this method was also considered in other industries, such as ([40]), health [54] and finance [4,57].

However, there is no study on the integrated stochastic fuzzy decision-making model based on FANP, FVIKOR, and FTOPSIS using the Monte Carlo Simulation in the literature. This study considers the FANP for weighting criteria and dimensions, as well as the FVIKOR and FTOPSIS for ranking the alternatives. In the integrated approach, Monte Carlo simulation is used for setting the data to evaluate the alternatives respectively. Thus, the proposed model provides a novel method to evaluate the banking performance for the NSD competencies.

3.2. FANP

AHP (Analytic Hierarchy Process) is mainly used to make decision under complex environment. Saaty [68] developed this methodology in which alternatives are evaluated in a hierarchical manner. On the other side, ANP (Analytic Network Process) is introduced the generalized version of the hierarchical approach to decision making by Saaty [69]. The method uses the expert choices on the relative importance of the factors non-hierarchically [16,43]. Evaluations of the criteria with the fuzzy sets are provided with the help of linguistic terms and scales [55]. ANP is

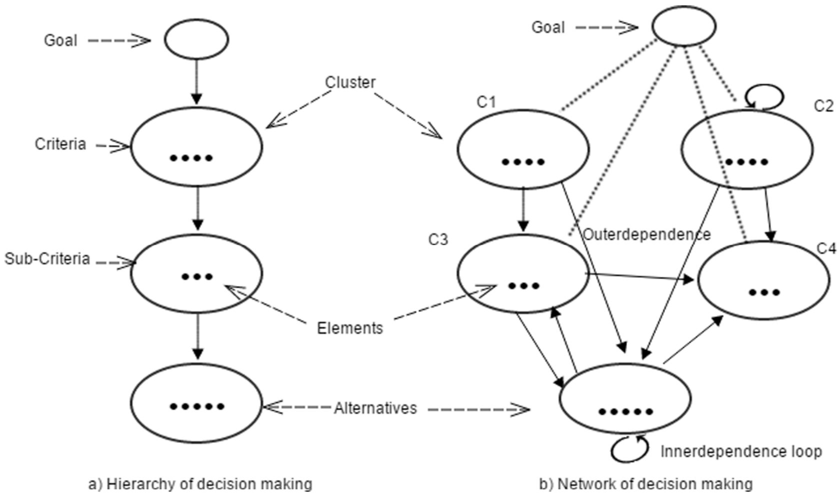

Fig. 1. The details of AHP and ANP approaches.

generally studied for the complex problems under the uncertainty with dependencies among the criteria as called the FANP in the literature (for instance, [6,9,11,49,71,97]). The details of both AHP and ANP methods are illustrated in Fig. 1 [23,70].

Moreover, the details of ANP approach can be analysed in four different steps. Firstly, the decision purpose is identified. Within this framework, the criteria related to this purpose are defined [22]. In addition to this issue, the evaluations of DM are obtained. On the other side, the second step is related to the pairwise comparison between the elements. In this context, these criteria are compared according to their significance. The pairwise comparison matrix is given on Eq. (3) [24].

$$A = \begin{bmatrix} a_{11} & a_{21} & a_{13} & & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & & \vdots \\ a_{n1} & a_{n2} & a_{n3} & & \cdots & a_{nn} \end{bmatrix} \quad (3)$$

The elements of this matrix (a_{ij}) give information about the weights and this process is detailed in Eq. (4).

$$a_{ij} = \frac{1}{a_{ji}}, \quad a_{ii} = 1, \quad a_{ij} > 0 \quad where\ i, j = 1, 2, \ldots n \quad (4)$$

After that, this matrix is normalized by using the priority vector (w). This situation is summarized in Eq. (5).

$$Aw = \lambda_{max} w \quad (5)$$

Furthermore, consistency index (CI) and consistency ratio (CR) are calculated after this issue. The details of this process are given in the Eqs. (6) and (7).

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (6)$$

$$CR = \frac{CI}{RI} \quad (7)$$

In Eq. (7), "RI" represents random index which is defined by Saaty [69]. In the third step, supermatrix is created. The details are demonstrated in Eq. (8).

$$W = \begin{array}{c} \\ \\ C_1 \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1m1} \end{array} \\ \vdots \\ C_k \\ \vdots \\ C_n \begin{array}{c} e_{n1} \\ e_{n2} \\ \vdots \\ e_{nmn} \end{array} \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & \cdots & C_k & \cdots & C_n \end{array} \\ \begin{array}{cccccccc} e_{11} & e_{12} & \cdots e_{1m1} & \cdots & e_{n1} & e_{n2} & \cdots e_{nmn} \end{array} \\ \begin{bmatrix} w_{11} & w_{21} & w_{13} & & \cdots & w_{1n} \\ w_{21} & w_{22} & w_{23} & & \cdots & w_{2n} \\ w_{31} & w_{32} & w_{33} & & \cdots & w_{3n} \\ \vdots & \vdots & \vdots & \ddots & & \vdots \\ w_{n1} & w_{n2} & w_{n3} & & \cdots & w_{nn} \end{bmatrix} \end{array} \tag{8}$$

Finally, the priorities of different alternatives are calculated so that the best one can be identified [21]. Chang's method is preferred in many different studies in which FANP methodology was taken into the consideration. On the other side, Chang's extent analysis was also improved in some studies [26,36,92].

Chang's method is used for weighting the criteria [8]. $X = \{x_1, x_2, \ldots, x_n\}$ is defined an object set, and $U = \{u_1, u_2, \ldots, u_n\}$ refers to the goal set. The extent analysis values can be attained with:

$$M_{gi}^1, M_{gi}^2, \ldots, M_{gi}^n, \quad i = 1, 2, \ldots, n, \tag{9}$$

where all the M_{gi}^j $(j = 1, 2, \ldots, n)$ are triangular fuzzy numbers. The method is detailed below [9]:

In the first step, the fuzzy synthetic extent value can be identified as stated in Eqs. (10)–(13).

$$S_j = \sum_{j=1}^{m} M_{gi}^j \otimes \left(\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j \right)^{-1} \tag{10}$$

$$\sum_{j=1}^{m} M_{gi}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right), \tag{11}$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j = \left(\sum_{j=1}^{m} l_i, \sum_{j=1}^{m} m_i, \sum_{j=1}^{m} u_i \right) \tag{12}$$

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \tag{13}$$

The degree of the possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is calculated in the second step. For this purpose, Eqs. (14) and (15) are taken into the consideration.

$$\begin{aligned} V(M_2 \geq M_1) &= \sup \lfloor \min(\mu_{M_1}(x), \mu_{M_2}(y)) \rfloor \\ V(M_2 \geq M_1) &= hgt(M_1 \cap M_2) = \mu_{M_2}(d) \end{aligned} \tag{14}$$

$$= \begin{cases} 1, & if \quad m_2 \geq m_1, \\ 0, & if \quad l_1 \geq u_2, \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{cases} \tag{15}$$

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The third step is related to the degree possibility that a convex fuzzy number is greater than k convex fuzzy numbers $M_i (i = 1, 2, \ldots, k)$. This situation is given in Eqs. (16)–(18).

$$V(M \geq M_1, M_2, \ldots, M_k) = V\left[(M \geq M_1)\, and\, (M \geq M_2)\, and ... and\, (M \geq M_k)\right] = min V\,(M \geq M_i)\,, \quad i = 1, 2, \ldots, k \tag{16}$$

$$d'(A_i) = min V(S_i \geq S_k) \tag{17}$$

$$W' = \left(d'(A_1), d'(A_2), \ldots, d'(A_n)\right)^T \tag{18}$$

The last step is related to the normalization. In this context, Eq. (19) is considered.

$$W' = (d(A_1), d(A_2), \ldots, d(A_n))^T \tag{19}$$

3.3. FVIKOR

The VIKOR (Vlsekriterijumska Optimizacija I Kompromisno Resenje) is introduced by Opricovic to optimize the complex systems under complex environment. The method provides the solution by defining the closest result to the ideal solution and the mutual concessions [58]. It also has some advantages in the ranking alternatives for this purpose [51]. The method is employed for selecting a set of alternatives and defining compromise solutions for the decision making problem with conflicting criteria to reach a final decision [62].

The FVIKOR is an extended method to provide the expert opinion under the uncertain conditions. The most popular topics with the FVIKOR are frequently generated in the industrial selection problems such as resource planning [46], logistics [86], outsourcing [13], supply chain and selection [5,72]. However, extremely limited studies are provided in the finance and banking sector using the VIKOR method [94]. The VIKOR method under the fuzzy environment can be explained with five different stages [12]. In the first step, the evaluations of decision makers are calculated with Eq. (27).

$$\tilde{x}_{ij} = \frac{1}{k}\left[\sum_{e=1}^{n} \tilde{x}_{ij}^{e}\right], i = 1, 2, 3 \ldots, m \tag{20}$$

In the second step, the best $\tilde{f}_j^*$ and the worst value $\tilde{f}_j^-$ are computed by Eq. (21).

$$\tilde{f}_J^* = \max_i \tilde{x}_{ij}, \text{and} \tilde{f}_j^- = \min_i \tilde{x}_{ij}, \tag{21}$$

On the other side, the third step s related to the calculation of mean group utility and maximal regret. For this purpose, Eqs. (22) and (23) are considered.

$$\tilde{S}_i = \sum_{i=1}^{n} \tilde{w}_j \frac{\left(\left|\tilde{f}_j^* - \tilde{x}_{ij}\right|\right)}{\left(\left|\tilde{f}_j^* - \tilde{f}_j^-\right|\right)} \tag{22}$$

$$\tilde{R}_i = \max_j \left[\tilde{w}_j \frac{\left(\left|\tilde{f}_j^* - \tilde{x}_{ij}\right|\right)}{\left(\left|\tilde{f}_j^* - \tilde{f}_j^-\right|\right)}\right] \tag{23}$$

In these equations, w represents the weights. Additionally, S_i gives information about the total distance whereas R_i is the maximum distance to the best value. In the fourth stage, the values of $\tilde{Q}_i$ are computed by using Eq. (24)

$$\tilde{Q}_i = v\left(\tilde{S}_i - \tilde{S}^*\right) / \left(\tilde{S}^- - \tilde{S}^*\right) + (1 - v)\left(\tilde{R}_i - \tilde{R}^*\right) / \left(\tilde{R}^- - \tilde{R}^*\right) \tag{24}$$

The defuzzification procedure is applied by using the kth weighted mean method. It is the membership function to the power of k as a weighted factor. The crisp value $Crisp(\tilde{N})$ for the triangular fuzzy number $\left(\tilde{N}\right) = (l, m, u)$

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is determined as [62]

$$Crisp\left(\tilde{N}\right) = \int_{l}^{u} x\mu^{k}(x)\,dx \Big/ \int_{l}^{u} \mu^{k}(x)\,dx \tag{25}$$

$$C = (km + l + u)/(k+2) \text{ or } C = m + (s_u - s_l)/(k+2) \tag{26}$$

where C is $Crisp\left(\tilde{N}\right)$, s_l and s_u are defined as $(m-l)$ and $(u-m)$ respectively.

$$\mu(c) = \begin{cases} \dfrac{k+1}{k+2} + \dfrac{s_u}{(k+2)s_l}, & C \le m \\ \dfrac{k+1}{k+2} + \dfrac{s_l}{(k+2)s_u}, & C \ge m \end{cases} \tag{27}$$

In the last step, the values of S, R and Q are sorted. Within this framework two conditions should be satisfied. The first condition is related to the acceptable advantage. It is given in Eq. (28).

$$Q\left(A^{(2)}\right) - Q\left(A^{(1)}\right) \ge 1/(j-1) \tag{28}$$

In this equation, $A^{(2)}$ represents the second best alternative. On the other side, the second condition focuses on acceptable stability. The solution is accepted as stable in the case of the maximum group utility (when $v > 0.5$ is needed), "by consensus" ($v \approx 0.5$), or "with veto" ($v < 0.5$) [19,63]. In this study, the value of v is selected as 0.5 in the limitation of having consensus among the experts.

3.4. FTOPSIS

Hwang and Yoon [38] introduced the TOPSIS (The Technique for Order of Preference by Similarity to Ideal Solution) to rank the alternatives. The best alternative is defined by measuring the longest distance from the negative-ideal solution and the shortest distance from the positive-ideal solution. The TOPSIS under the fuzzy environment is also a well-known technique for the MCDM in the ambiguous conditions of production management. Accordingly, the FTOPSIS method was considered in many studies, such as supplier selection [89], business [67,84], risk management and investment [24,90], transportation [85], waste management [14]. The details of this methodology are given as following. The step 1 is related to the obtaining the evaluations from the decision makers. The computation is demonstrated in Eq. (29).

$$\tilde{X}_{ij} = \frac{1}{k}\left(\tilde{X}_{ij}^{1} + \tilde{X}_{ij}^{2} + \tilde{X}_{ij}^{3} + \cdots + \tilde{X}_{ij}^{k}\right) \tag{29}$$

In this equation, $\tilde{X}_{ij}^{k}$ represents the evaluation of a decision maker. Moreover, the second step is related to the normalization of the fuzzy decision matrix which is shown in Eqs. (30) and (31)

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_{ij}^{*}}, \frac{b_{ij}}{c_{ij}^{*}}, \frac{c_{ij}}{c_{ij}^{*}}\right) \tag{30}$$

$$c_{ij}^{*} = \sqrt{\sum_{i=1}^{m} c_{ij}^{2}} \tag{31}$$

Furthermore, the positive (A^{+}) and negative (A^{-}) ideal solutions are defined in the third step. The triangular fuzzy numbers are converted into the defuzzified crisp values as similarly used in fuzzy VIKOR method. So, it is possible to define the ideal and negative-ideal solutions. Within this framework, Eqs. (32) are considered.

$$A^{+} = \left(\tilde{v}_1^{*}, \tilde{v}_2^{*}, \tilde{v}_3^{*}, \ldots \tilde{v}_n^{*}\right) \text{ and } A^{-} = \left(\tilde{v}_1^{-}, \tilde{v}_2^{-}, \tilde{v}_3^{-}, \ldots \tilde{v}_n^{-}\right) \tag{32}$$

On the other side, the distances from the positive and negative-ideal solution are identified with the help of the Eqs. (33) and (34).

$$D_i^{*} = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^{*}) \tag{33}$$

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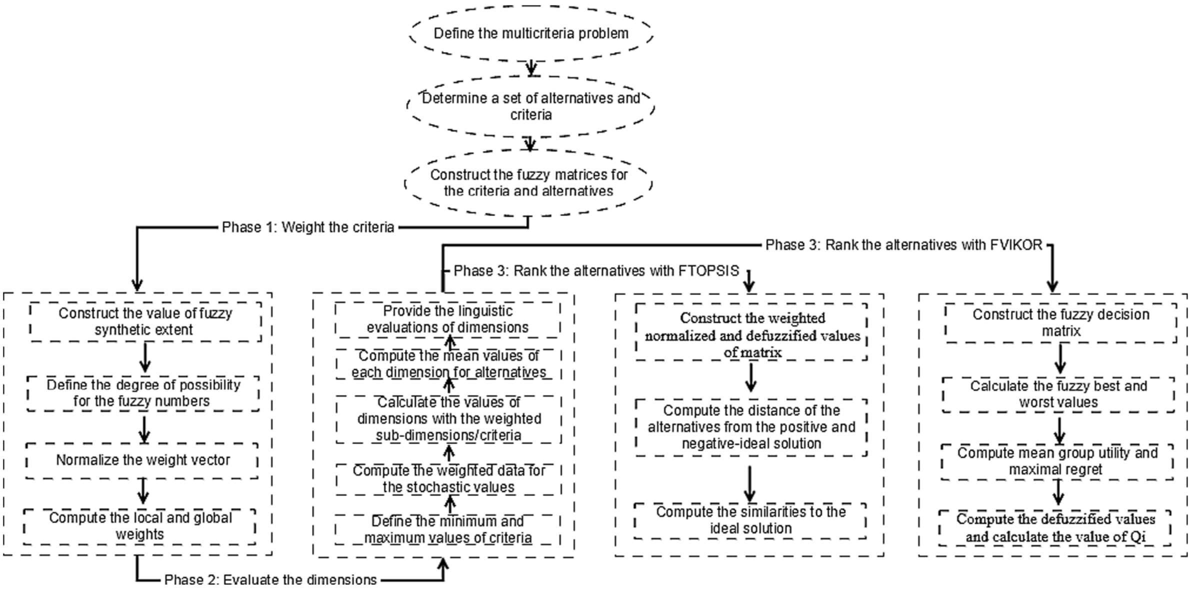

Fig. 2. The flowchart of the proposed decision-making model.

$$D_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-) \tag{34}$$

Finally, the last step is related to the ranking of the alternative according to the CC_i (closeness coefficient index) values by using Eq. (35).

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{35}$$

4. Analysis

4.1. Proposed model

This study proposes a stochastic hybrid fuzzy MCDM approach to rank the alternatives more accurately using the massive expert opinions. The hybrid model integrates the FANP, Monte Carlo simulation, FTOPSIS and FVIKOR respectively. For this purpose, it includes three phases from the weighting of criteria to the ranking of the alternatives consecutively. The details of the flowchart for the proposed model are illustrated in Fig. 2.

Initial step of the integrated stochastic decision-making approach is to define the multicriteria problem for the performance measurement. In the following step, a set of criteria, dimensions and alternatives are defined to construct the fuzzy pairwise comparison and decision matrices by Eqs. (36)–(37). Accordingly, 8 decision makers from the academicians and experts are appointed to obtain their priorities on the criteria. There are only 9 deposit banks that have available data for NSD competency and they are selected as alternatives. 4 dimensions, adapted from the balanced scorecard perspectives, and 12 criteria are determined with the supported literature for the NSD performance of banking sector. Table 3 represents the key performance indicators of NSD competencies based on balanced scorecard approach. Fuzzy pair-wise comparison decision matrix is defined $\tilde{A}$

$$\begin{bmatrix} 1 & \tilde{a}_{12} & \tilde{a}_{13} & & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \tilde{a}_{23} & & \cdots & \tilde{a}_{2n} \\ \tilde{a}_{31} & \tilde{a}_{32} & 1 & & \cdots & \tilde{a}_{3n} \\ \vdots & \vdots & \vdots & \ddots & & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \tilde{a}_{n3} & & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \tilde{a}_{13} & & \cdots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \tilde{a}_{23} & & \cdots & \tilde{a}_{2n} \\ 1/\tilde{a}_{13} & 1/\tilde{a}_{23} & 1 & & \cdots & \tilde{a}_{3n} \\ \vdots & \vdots & \vdots & \ddots & & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & 1/\tilde{a}_{3n} & & \cdots & 1 \end{bmatrix} \tag{36}$$

Linguistic terms and triangular fuzzy numbers are used for assessing criteria as seen in Table 2.

Table 2
The triangular fuzzy numbers for the criteria evaluation.
Source: Chang [8].

Linguistic scales	Fuzzy numbers		
Equally important (EI)	0.5	1	1.5
Weakly more important (WI)	1	1.5	2
Strongly more important (SI)	1.5	2	2.5
Very strongly more important (VI)	2	2.5	3
Absolutely more important (AI)	2.5	3	3.5

Table 3
Key performance indicators of NSD.

Perspective	Dimensions	Criteria	Studies
Financial	Performance (D1)	Profitability (C1)	Dinçer et al. [21], Storey and Hughes [76], Wu et al. [94]
		Market Share (C2)	Tajeddini [79], Storey and Kelly [77]
		Efficiency (C3)	Gremyr et al. [33], Kuester et al. [47], Tajeddini [79]
Customer	Market compliance (D2)	Satisfaction (C4)	Cheng et al. [15], Sigala [73]
		Customization (C5)	Edvardsson et al. [28], Bitran and Pedrosa [7]
		Experience (C6)	Makkonen and Komulainen [56], Jaw et al. [42], Edvardsson et al. [27]
Internal Process	Organizational compliance (D3)	Consistency (C7)	Homburg and Kuehnl [35], Jaw et al. [42]
		Clarity (C8)	Homburg and Kuehnl [35], Limpibunterng and Johri [50], Smith et al. [74]
		Participation (C9)	Storey and Hughes [76], Hernández [34], Makkonen and Komulainen [56],
Learning and Growth	Information and Communications Infrastructure (D4)	Training (C10)	Alam [1], Wu et al. [94], Montoya-Weiss and Calantone [59]
		Technology (C11)	Liu [52], Van Riel and Lievens [87], Ittner and Larcker [39]
		Information (C12)	Storey and Perks [78], Liu [52], Edvardsson et al. [27], Veflen Olsen and Sallis [88]

The fuzzy decision matrix of multi-criteria problem is presented as

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccccc} \mathrm{C}_1 & \mathrm{C}_2 & \mathrm{C}_3 & & \cdots & \mathrm{C}_\mathrm{n} \end{array} \\ \begin{bmatrix} \tilde{X}_{11} & \tilde{X}_{12} & \tilde{X}_{13} & & \cdots & \tilde{X}_{1n} \\ \tilde{X}_{21} & \tilde{X}_{22} & \tilde{X}_{23} & & \cdots & \tilde{X}_{2n} \\ \tilde{X}_{31} & \tilde{X}_{32} & \tilde{X}_{33} & & \cdots & \tilde{X}_{3n} \\ \vdots & \vdots & \vdots & \ddots & & \vdots \\ \tilde{X}_{m1} & \tilde{X}_{m2} & \tilde{X}_{m3} & & \cdots & \tilde{X}_{mn} \end{bmatrix} \end{array} \tag{37}$$

where A_1, A_2, …, A_m are possible alternatives. On the other side, C_1, C_2, …, C_n represent criteria. Additionally, $\tilde{X}_{\mathrm{ij}}$ gives information about the rating of alternative A_i by considering C_j.

First phase of the integrated model is to weight the criteria with the FANP. For this purpose, the value of fuzzy synthetic extent with the respect to the ith object by the formulae (4)–(7). After that, the degree of the possibility is defined with Eqs. (8)–(9). Normalized weight vectors are constructed to compute the local and global weights of the criteria by (10)–(13).

The second phase of the model is to evaluate the dimensions with Monte Carlo Simulation. Accordingly, the minimum and maximum values of each criterion are defined to generate the stochastic dataset by considering the annual reports from 2011 to 2016. These annual reports are obtained from the websites of the banks (for detailed information, visit official website of The Banks Association of Turkey, www.tbb.org.tr) Monte Carlo simulation are employed with 5000 samples. Thus, the criteria of each dimension are weighted in the simulation model by considering the FANP results. The mean values provided from the simulation results are converted to five-point linguistic scale to construct the fuzzy decision matrix.

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Table 4
The triangular fuzzy numbers for the alternative evaluation.
Source: Dinçer et al. [20].

Linguistic scales	Fuzzy numbers		
Worst (W)	0	0	2.5
Poor (P)	0	2.5	5
Fair (F)	2.5	5	7.5
Good (G)	5	7.5	10
Best (B)	7.5	10	10

Table 5
Pairwise matrix for dimensions.

Dimensions	Dimension 1			Dimension 2			Dimension 3			Dimension 4		
Dimension 1	1.00	1.00	1.00	1.38	1.88	2.38	1.50	2.00	2.50	1.25	1.75	2.25
Dimension 2	0.43	0.54	0.75	1.00	1.00	1.00	1.13	1.63	2.13	1.25	1.75	2.25
Dimension 3	0.40	0.50	0.67	0.48	0.63	0.92	1.00	1.00	1.00	0.88	1.38	1.88
Dimension 4	0.45	0.58	0.83	0.45	0.58	0.83	0.56	0.79	1.42	1.00	1.00	1.00

Table 6
Inner dependence matrix for Dimension 1.

Dimensions	Dimension 2			Dimension 3			Dimension 4			Weights
Dimension 2	1.00	1.00	1.00	0.88	1.38	1.88	0.75	1.25	1.75	0.38
Dimension 3	0.54	0.75	1.25	1.00	1.00	1.00	0.63	1.13	1.63	0.31
Dimension 4	0.58	0.83	1.50	0.63	0.92	1.75	1.00	1.00	1.00	0.31

Table 7
Inner dependence matrix for Criterion 1.

Criteria	Criterion 2			Criterion 3			Weights
Criterion 2	1.00	1.00	1.00	0.88	1.38	1.88	0.60
Criterion 3	0.54	0.75	1.25	1.00	1.00	1.00	0.40

The third phase is to rank the alternatives comparatively with FTOPSIS and FVIKOR. Linguistic scales and the triangular fuzzy numbers are used for the fuzzy decision matrix as seen in Table 4.

4.2. Results

Linguistic evaluations of pairwise comparison for dimensions and criteria have been provided from the DM and the averaged values of triangular fuzzy numbers have been used to evaluate the importance of the criteria and dimensions under the assumption of inner dependency among the factors with the FANP. Table 5 represents the fuzzy pairwise comparison matrix for the dimensions.

After that, the inner dependency results of dimensions with respect to each dimension have been constructed and Table 6 illustrates the inner dependency results of dimensions with respect to D1.

Accordingly, the inner dependency matrices of the criteria have been computed and the inner dependence matrix of the criteria with respect to C1 is shown in Table 7.

Local and global weights of the NSD competencies have been calculated using the FANP. The details are examined in Table 8. The results demonstrate that the performance (D1) is the most importance dimension with 33% while information and communications infrastructure (D4) is the weakest with 18% in the BSC-evaluation perspectives of the banking service innovations. However, the profitability criteria (C1) that is the sub-dimension of the performance has the most importance in the global weights of NSD competencies as the technology (C11) and information (C12) have relatively the lowest weights.

Table 8
Local and global weights.

Dimensions	Local weights	Criteria	Local weights	Global weights
Performance (D1)	0.33	Profitability (C1)	0.35	0.116
		Market Share (C2)	0.35	0.115
		Efficiency (C3)	0.30	0.099
Market compliance (D2)	0.28	Satisfaction (C4)	0.39	0.108
		Customization (C5)	0.34	0.096
		Experience (C6)	0.27	0.075
Organizational compliance (D3)	0.21	Consistency (C7)	0.35	0.074
		Clarity (C8)	0.34	0.071
		Participation (C9)	0.31	0.064
Information and Communications Infrastructure (D4)	0.18	Training (C10)	0.36	0.067
		Technology (C11)	0.32	0.058
		Information (C12)	0.32	0.058

Table 9
Summary statistics of Monte Carlo simulation (n:5000).

	Mean				St Error				St Dev			
	D1	D2	D3	D4	D1	D2	D3	D4	D1	D2	D3	D4
S1	0.232	11.501	0.209	−2.175	0.005	0.095	0.002	0.042	0.319	6.744	0.140	2.955
S2	0.016	0.453	−0.044	3.138	0.003	0.001	0.002	0.069	0.184	0.083	0.122	4.882
P1	0.169	0.605	0.553	18.773	0.010	0.005	0.006	0.156	0.699	0.322	0.416	11.024
P2	1.165	0.303	0.537	7.421	0.011	0.003	0.005	0.057	0.780	0.241	0.319	3.998
P3	−0.298	0.485	−0.017	1.493	0.003	0.005	0.000	0.014	0.213	0.327	0.029	0.962
P4	−1.191	1.645	0.252	11.274	0.004	0.011	0.002	0.099	0.294	0.744	0.118	6.986
F1	0.479	2.362	−0.012	−20.890	0.008	0.035	0.003	0.270	0.560	2.472	0.190	19.061
F2	−0.551	−3.691	0.080	8.110	0.006	0.048	0.004	0.072	0.399	3.383	0.265	5.078
F3	−1.595	−5.928	0.289	−0.166	0.020	0.053	0.003	0.028	1.419	3.757	0.223	1.957

	Skewness				Kurtosis			
	D1	D2	D3	D4	D1	D2	D3	D4
S1	0.000	0.022	0.011	0.009	−0.593	−1.187	−0.462	−0.998
S2	0.016	0.008	−0.033	−0.008	−0.602	−0.579	−0.654	−1.202
P1	−0.010	−0.002	−0.009	0.016	−0.646	−0.611	−0.972	−1.200
P2	−0.030	−0.044	−0.008	−0.001	−0.941	−0.488	−0.557	−1.100
P3	−0.019	−0.030	−0.054	−0.005	−0.948	−0.685	−0.495	−1.191
P4	−0.003	−0.025	−0.025	−0.018	−0.860	−1.073	−0.474	−1.210
F1	0.007	0.027	0.024	−0.007	−0.878	−0.607	−0.812	−1.223
F2	0.009	0.021	−0.041	−0.008	−0.969	−1.111	−0.453	−1.192
F3	−0.003	0.036	0.017	0.002	−1.174	−1.230	−1.060	−1.173

After calculating the weights for the criteria, the minimum and maximum values of the criteria have been determined by considering the annual reports of the banks from 2011 to 2016 and Monte Carlo simulation has been employed with the 5000 samples to obtain the stochastic evaluation results of each criteria. The stochastic values of the criteria have been weighted using the FANP results to compute the overall evaluations of each dimension with the stochastic approach. Table 9 represents the simulation statistics of the dimensions for the banks.

Additionally, the histograms of Monte Carlo simulation results for each bank by the dimensions have been illustrated in Appendix. In the final phase, the banks have been ranked by considering the FVIKOR and the FTOPSIS comparatively. For this reason, the mean values of the dimensions, provided from Monte Carlo, are converted to the 5-point linguistic scales and then, the triangular fuzzy numbers are appointed for each alternative. Table 10 represents the weighted normalized fuzzy decision matrix of dimensions for the banks based on the stochastic approach.

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Table 10
Weighted normalized fuzzy decision matrix.

	D1			D2			D3			D4		
S1	0.067	0.101	0.135	0.116	0.155	0.155	0.026	0.052	0.077	0.018	0.035	0.053
S2	0.034	0.067	0.101	0.000	0.039	0.077	0.000	0.000	0.026	0.035	0.053	0.070
P1	0.067	0.101	0.135	0.000	0.039	0.077	0.077	0.103	0.103	0.053	0.070	0.070
P2	0.101	0.135	0.135	0.000	0.039	0.077	0.077	0.103	0.103	0.035	0.053	0.070
P3	0.034	0.067	0.101	0.000	0.039	0.077	0.000	0.000	0.026	0.018	0.035	0.053
P4	0.034	0.067	0.101	0.039	0.077	0.116	0.026	0.052	0.077	0.053	0.070	0.070
F1	0.067	0.101	0.135	0.039	0.077	0.116	0.000	0.000	0.026	0.000	0.000	0.018
F2	0.000	0.034	0.067	0.000	0.000	0.039	0.000	0.026	0.052	0.035	0.053	0.070
F3	0.000	0.000	0.034	0.000	0.000	0.039	0.026	0.052	0.077	0.018	0.035	0.053

Table 11
Evaluation results with FTOPSIS.

	D+	D−	CC_i
S1	11.672	0.341	0.028
S2	11.834	0.192	0.016
P1	11.703	0.315	0.026
P2	11.692	0.324	0.027
P3	11.851	0.175	0.015
P4	11.741	0.277	0.023
F1	11.808	0.213	0.018
F2	11.876	0.154	0.013
F3	11.890	0.135	0.011

Table 12
Evaluations results with FVIKOR.

	Si	Ri	Qi
S1	0.260	0.105	0.017
S2	0.634	0.232	0.638
P1	0.289	0.225	0.316
P2	0.260	0.225	0.289
P3	0.690	0.232	0.687
P4	0.409	0.165	0.290
F1	0.595	0.209	0.541
F2	0.748	0.296	0.879
F3	0.804	0.330	0.997

The FTOPSIS method is considered to rank the banks. The analysis results are given in Table 11. According to the results, State-owned bank 1 (S1) is the best alternative in the banking sector because it has the highest CC_i value. On the other hand, foreign bank 3 (F3) has the worst performance relatively.

Alternatively, the banks have been ranked by using the FVIKOR. For that, the values of Si, Ri, and Qi have been computed. The results are given in Table 12.

S1 is the first and F3 has the last rank in the NSD competencies of banking sector with FVIKOR method. The main reason is that it has the lowest Q_i value. On the other side, comparative ranking results between FTOPSIS and FVIKOR is demonstrated in Table 13.

The comparative results of FVIKOR and FTOPSIS demonstrate that both techniques are coherent for the stochastic fuzzy MCDM approach. In other words, most of the results are very similar in both FVIKOR and FTOPSIS approaches. For example, S1 and P2 are the best deposit banks for both two different methods. On the other side, S2, P3, F2 and F3 are on the last ranks according to the results of these two different methodologies. This condition expresses the accuracy and consistency of the analysis results. As it can be understood from Table 13

Table 13
Comparative ranking results with FTOPSIS and FVIKOR.

	Ranking with FTOPSIS	Ranking with FVIKOR
S1	1	1
S2	6	6
P1	3	4
P2	2	2
P3	7	7
P4	4	3
F1	5	5
F2	8	8
F3	9	9

Table 14
The results of sensitivity analysis for FTOPSIS.

	Case 1	Case 2	Case 3	Case 4
S1	1	1	1	1
S2	6	6	6	6
P1	3	3	3	3
P2	2	2	2	2
P3	7	7	7	7
P4	4	4	4	4
F1	5	5	5	5
F2	8	8	8	8
F3	9	9	9	9

Table 15
The results of sensitivity analysis for FVIKOR.

	Case 1	Case 2	Case 3	Case 4
S1	1	1	1	1
S2	6	6	6	6
P1	4	4	4	4
P2	2	2	2	2
P3	7	7	7	7
P4	3	3	3	3
F1	5	5	5	5
F2	8	8	8	8
F3	9	9	9	9

is that foreign banks have lower performance in comparison with state and private banks. Hence, it can be said that these banks should give more importance to NSD process to increase their competitive power.

Final ranking results have been validated by using the sensitivity analysis. The method can be applied by changing the values of each criterion weight consecutively to check the robustness of proposed model. For this reason, the weights of the dimensions have been changed with 4 cases to compare the consistency of the results for the FTOPSIS and FVIKOR respectively.

Tables 11–13 represent the evaluation and ranking results of FTOPSIS and FVIKOR for the case 1. However, Tables 14 and 15 show the ranking results of comparative analysis for each case according to the sensitivity analysis.

The sensitivity analysis results demonstrate that the ranking results are coherent for all cases of FTOPSIS and FVIKOR models.

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5. Discussion and conclusions

Knowledge-based system gives more opportunities to the globalized firms in the competitive market environment due to the possible multifaced data. New market-based statements force to the rivals for making decisions more accurately. Especially, generating the data and its evaluation arise as a novel issue to make a decision under the uncertain conditions. For this reason, innovative strategies on the service and product management and new multidimensional evaluations of competitive market are key components of successful business operations. Accordingly, the multidimensional assessment of innovative strategies, the critical success factors of innovative service thinking [3], formalized development process based on customer interaction [28], the role of innovation [33], interactive actors [47,52], and market compliance [1,42] are clear evidences of the multidimensional performance measurement of service firms.

Innovation strategies based on multifaced policies include a set of factors such as the organizational competency [76,78], integration of external factors [35], customer expectations [15], financial evaluations[21]. Thus, the dynamic innovation policies towards the service development process need the multidimensional evaluations of service innovations under the competitive market environment. Accordingly, the BSC method provides the main perspectives of performance, customer, organization, competition [44,45,77] and could be adapted to evaluate the service development performance multidimensionally.

Effective decision-making process and applications is also another important issue to evaluate the NSD. For this purpose, MCDM approach is widely used for solving the several managerial problems under the fuzzy environment. Furthermore, the current extensions of the decision modelling using stochastic approach are limitedly generated to make a decision more accurately in the sophisticated decision-making process [17,32,66,82]. But, the stochastic extensions to the decision making are extremely limited under the fuzzy environment [41,83,98]. However, the integrated stochastic fuzzy decision-making model with FANP, FVIKOR, FTOPSIS, and the Monte Carlo Simulation is a novel approach for assessing the NSD competencies in banking sector.

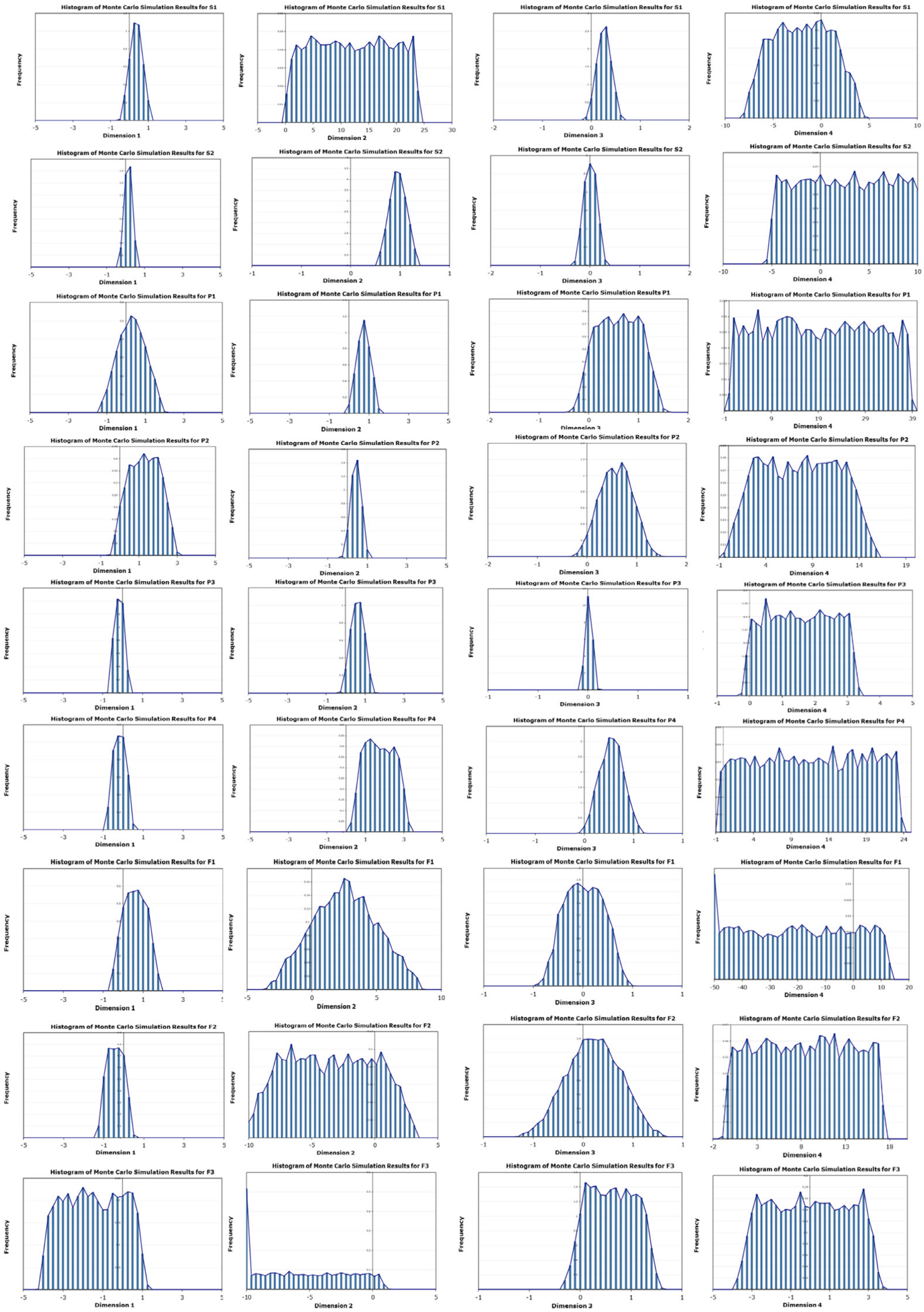
Accordingly, hybrid decision making approach has been proposed to analyse the results more sensitively and the stochastic approach has been added in the decision-making process to provide more accurate results under the assumption of immense expert evaluations. For that, a stochastic fuzzy hybrid decision making model has been proposed with a three-stage analysis. In the first stage, the FANP method has been applied to weight the criteria. In the following stage, Monte Carlo Simulation has been computed to provide the stochastic values for the dimensions. In the final stage, the stochastic values of BSC-based dimensions of NSD competencies have been evaluated by using FTOPSIS and FVIKOR methods.

As a result, it is identified that the dimension of the performance (D1) has the highest significance. On the other hand, information and communications infrastructure (D4) is on the last rank. In addition to these aspects, it is also determined that profitability (C1) has the most importance. On the other hand, technology (C11) and information (C12) have relatively the lowest weights in comparison with the others. Furthermore, another important point in this study is that the comparative results of FVIKOR and FTOPSIS demonstrate that both techniques are coherent.

Additionally, it is concluded that the bank that has the highest performance regarding new service competency is a state bank (S1). Moreover, a private bank (P2) has the second highest performance for this situation. Another significant point is that the banks that have the worst performance with respect to this subject are the foreign banks (F2 and F3). Similarly, it can also be seen that foreign banks have lower performance by comparing with state and private banks. Therefore, it is strongly recommended that foreign banks should take necessary actions to increase the performance this process.

The comparative analysis provides the coherent results to evaluate the NSD competencies of banking sector. Especially, the strategic priorities of foreign banks should be revised for the NSD in the competitive market environment. In this study, it is aimed to make contribution to the literature by focusing on the significant issue for the banking sector. The main limitation of this study is to include Turkish banks in the analysis process that have enough data for NSD process. Nevertheless, the study could be extended by considering the cross-country analysis and other decision-making approaches such as ELECTRE and PROMETHE for further researches.

Appendix A. Histograms of Monte Carlo simulation results for banks



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