



## ANALYSIS OF SERVICE INNOVATION PERFORMANCE IN TURKISH BANKING SECTOR USING A COMBINING METHOD OF FUZZY MCDM AND TEXT MINING\*

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### Abstract

The purpose of the study is to examine the effecting factors for new service development capabilities in Turkish banking sector and to evaluate the performance of the banks in listed BIST based on the service innovation performance. The novelty of the study is to employ a two-step analysis considering the data mining and the hybrid MCDM respectively. The method is applied by using the data mining for extracting the literature based-criteria of service innovation. Accordingly, the fuzzy AHP is computed for weighting the criteria and the fuzzy TOPSIS is considered to rank the banks based on the service innovation performance. The results demonstrate that the service conditions for the customers are the most important factor in the service innovation performance while the employees are weakly considered to evaluate the new service development. In addition, it is seen that no bank type has a clear advantage over others. In other words, there are banks with both good and bad performance outcomes within each type of banking group. However, it is determined that foreign banks and private banks took place in the worst order. In this context, in order to achieve a competitive advantage, these low performing banks should focus on new services that take into account the customer expectations.

**Keywords:** Banking Sector, Service Innovation, Text Mining, Fuzzy AHP, Fuzzy TOPSIS

### TÜRK BANKACILIK SEKTÖRÜNDEKİ HİZMET YENİLİĞİ PERFORMANSININ METİN MADENCİLİĞİ VE BULANIK ÇOK KRİTERLİ KARAR VERME YÖNTEMLERİ İLE ANALİZİ

### Özet

Bu çalışmanın amacı, Türk bankacılık sektöründeki yeni hizmet geliştirme kabiliyetlerine etki eden faktörleri incelemek ve BIST'de işlem gören bankaların performansını, hizmet yeniliğine göre değerlendirmektir. Çalışmanın yeniliği, veri madenciliği ve hibrit çok kriterli karar verme yöntemlerini birlikte dikkate alan iki aşamalı bir analiz kullanmasıdır. Literatür tabanlı hizmet geliştirme kriterleri için veri madenciliği yöntemi uygulanmıştır. Buna göre, ölçütlerin ağırlıklandırılması için bulanık AHP, bankaların hizmet yeniliği performansına göre sıralanması için ise bulanık TOPSIS yöntemlerinden faydalanılmıştır. Elde edilen sonuçlara göre,

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müşterilerin en önemli boyut olduğu belirlenmiştir. Buna karşın, çalışanların ise daha düşük önem ağırlığına sahip olduğu sonucuna ulaşılmıştır. Ek olarak, herhangi bir banka türünün diğerlerine kıyasla bariz bir üstünlüğü bulunmadığı görülmüştür. Diğer bir ifadeyle, her banka türü içerisinde hem iyi hem de kötü performans sonuçlarına sahip olan bankalar bulunmaktadır. Bununla birlikte, en son sıralarda yabancı ve özel bankaların yer aldığı belirlenmiştir. Bu bağlamda, rekabetçi avantaj elde edebilmek için performansı düşük olan bu bankaların müşteri beklentilerini dikkate alan yeni hizmetler geliştirmeleri yerinde olacaktır.

**Anahtar Kelimeler:** Bankacılık Sektörü, Hizmet Yeniliği, Metin Madenciliği, Bulanık AHP, Bulanık TOPSIS

## 1. Introduction

Especially after the globalization, competition has increased almost all over the world. The main reason is that companies took the opportunity to enter new markets because of disappearing economic borders among the countries (Tunay and Yüksel, 2017:1628). Although this situation has many benefits for the consumers, it makes very hard for the companies to increase their profitability. Therefore, it becomes necessary for the companies to take some actions so as to survive in such a competitive environment (Yüksel, 2016:42).

Innovation and new service development are some example actions for these companies to reach this objective (Yüksel, 2017:2). With the help of innovative thinking, companies can have a chance to increase their efficiency. Within this framework, the concept of new service development plays a significant role to have a competitive power. In other words, companies should develop new services to become different in comparison with their rivals (Eti and İnel, 2016:470; Yüksel et al., 2016:1059).

Banking sector is also a market in which there is an important increase in the competition. Since foreign trade has an increasing trend after globalization, the significance of the banking sector went up considerably (Dinçer et al., 2018:203; Mukhtarov et al., 2018:65). Hence, many international banks entered into different countries. This situation has an increasing effect on the competition in this sector. Therefore, it is obvious that banks should develop new services to attract the attention of the consumers. Owing to this aspect, it can be much easier for them to survive in the market (Kartal, 2017:85; Ersin and Duran, 2017:110; Yüksel and Zengin, 2016:495).

Similar to the issues emphasized above, the aim of this study is to evaluate the performance of Turkish banks in listed BIST based on the service innovation performance. By using data mining methodology to the similar studies in the literature, the criteria for service innovation are identified. Additionally, the weights of the criteria are determined with the help of fuzzy AHP method. Moreover, fuzzy TOPSIS approach is taken into the consideration to rank the performance of the banks.

This study consists of 5 different sections. After the introduction part, the second section gives information about the text mining approach to multi criteria decision making. For this purpose, some similar studies in the literature are shared. Moreover, the third section explains fuzzy AHP and fuzzy TOPSIS methodologies. Furthermore, the fourth section focuses on the application on Turkish banking sector. Also, in the final part, the results and the recommendations are given.

## **2. Text Mining Approach to Multi Criteria Decision Making**

### **2.1. Text Mining**

Text mining is an approach for mining useful and novel patterns in textual data. Extracting these patterns is not an easy task because in contrast to numerical data, textual data is not structured. Hence, it must be organized in a way that is suitable for analytical methods. For this purpose, several preprocessing steps such as tokenizing, stemming, filtering stopword are implemented to represent textual data quantitatively.

Information retrieval includes collecting data from the data source which can be text files, reports, sheets, blogs, web pages, or social media and store collected data in the corpus. In preprocessing textual data transformed into numerical values. Tokenizing (breaking sentences into words), stemming (removing suffixes such as -ing or -er and obtaining the root), filtering stopwords (removing words that have no meaning such as “the”, “is” etc.) operations are executed (Karatzoglou & Feinerer, 2010:290). After this step, besides methods that are commonly used for text related tasks such as topic identification, sentiment analysis etc., standard data mining methods that are used for classification, clustering, and prediction can also be implemented on transformed data. Thanks to text mining that it is now possible to analyze voluminous textual data which is both online and offline data even if they are in very different file formats. In data model phase suitable algorithms are run for the intended task for example topic modeling or clustering. The result can be presented visually in visualization phase by using word clouds, histograms or correlation maps. At the final stage, interpretation of the results is performed.

Recent years number of studies that apply text mining methods has been increased. It is commonly used in diverse fields especially in biochemical research, computational biology, information science, engineering, business, and finance. Table 1 presents some of the studies on the main application areas of text mining especially in finance and business domain.

**Table 1.** Selected studies on text mining

Subject	Study
Topic identification	(Correia & Goncalves, 2017), (Yao et al., 2017), (Schneider et al., 2017), (Clifton & Cooley, 1999)
Sentiment analysis, opinion mining	(Delmonte & Pallotta, 2011), (Hu et al., 2017), (Mostafa, 2013), (Khan et al., 2014), (Nagar & Hahsler, 2012)
Prediction	(Fung et al., 2003), (Wang et al., 2012), (Wong et al., 2014), (Ghose & Ipeiritis, 2011), (Kroha et al., 2006), (Ming et al., 2014), (Smalheiser, 2001)
Trend mining	(Baek & Hong, 2017), (Hung & Zhang, 2012), (Thorleuchter, 2008), (Li et al., 2017), (Park et al., 2017)

Text mining is also commonly used for bibliometric research namely analyzing the literature of a specified domain and finding patterns, trends, clusters or forming a specified dictionary for the field. For example, Delen & Crossland (2008) employed text mining to identify clusters and trends of related research topics from three major journals in the management information systems field. Garten & Altman (2009) developed a tool to assist in extracting pharmacogenomic concepts from the literature (using full-text articles) automatically. Scherf et al. (2005) used results from literature analysis in combination with evidence from experiments and genome analysis to improve the accuracy of results. Natarajan et al. (2006) reported that mining biological literature promises to play an increasingly important role in biological knowledge discovery. Yu et al. (2017) inspected 7721 publications in Information Sciences from 1968 to 2016. They used text mining to find the key contributors articles that have made a profound impact and illustrated salient patterns and emerging trends. Moro et al. (2017) performed text mining on articles published between 1996- 2016 related to the tourism research to uncover trends and gaps in the literature. Westergaard et al. (2018) presented the analysis results of 15 million English scientific full-text articles published during the period 1823–2016. They described the development in article length and publication sub-topics. They also extracted published protein-protein, disease–gene, and protein subcellular associations.

## 2.2. Multi-Criteria Decision Making (MCDM)

A classical Multi-Criteria Decision Making (MCDM) approach is applied for ranking decision alternatives based on predefined criteria. Criteria can be in conflict with each other. The scores for each criterion and decision alternatives are obtained from domain experts based on scales that are developed for selected MCDM method. In literature, there are numerous different MCDM methods that have differences in their theoretical bases, areas that they are particularly applied and the result that they produce. Some of these methods and references are listed in Table 2.

**Table 2.** Selected methods on the MCDM

MCDM Method	Reference
AHP	(Saaty, 1986), (Saaty & Vargas, 1987), (Saaty, 1990), (Saaty, 1994), (Saaty et al., 2007), (Saaty, 2008), (Dong et al., 2010; Kaya & Kahraman, 2010; Macharis et al., 2004; Tam & Tummala, 2001; Wei et al., 2005)
ANP	(Saaty, 1999), (Saaty, 2004), (Saaty, 2005), (Agarwal et al., 2006; Jharkharia & Shankar, 2007; Ravi et al., 2005; Wu, 2008; Yuksel & Dagdeviren, 2007)
ARAS	(Zavadskas et al., 2010), (Zavadskas & Turskis, 2010), (Dadelo et al., 2012), (Karabasevic et al., 2016)
COPRAS	(Zavadskas et al., 2007), (Podvezko, 2011), (Ecer, 2014), (Hashemkhani et al., 2014), (Stefano et al., 2015)
DEMATEL	(Wu & Lee, 2007), (Tzeng et al., 2007), (Wu, 2008), (Tseng, 2009), (Tsai & Chou, 2009), (Shieh et al., 2010), (Buyukozkan & Cifci, 2012)
ELECTRE	(Roy, 1991), (Mousseau & Slowinski, 1998), (Beccali et al., 2003), (de Almeida, 2007), (Wang & Triantaphyllou, 2008), (Sevкли, 2010), (Hatami-Marbini & Tavana, 2011)
MOORA	(Brauwers & Zavadskas, 2006), (Brauwers et al., 2008), (Kalibatas & Turskis, 2008), (Brauwers & Zavadskas, 2009), (Chakraborty, 2011), (Karande & Chakraborty, 2012), (Stanujkic et al., 2012)
OWA	(Herrera et al., 1996), (Torra, 1997), (Xu, 2005), (Yager, 1992), (Yager, 1996)
PROMETHEE	(Albadvi et al., 2007), (Behzadian et al., 2010), (Brans & Vincke, 1985), (Brans et al., 1986), (Briggs et al., 1990), (Dagdeviren, 2008), (Macharis et al., 2004)
SAW	(Jibao et al., 2006), (Kaliszewski & Podkopaev, 2016), (Kavaliauskas et al., 2011), (Salih et al., 2015), (Shakouri et al., 2014), (Van Wijk et al., 2006)
SWARA	(Aghdaie et al., 2013), (Alimardani et al., 2013), (Hashemkhani Zolfani & Bahrami, 2014), (Hashemkhani Zolfani & Sapauskas, 2013), (Hashemkhani Zolfani et al., 2013), (Kersulienė et al., 2010), (Ruzgys et al., 2014)
TOPSIS	(Behzadian et al., 2012), (Chen & Tzeng, 2004), (Ertugrul & Karakasoglu, 2009), (Gumus, 2009), (Lai et al., 1994), (Lin et al., 2008), (Opricovic & Tzeng, 2004)
VIKOR	(Kaya & Kahraman, 2010), (Opricovic & Tzeng, 2004a, 2004b), (Serafim Opricovic & Tzeng, 2007), (San Cristobal, 2011)
WASPAS	(Chakraborty & Zavadskas, 2014), (Chakraborty et al., 2015), (Urosevic et al., 2017), (Zavadskas et al., 2016; (Zavadskas et al., 2013)

In this study, we applied text mining on the balanced scorecard literature to find out the potential of text mining to extract sub-dimensions of the four dimensions of the balanced scorecard. For this purpose, a total of 3756 scientific research abstracts were analyzed. By inspecting automated text mining results, a group of three keywords was identified for each dimension. These subdimensions were used to form criteria for solving the decision-making problem. Frequencies of each subdimensions are interpreted as scores to be used for the further steps of the analysis. Shortly, as a novel approach, criteria and scores were formed by text mining backed literature analysis automatically instead of a classical way of utilizing expert opinion or reviewing literature manually. In addition, results of the text mining combined with fuzzy AHP and fuzzy TOPSIS methods to weight criteria and ranking alternatives respectively in a fuzzy setting. In this manner, a hybrid decision making model is developed.

### 3. Methodology

In classical MCDM methods, experts use natural language expressions (linguistic variables) such as “Good” or “Very Important” or “Extremely preferred” in order to convey

their subjective evaluations. Corresponding numerical values of these linguistic variables are used for evaluation of criteria directly. However, due to the inherent uncertainty in natural languages in addition to lack of enough information boundaries of these expressions are not so well defined. This is a common problem in MCDM methods. For expressing linguistic variables more appropriately, MCDM methods are occupied in fuzzy environments. Almost for every MCDM method, there is a fuzzy variant to overcome this difficulty.

The fuzzy set theory developed by Zadeh (1965, 1976) gives the opportunity to express linguistic variables to describe experts' subjective judgment in a quantitative way by using fuzzy numbers. Close interaction between fuzzy set theory and MCDM has resulted in a new decision theory called fuzzy multi-criteria decision-making (F-MCDM) (Nădăban et al., 2016:823). Considering benefits, F-MCDM is becoming more commonly used in literature in spite of their computational complexities.

A usual fuzzy MCDM process flow consists of three main parts. These are judgmental, analytical and evaluation parts. The judgmental part includes identifying objectives, criteria or topic related to the subject of decision-making, identifying and selecting experts, identifying and developing alternatives, weighting fuzzy criteria, defining the hierarchy of objectives. The analytical part contains reviewing the quality of data and information available for applying fuzzy weighting and hierarchy, selecting fuzzy mathematical algorithms and procedures, collecting data and applying the fuzzy algorithm. In the evaluation part reviewing data quality and criteria weighting, running several iterations, interpreting fuzzy decision-making calculations and results, and finalizing recommendations steps are carried out (Mardani et al., 2015:4126).

### **3.1. Fuzzy AHP**

Saaty (1990, 1994) developed the analytic hierarchy process (AHP) to solve complex decision-making problems. AHP uses a hierarchical structure of elements to incorporate expert's knowledge for the decision-making problem. Priorities for each criterion in terms of their importance with respect to achieving objective are determined based on a scale. Similarly, priorities for the alternatives on each criterion are derived. By using pairwise comparison of criteria and alternatives a decision matrix is formed. To calculate the overall priorities for each alternative based on how they help to achieve the objectives, a weighting process is employed. In standard AHP all scores for comparisons are based on Saaty's rating scale. However, in Fuzzy AHP, all crisp scale values are transformed into triangular fuzzy numbers (fuzzification) so all operations are based on these triangular fuzzy numbers. Ranking of alternatives is performed

after the defuzzification step (Özdağoğlu & Özdağoğlu, 2007:65)

Fuzzy AHP is applied in diverse fields such management, business, medicine, engineering, logistics, technology, tourism, and agriculture. Table 3 shows some of the most recent studies that employed fuzzy AHP method as a tool for designing a decision-making system.

**Table 3.** Selected studies on fuzzy AHP

Study	Application
(Nazari et al., 2018)	Developing a clinical decision support system for diagnosis of heart diseases
(Fadafan et al., 2018)	Identifying suitable zones for intensive tourism in an environmentally sensitive landscape
(Yadegaridehkordi et al., 2018)	Predicting the adoption of cloud-based technology
(Sirisawat & Kiatcharoenpol, 2018)	Prioritizing solutions for reverse logistics barriers
(Ilbahar et al., 2018)	Assessing risk for occupational health and safety
(Dožić et al., 2018)	Passenger aircraft type selection
(Seyedmohammadi et al., 2018)	Cultivation priority planning crops
(Rufuss et al., 2018)	Techno-economic analysis of solar stills
(Jayawickrama et al., 2017)	Plant sustainability evaluation
(Awasthi et al., 2018)	Global supplier selection
(Tyagi et al., 2017)	Ranking the influences of factors on product development phase.
(Asakereh et al., 2017)	Evaluation of solar farms locations
(Modak et al., 2017)	Performance evaluation of outsourcing decision
(Anand et al., 2017)	Evaluation of sustainability indicators in smart cities
(Kanuganti et al., 2017)	Analyzing road safety
(Neokosmidis et al., 2017)	Assessing of socio-techno-economic factors affecting the market adoption and evolution of 5G networks

The flow of Fuzzy AHP steps are summarized as follows:

**Step 1.** Identifying the decision-making problem exactly and determining objectives, criteria, and alternatives clearly.

**Step 2.** Transforming the complex decision-making problem into a hierarchical structure with criteria and alternatives.

**Step 3.** Constructing pairwise comparisons between decision elements and so form comparison matrices with fuzzy numbers.

To estimate the relative importance of elements pairwise comparisons are performed. For all pairwise comparisons, triangular fuzzy numbers are used. A fuzzy number  $M$  on  $\mathcal{R}$  to be a triangular fuzzy number if its membership function  $\mu_M(x):\mathcal{R} \rightarrow [0,1]$  is

$$\mu_M(x) = \begin{cases} \frac{x}{m-l} - \frac{l}{m-l}, & x \in [l, m] \\ \frac{x}{m-u} - \frac{u}{m-u}, & x \in [m, u] \\ 0, & otherwise \end{cases}$$

The parameters of the membership function are  $l$  (smallest possible value),  $m$  (the most promising value) and  $u$  (the largest possible value). The fuzzy pairwise comparison matrix is denoted as  $A = (a_{ij})_{n \times m}$  where  $a_{ij} = (l_{ij}, m_{ij}, u_{ij})$  which are satisfied with  $l_{ij} = 1/l_{ji}$ ,  $m_{ij} = 1/m_{ji}$  and  $u_{ij} = 1/u_{ji}$ .

Triangular fuzzy numbers are helpful for capturing vagueness inherently exists in linguistic scales that appraised by decision makers. Linguistic scales and their corresponding Triangular Fuzzy Numbers (TFN), which are used for representing the relative importance of criteria, are shown in Table 4.

**Table 4.** Linguistic variables for relative importance

Linguistic Scales	Corresponding TFN (l, m, u)
Equally important (EI)	(1/2, 1, 3/2)
Moderately more important (MI)	(1, 3/2, 2)
Strongly more important (SI)	(3/2, 2, 5/2)
Very strong more important (VSI)	(2, 5/2, 3)
Extremely more important (EMI)	(5/2, 3, 7/2)

Source: Chang, 1996:649; Lee, 2010:4941; Bozbura et. al., 2007:1100

**Step 4.** Using a fuzzy mathematical algorithm to build the relative weights of the decision elements.

In literature, there exist different methods for relative weights of the decision elements. These methods are listed in Table 5.

**Table 5.** Methods for computing local weights.

Method	Reference
Fuzzy logarithmic least squares	(Van Laarhoven and Pedrycz, 1983)
Geometric mean	(Buckley, 1985)
Fuzzy extend analysis	(Chang, 1996)
Fuzzy least squares priority	(Xu, 2000)
Lambda-Max	(Csutora and Buckley, 2001)
Fuzzy preference programming	(Mikhailov, 2003)

In this study, Chang's fuzzy extend analysis (Chang, 1996:649) which is the most widely used of these methods is preferred. Details of the method are given below.

Let  $X = \{x_1, x_2, \dots, x_n\}$  be object set, and  $U = \{u_1, u_2, \dots, u_m\}$  be a goal set.  $m$  extent analysis values for each object, with the following signs:

$$M_{g_i}^j: M_{g_i}^1, M_{g_i}^2, \dots, M_{g_i}^m, \quad i = 1, 2, \dots, n, \quad j = 1, 2, \dots, m$$

where all the  $M_{g_i}^j$ , ( $i = 1, 2, \dots, n$ ,  $j = 1, 2, \dots, m$ ) are triangular fuzzy numbers.

**Step 4.1.** The value of fuzzy synthetic extent with respect to the  $i$ th object ( $S_i$ ) is defined as:



$$S_i = \sum_{j=1}^m M_{g_i}^j \otimes \left[ \sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j \right]^{-1}$$

For the triangular fuzzy numbers  $M_1 = (l_1, m_1, u_1)$  and  $M_2 = (l_2, m_2, u_2)$  fuzzy addition, fuzzy multiplication and fuzzy inverse operators are defined

$$M_1 \oplus M_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$$

$$M_1 \otimes M_2 = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2)$$

$$(M_1)^{-1} \approx (1/u_1, 1/m_1, 1/l_1)$$

Considering these operations  $S_i$  can be decomposed by following

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

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

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

Finally,  $S_i$  can be expressed as

$$S_i \approx \left( \sum_{j=1}^m l_j \times \frac{1}{\sum_{i=1}^n u_i}, \sum_{j=1}^m m_j \times \frac{1}{\sum_{i=1}^n m_i}, \sum_{j=1}^m u_j \times \frac{1}{\sum_{i=1}^n l_i} \right)$$

**Step 4.2.** The degree of possibility of  $M_1 \geq M_2$  is defined as

$$V(M_1 \geq M_2) = \sup_{x \geq y} \left[ \min \left( \mu_{M_1}(x), \mu_{M_2}(y) \right) \right]$$

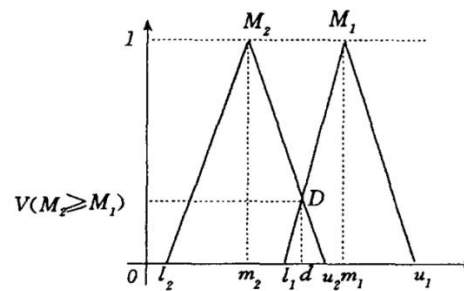
Since  $M_1$  and  $M_2$  are convex fuzzy numbers we have  $V(M_1 \geq M_2) = 1$  iff  $m_1 \geq m_2$ .

The degree of possibility of  $M_2 \geq M_1$  is defined as  $V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_1}(d)$

where  $d$  is the ordinate of the highest intersection point  $D$  between  $\mu_{M_1}$  and  $\mu_{M_2}$  and can be

computed as  $\frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}$ . These explanations can be shortly expressed as

$$V(M_2 \geq M_1) = \begin{cases} 1, & m_2 \geq m_1 \\ 0, & l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise} \end{cases}$$



**Figure 2:** The degree of possibility  $V(M_2 \geq M_1)$  (Chang, 1996:649)

To compare  $M_1$  and  $M_2$ , both the values of  $V(M_1 \geq M_2)$  and  $V(M_2 \geq M_1)$  is employed.

**Step 4.3.** The degree of possibility for a convex fuzzy number to be greater than  $k$  convex fuzzy numbers  $M_i$  ( $i = 1, 2, \dots, k$ ) can be defined by

$$\begin{aligned} V(M \geq M_1, M_2, \dots, M_k) &= V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \dots \text{ and } (M \geq M_k)] \\ &= \min V(M \geq M_i), \quad i = 1, 2, \dots, k. \end{aligned}$$

Assuming that  $d'(A_i) = \min V(S_i \geq S_k)$  for  $k = 1, 2, \dots, n; k \neq i$ . Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), \dots, d'(A_n))^T$$

**Step 4.4.** Via normalization, the normalized weight vectors are obtained.

$$W = (d(A_1), d(A_2), \dots, d(A_n))^T \text{ where } d(A_i) = \frac{d'(A_i)}{\sum_{i=1}^n d'(A_i)}$$

$W$  is a nonfuzzy number.

**Step 5.** Consistency checking to be certain of the judgments of the decision makers are consistent.

**Step 6.** Ranking the alternatives by aggregating the relative weights of decision elements.

### 3.2. Fuzzy TOPSIS

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is one of multi-criteria decision-making techniques developed by Hwang and Yoon (1981). Alternatives are ranked by their similarity to the ideal solution. The main assumption of the method is that the best alternative is the one that has the shortest distance from the positive ideal solution and the furthest distance from the negative ideal solution (Aydođan, 2011:3992). In this paper, we used fuzzy TOPSIS instead of traditional TOPSIS to be able to model real-life problems that have uncertainty and imprecision inherently. Table 6 presents some of the most cited studies that employ Fuzzy TOPSIS as a decision-making tool.

**Table 6: Literature Review of Fuzzy TOPSIS**

Study	Application
(Amiri, 2010)	Project selection for oil-fields development
(Buyukozkan and Cifci, 2012a)	Strategic analysis of electronic service quality in the healthcare industry
(Buyukozkan and Cifci, 2012b)	Evaluating green suppliers
(Chu, 2002)	Facility location selection
(Chu & Lin, 2003)	Robot selection
(Dagdeviren et al., 2009)	Weapon selection
(Ertugrul & Karakasoglu, 2009)	Performance evaluation of cement firms
(Kannan et al., 2014)	Green suppliers selection
(Kannan et al., 2009)	Selection of reverse logistics provider
(Kaya & Kahraman, 2011)	Energy planning
(Kutlu & Ekmekcioglu, 2012)	Failure mode and effects analysis
(Liao & Kao, 2011)	Supplier selection in supply chain management
(Oenuet & Soner, 2008)	Transshipment site selection
(Secme et al., 2009)	Performance evaluation in the banking sector
(Sun, 2010)	Performance evaluation
(Taylan et al., 2014)	Construction projects selection and risk assessment
(Wang et al., 2009)	Supplier selection
(Yong, 2006)	Plant location selection

Fuzzy TOPSIS steps are summarized below (Chen, 2000:2; Paksoy et. al., 2013:15):

**Step 1.** Construct fuzzy decision matrix.

$\tilde{x}_{ij}^k$  denotes the fuzzy weight of *ith* alternative for the *jth* criterion of *kth* expert.  $\tilde{x}_{ij}$  is a linguistic variable that is represented by triangular fuzzy numbers in the form of  $(l_{ij}, m_{ij}, u_{ij})$ . For a group of *K* experts fuzzy weight of *ith* alternative for the *jth* criterion is computed as:

$$\tilde{x}_{ij} = \frac{1}{K} [\tilde{x}_{ij}^1 + \tilde{x}_{ij}^2 + \dots + \tilde{x}_{ij}^K]$$

For *m* alternatives  $(A_1, A_2, \dots, A_m)$  and *n* criteria  $(C_1, C_2, \dots, C_n)$  fuzzy decision matrix ( $\tilde{D}$ ) is shown as:

$$\tilde{D} = \begin{matrix} & C_1 & C_2 & C_3 & \dots & C_n \\ \begin{matrix} A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \tilde{x}_{13} & \dots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \tilde{x}_{23} & \dots & \tilde{x}_{2n} \\ \tilde{x}_{31} & \tilde{x}_{32} & \tilde{x}_{33} & \dots & \tilde{x}_{3n} \\ \vdots & \vdots & \ddots & \dots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \tilde{x}_{m3} & \dots & \tilde{x}_{mn} \end{bmatrix} \end{matrix}$$

**Step 2.** Obtain the weights of criteria.

Let  $\tilde{w}_j^k$  denotes the fuzzy weight of *jth* criterion according to *kth* expert. For a group of *K* expert fuzzy weight of *jth* criterion is calculated as:

$$\tilde{w}_j = \frac{1}{K} [\tilde{w}_j^1 + \tilde{w}_j^2 + \dots + \tilde{w}_j^K]$$

**Step 3.** Compute the normalized fuzzy decision matrix.

$\tilde{R} = [\tilde{r}_{ij}]_{m \times n}$  represents the normalized fuzzy decision matrix formed from fuzzy decision matrix by using:

$$\tilde{r}_{ij} = \left( \frac{l_{ij}}{u_j^*}, \frac{m_{ij}}{u_j^*}, \frac{u_{ij}}{u_j^*} \right), \text{ where } u_j^* = \max_i u_{ij} \text{ (For Utility Criteria)}$$

or

$$\tilde{r}_{ij} = \left( \frac{l_j^-}{u_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{l_{ij}} \right), \text{ where } l_j^- = \min_i l_{ij} \text{ (For Cost Criteria)}$$

**Step 4.** Construct the weighted normalized fuzzy decision matrix.

The weighted normalized fuzzy decision matrix is represented as  $\tilde{V} = [\tilde{v}_{ij}]_{m \times n}$  and computed as

$$\tilde{v}_{ij} = \tilde{r}_{ij} \times \tilde{w}_j$$

All the elements of  $\tilde{v}_{ij}$  are normalized and weighted triangular fuzzy numbers that are in  $[0,1]$  interval.

**Step 5:** Compute distances from fuzzy positive ideal and fuzzy negative ideal solutions.

Fuzzy positive ideal solution and fuzzy negative ideal solution are represented by  $A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_n^*)$  and  $A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-)$  respectively where  $\tilde{v}_j^* = (1, 1, 1)$  and  $\tilde{v}_j^- = (0, 0, 0)$ . For each alternative distances from fuzzy positive ideal solution ( $d_i^*$ ) and fuzzy negative ideal solution ( $d_i^-$ ) are computed respectively as follows:

$$d_i^* = \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{v}_j^*), i = 1, 2, \dots, m$$

and

$$d_i^- = \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{v}_j^-), i = 1, 2, \dots, m$$

Let  $\tilde{a} = (l_1, m_1, u_1)$  and  $\tilde{b} = (l_2, m_2, u_2)$  are two fuzzy triangular fuzzy numbers.

Then, Vertex method gives the distance as

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3} [(l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2]}$$

**Step 6.** Compute closeness coefficient.

For the  $i$ th alternative closeness coefficient ( $CC_i$ ) is computed as

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \quad i = 1, 2, \dots, m$$

$CC_i$  takes values between 0 and 1 and used for ranking alternatives. The alternative having the maximum closeness coefficient is selected by the optimum alternative.

#### 4. Analysis of Banking Sector

For identifying the three most important sub-dimensions for each dimension text mining technique that is based on literature analysis is applied. For collecting data to achieve domain analysis, search queries were executed on ScienceDirect portal. Only research articles published after 2007 in (Business, Management and Accounting), (Decision Sciences), and (Economics, Econometrics and Finance) subsections of ScienceDirect were taken into consideration. Search keywords used for dimensions were "competition", "customer", "organizational" and "financial". Abstracts of studies that resulted from each search were ordered in relevance. Following these lists, for each dimension, a corpus that containing 939 abstracts were constructed. A total of 3756 research article abstracts were included in the analysis. By following standard text mining steps such as transforming cases, tokenization, filtering stopwords, stemming, generating n-grams, filtering token by the length the most frequent keywords were determined for each dimension. Since there was the same number of abstract for each dimension, no normalization procedure was applied on frequency results. Resulting keywords were accepted as sub-dimensions (criteria for decision making problem). Table 7 shows final dimensions and sub-dimensions.

**Table 7.** The most frequent keywords for each dimension resulting from domain analysis.

competition		customer			organizational			financial			
market	price	product	service	satisfaction	value	management	innovation	employee	risk	crisis	growth
1145	579	484	1282	873	776	863	597	590	479	470	419

Annual reports of deposit banks that are listed in BIST-100 were collected from their websites to analyze by text mining technique for identifying the frequency of each sub-dimension keyword on these reports. Some of these banks had not on 2017 annual reports of their websites so 2016 annual reports were used in the analysis. A normalization procedure is applied because of the different sizes of annual reports. For a bank, the frequency of each sub-dimension was divided by the frequency of most frequent sub-dimension for this bank. Thus, for each bank, the most frequent sub-dimension has the value of 1 and the others less than 1. Resulting frequencies of sub-dimensions results are given and for gaining more understandable scores that lie in [0, 1000] interval each score is multiplied by 1000 and rounded to the nearest upper integer. Details of these operations are given in Table 8 and 9.

**Table 8.** Results of the normalized frequencies obtained from 2016 annual reports for each bank

	competition			customer			organizational			financial		
	market	price	product	service	satisfaction	value	management	innovation	employee	risk	crisis	growth
S1	0.5895	0.0738	0.1940	0.3217	0.0125	0.5457	0.8811	0.0188	0.1414	1.0000	0.0038	0.0551
S2	0.3853	0.1068	0.1829	0.2591	0.0223	0.4234	0.6825	0.0102	0.1337	1.0000	0.0084	0.1031
P1	0.4624	0.1686	0.7494	0.1663	0.0501	0.4123	1.0000	0.0433	0.2483	0.6401	0.0046	0.0524
P2	0.4635	0.0527	0.1358	0.2099	0.0034	0.4961	0.5477	0.0123	0.1358	1.0000	0.0011	0.0606
P3	0.3264	0.0803	0.0903	0.1913	0.0060	0.3492	0.3946	0.0187	0.1110	1.0000	0.0033	0.0455
P4	0.4752	0.1031	0.1739	0.2912	0.0243	0.5399	0.7199	0.0374	0.1476	1.0000	0.0051	0.0708
F1	0.4327	0.0926	0.2670	0.6383	0.0258	0.3628	0.5404	0.1432	0.1421	1.0000	0.0000	0.0280
F2	0.3699	0.0881	0.1096	0.1977	0.0222	0.4885	0.4555	0.0107	0.0988	1.0000	0.0132	0.0280
F3	0.3282	0.0305	0.1145	0.2672	0.0267	0.0802	1.0000	0.0229	0.2061	0.5496	0.0000	0.0649
F4	0.3680	0.0596	0.2107	0.3021	0.0360	0.4532	0.5752	0.0554	0.1601	1.0000	0.0028	0.0603

**Table 9.** Results of the frequencies in [0, 1000] interval

	competition			customer			organizational			financial		
	market	price	product	service	satisfaction	value	management	innovation	employee	Risk	crisis	growth
S1	590	74	194	322	13	546	882	19	142	1000	4	56
S2	386	107	183	260	23	424	683	11	134	1000	9	104
P1	463	169	750	167	51	413	1000	44	249	641	5	53
P2	464	53	136	210	4	497	548	13	136	1000	2	61
P3	327	81	91	192	7	350	395	19	112	1000	4	46
P4	476	104	174	292	25	540	720	38	148	1000	6	71
F1	433	93	267	639	26	363	541	144	143	1000	0	28
F2	370	89	110	198	23	489	456	11	99	1000	14	29
F3	329	31	115	268	27	81	1000	23	207	550	0	65
F4	368	60	211	303	37	454	576	56	161	1000	3	61

For weighting the criteria using Fuzzy AHP. Initially, weights of dimensions have been computed with the frequencies of each dimension in the data mining process and then, linguistic evaluations have been obtained from the expert team to construct the pairwise comparison matrices. Data mining results demonstrate that customer dimension is the most importance factor in the balanced-scorecard perspectives while the finance is the relatively weakest as seen in Table 10. The weights of dimensions have been considered to compute the global weights of the criteria.

**Table 10.** Frequencies and weights of dimensions with data mining

Dimensions	Defined Keywords	Count	Dimension Frequencies	Weights
Finance (D1)	Risk	479	1368	0.16
	Crisis	470		
	Growth	419		
Customer (D2)	Service	1282	2931	0.34
	Satisfaction	873		
	Value	776		
Organization (D3)	Management	863	2050	0.24
	Innovation	597		
	Employee	590		
Competition (D4)	Market	1145	2208	0.26
	Price	579		
	Product	484		

The fuzzy pair-wise comparison matrices of the criteria have been constructed in table 11.

**Table 11.** Fuzzy pair-wise comparison matrix for the criteria and weights

	<b>C1</b>		<b>C2</b>		<b>C3</b>		<b>Weights</b>			
Risk (C1)	1.00	1.00	1.00	1.00	1.50	2.00	1.00	1.50	2.00	0.43
Crisis (C2)	0.50	0.67	1.00	1.00	1.00	1.00	0.50	1.00	1.50	0.27
Growth (C3)	0.50	0.67	1.00	0.67	1.00	2.00	1.00	1.00	1.00	0.30
	<b>C4</b>		<b>C5</b>		<b>C6</b>					
Service (C4)	1.00	1.00	1.00	1.00	1.50	2.00	1.00	1.50	2.00	0.43
Satisfaction (C5)	0.50	0.67	1.00	1.00	1.00	1.00	0.50	1.00	1.50	0.27
Value (C6)	0.50	0.67	1.00	0.67	1.00	2.00	1.00	1.00	1.00	0.30
	<b>C7</b>		<b>C8</b>		<b>C9</b>					
Management (C7)	1.00	1.00	1.00	1.00	1.50	2.00	1.00	1.50	2.00	0.45
Innovation (C8)	0.50	0.67	1.00	1.00	1.00	1.00	1.00	1.50	2.00	0.34
Employee (C9)	0.50	0.67	1.00	0.50	0.67	1.00	1.00	1.00	1.00	0.21
	<b>C10</b>		<b>C11</b>		<b>C12</b>					
Market (C10)	1.00	1.00	1.00	0.50	1.00	1.50	1.00	1.50	2.00	0.37
Price (C11)	0.67	1.00	2.00	1.00	1.00	1.00	0.50	1.00	1.50	0.33
Product (C12)	0.50	0.67	1.00	0.67	1.00	2.00	1.00	1.00	1.00	0.30

After the pairwise comparison matrices of the criteria, the local weights of the criteria have been computed as seen in Table 12.

**Table 12.** Local and Global weights of new service development factors

Dimensions	Dimension Weights	Criteria	Local Weights	Global Weights
Finance (D1)	0.16	Risk (C1)	0.43	0.069
		Crisis (C2)	0.27	0.044
		Growth (C3)	0.30	0.047
Customer (D2)	0.34	Service (C4)	0.43	0.147
		Satisfaction (C5)	0.27	0.094
		Value (C6)	0.30	0.102
Organization (D3)	0.24	Management (C7)	0.45	0.108
		Innovation (C8)	0.34	0.082
		Employee (C9)	0.21	0.050
Competition (D4)	0.26	Market (C10)	0.37	0.095
		Price (C11)	0.33	0.085
		Product (C12)	0.30	0.077

The weights of the new service development factors are shown in Table 12 and the global weights illustrate that the service is the most important criteria in the balanced scorecard-based factors of new service development. This result is also underlined in many different studies in the literature (Lin et al., 2008; Cui and Wu, 2017; Romano et al., 2017). On the other side, employee factor has the weakest importance in comparison with the others.

**Table 13.** Weighted normalized fuzzy decision matrix

	C1			C2			C3			C4			C5			C6		
S1	0.00	0.02	0.04	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.01	0.01	0.02	0.03	0.04
S2	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.01	0.03	0.01	0.02	0.03
P1	0.00	0.00	0.02	0.01	0.02	0.03	0.02	0.03	0.04	0.00	0.00	0.03	0.04	0.05	0.05	0.01	0.02	0.03
P2	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.01	0.02	0.03	0.04
P3	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.01	0.01	0.02	0.03
P4	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.01	0.03	0.02	0.03	0.04
F1	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.01	0.02	0.03	0.07	0.10	0.00	0.01	0.03	0.01	0.02	0.03
F2	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.01	0.03	0.02	0.03	0.04
F3	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.01	0.03	0.04	0.00	0.00	0.01
F4	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.01	0.03	0.04	0.01	0.02	0.03
	C7			C8			C9			C10			C11			C12		
S1	0.00	0.02	0.04	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.03	0.00	0.01	0.02	0.00	0.01	0.01	0.03
S2	0.00	0.02	0.04	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.03	0.02	0.03	0.04	0.01	0.03	0.04
P1	0.02	0.04	0.05	0.00	0.01	0.03	0.01	0.02	0.03	0.00	0.00	0.02	0.00	0.01	0.02	0.00	0.00	0.01
P2	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.03	0.00	0.00	0.01	0.00	0.01	0.03
P3	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.03	0.00	0.01	0.02	0.00	0.00	0.01
P4	0.00	0.02	0.04	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.03	0.01	0.02	0.03	0.00	0.01	0.03
F1	0.00	0.00	0.02	0.04	0.06	0.06	0.00	0.00	0.01	0.00	0.02	0.03	0.00	0.00	0.01	0.00	0.00	0.01
F2	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.03	0.03	0.04	0.04	0.00	0.00	0.01
F3	0.02	0.04	0.05	0.00	0.00	0.01	0.00	0.01	0.02	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.01	0.03
F4	0.00	0.00	0.02	0.00	0.01	0.03	0.00	0.00	0.01	0.00	0.02	0.03	0.00	0.01	0.02	0.00	0.01	0.03

Table 13 represents the weighted values of normalized decision matrix using the results of the fuzzy AHP. Table 14 shows the distances of each alternative from the positive and negative ideal solution as well as the values of the closeness coefficient.

**Table 14.** Ranking Results with Fuzzy TOPSIS

	D+	D-	Cci	Ranking
S1	11.859	0.187	0.0155	5
S2	11.838	0.205	0.0170	3
P1	11.775	0.261	0.0217	1
P2	11.896	0.148	0.0123	9
P3	11.903	0.142	0.0118	10
P4	11.853	0.192	0.0160	4
F1	11.789	0.250	0.0208	2
F2	11.855	0.186	0.0155	6
F3	11.874	0.168	0.0140	8
F4	11.867	0.177	0.0147	7

Ranking results demonstrate that P1 is the best bank in the balanced scorecard-based new service development evaluations while P3 has the worst rank in the list. However, state owned banks are listed in the third and fifth seats and foreign banks are in the second, sixth, seventh, and eighth ranks. These results show that the best and worst performed banks are owned by the private sector.

Moreover, it can be seen that no bank type has a clear advantage over others. In other words, there are banks with both good and bad performance outcomes within each type of banking group. However, it is determined that foreign banks and private banks took place in the worst order. In this context, in order to achieve a competitive advantage, these low performing banks should focus on new services that take into account the customer expectations. Yüksel et al. (2017) also underlined the importance of the same issue in their study.



## 5. Discussions and Conclusions

With the effect of globalization, the competition in banking sector increased significantly. Because banks play a significant role in foreign trade, a lot of international banks entered to many different countries to increase their profitability (Oktar and Yüksel, 2016:31; Yüksel and Özşarı, 2017:16). Therefore, it can be said that banks must take necessary actions to increase their competitive power. Otherwise, it may be impossible for these countries to survive in this environment (Kartal et al., 2018:209). Generating new services is a way of increasing competitive advantage because with the help of innovative services, banks can attract the attention of the consumers (Terzioğlu, 2018:155; Girgin, 2018:621).

The aim of this study is to evaluate the performance of Turkish deposit banks with respect to the service innovation performance. Within this context, by using content data mining approach, similar studies in the literature are searched and the criteria for service innovation are identified. In addition to this situation, by using fuzzy AHP method, the weights of the criteria are determined. Furthermore, fuzzy TOPSIS approach is used to rank the performance of these deposit banks.

As a result, it is defined that customer is the most important dimension whereas finance has the least significance in comparison with the others. Additionally, service is defined as the most important criterion, but crisis and growth have the lowest weights. Moreover, it is determined that a private bank has the highest performance. Also, a foreign bank is on the second rank and a state bank has the third highest performance. Furthermore, two different private banks have the lowest performance.

While considering the results of this study, it is understood that no bank type has a clear advantage over others. That is to say, there are banks with both good and bad performance outcomes within each type of banking group. Nevertheless, it is defined that the banks, which have the lowest performance, are the foreign banks and private banks. Within this framework, with respect to the strategic policy, it is recommended that the low performing banks should focus on new services that consider the customer expectations to have a competitive advantage. By focusing on this important topic for banking sector, it is aimed to make contribution to the literature. However, it is also believed that a new study considering banking sectors in different countries at the same time will also very beneficial.

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