International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-12 Issue-1, May 2023

An Application of Fuzzy Logic to Bank Ranking: A study of the Banking Sector in Bangladesh

Khadijatul Kobra, Md. Atiqur Rahman, Syeda Maria Rahman, Nafees Imran, Md Faisal Kabir

Abstract: ***Creditors, investors, policymakers, and other stakeholders are all significantly impacted by banks' performance ratings since these ratings affect how well banks are able to compete in the banking industry, which is crucial for the growth of this industry. The criteria used to evaluate a bank's success in the banking industry are nebulous and vague. Consequently, it is no longer possible to precisely determine the state of a bank using the analytical method. Furthermore, there is no standard framework that can evaluate private commercial banks using the CAMELS criterion and eliminates ambiguity that we can witness in Bangladesh. The literature shows that two multi-criteria decision-making procedures, FAHP and TOPSIS, are employed in many countries to rank banks according to the CAMELS criteria. However, in Bangladeshi private commercial banks, we have never used such models using the CAMELS criteria. In order to assess the performance of Bangladeshi private commercial banks, this study aims to propose a Fuzzy Multi-Criteria Decision Model (FCDM) that can handle uncertain and ambiguous data. The CAMELS (Capital Adequacy, Asset Quality, Management Efficiency, Earnings, Liquidity, and Sensitivity to Market Risk) criteria are used to analyze and rank the ten commercial banks in Bangladesh. The suggested model incorporates the Fuzzy Analytic Hierarchy Process (FAHP) and Technique of Order Performance by Similarity to Ideal Solution (TOPSIS) methodologies. The weights are input into the TOPSIS algorithm to rank the Banks after determining the weight vector of the CAMELS criteria based on the opinions of experts using FAHP. The outcome displays the ten Bangladeshi commercial banks' final rankings.***

Keywords: ***Capital Adequacy, Asset Quality, Management Efficiency, Earnings, Liquidity, Sensitivity to Market Risk, Pairwise Comparison Matrix, Fuzzy Geometric Mean, Defuzzification, Fuzzy Weights, FAHP, TOPSIS, Mean, Fuzzy Number.***

Manuscript received on 17 October 2022 | Revised Manuscript received on 05 April 2023 | Manuscript Accepted on 15 May 2023 | Manuscript published on 30 May 2023.

*Correspondence Author(s)

Khadijatul Kobra, Department of General Educational Development, Daffodil International University, Bangladesh. E-mail: khadija.ged@daffodilvarsity.edu.bd, ORCID ID: https://orcid.org/0009-0001-5497-1369

Md. Atiqur Rahman*, Department of Computer Science and Engineering, Daffodil International University, Bangladesh. E-mail: atick.rasel@gmail.com, ORCID ID: https://orcid.org/0000-0003-3450-6416

Syeda Maria Rahman, Department of Software Engineering, Daffodil International University, Birulia, Bangladesh. E-mail: maria.bba@diu.edu.bd, ORCID ID: https://orcid.org/0009-0001-5307-2919

Nafees Imran, Department of Information Technology and Management, Daffodil International University, Birulia, Bangladesh. E-mail: nafees.itm@diu.edu.bd, ORCID ID: https://orcid.org/0009-0006-3191-3445

Md Faisal Kabir, South Bangla Agriculture, Commerce Bank, Bangladesh. E-mail: faisal.04108@gmail.com, ORCID ID: https://orcid.org/0009-0005-2658-9380

I. INTRODUCTION

Banks that make profits through investments are among the financial institutions that redistribute unused resources and competencies from areas of excess funds to areas of need [1], [2]. Every day, banks handle millions of transactions, such as providing credit cards, lending money for short- or long-term loans, opening LCs, and performing other activities that help to maintain liquidity in the market. The banking sector is, therefore, dependent on the operations of every industry and organization [2]. As a result of such dependency, we can assess the Bank's performance. Performance is a metric used by banks to assess how efficiently they achieve their targets [3]. One of the most critical aspects of banking performance is its financial performance [4]. Evaluation of a bank's financial performance is crucial for management, creditors, regulators, current/potential investors, as well as competitors in the same industry in today's highly competitive market. The literature describes a variety of methods that have been developed to evaluate a bank's financial standing, including ratio analysis, linear programming, DEA, CAMELS evaluation system, VIKOR, SAW, and PSO [5]–[26]. However, they failed because financial standing and indexing are both quantitative and qualitative processes. Therefore, converting qualitative preferences to point estimations may not be logical [27]. Several vague and imprecise financial indicators represent a Bank's competitiveness, so we must consider them when assessing its financial performance [4]. In order to develop an applicable financial performance evaluation model, we need to construct a suitable and trustworthy framework based on past studies, reviewed indexes, and criteria. The multi-criteria decision-making (MCDM) model could, therefore, be a very effective method for evaluating the index and, consequently, the Bank's financial condition. In MCDM, the various types of uncertainty must be considered. With its inherent capacity to deal with uncertainty, the fuzzy set theory may provide the flexibility required to deal with uncertainty in decision-making. Since fuzzy linguistic approaches can take into account the optimism or pessimism rating attitude of decision makers [28], it is recommended to use linguistic values, whose membership functions are often represented by triangular fuzzy numbers, to assess preference ratings rather than the traditional numerical equivalency method. Accordingly, the fuzzy MCDM is more suitable and efficient than the traditional MCDM in actuality [4].

This study aims to develop a new decision-making model that enables decision-makers to evaluate the performance of banks [4].

We propose a new decision-making model for evaluating the financial standing of banks by integrating two key MCDM models: Fuzzy Analytic Hierarchy Process (FAHP) and Technique for Ordering Performance by Similarity to Ideal Solution (TOPSIS) [4]. As a result of the proposed model, clients, investors, and financial analysts can assess the performance of the banks before making financial investments [4]. Based on FAHP, we determined the CAMELS criteria weight, then applied this weight to TOPSIS to identify the best bank.

This article is organized as follows: section 2 summarizes current state-of-the-art techniques in this field. Sections 3 describes the methodology. Sections 4, 5, and 6 discuss three important evaluation matrices: CAMELS, FAHP, and TOPSIS, respectively. Section 7 discusses our findings. Finally, section 8 concludes the article.

II. LITERATURE REVIEW

Various methods have been developed to measure the performance of banks, and this research is becoming increasingly significant. Below are some brief descriptions of some of the methods.

In the past, financial ratio analysis has been used to evaluate a bank's financial performance. Due to the preliminary nature of conventional financial ratio analysis, future judgments cannot be made from their results. Sherman and Gold (1985) and Oral and Yolalan (1990) have suggested that performance standards should not be restricted to financial ratios alone [6-11]. A second investigation was conducted by Yeh (1996) [32]. His study found that evaluating bank performance that solely depends on financial ratios would not be suitable. Li, Liu, Liu, and Whitmore (2001) [29] compared the performances of Chinese banks using financial ratio analysis. T ö z ü m (2002) [12] used a financial ratio analysis to measure performance. In contrast to traditional ratio evaluations, he emphasized the need for multilateral oversight of banks' performance. A model was developed by Zopounidis, Pouliezos, and Yannacopoulo (1992) [13] and Siskos, Zopounidis, and Pouliezos (1994) [14] in order to measure failure. In order to evaluate bank performance, G ü ven and Persen- tili (1997) [15] used a linear programming model to analyze bank balance sheets. Kaya (2001) [16] conducted a performance analysis of the Turkish banking sector using the CAMELS evaluation system. In addition to Isk, Uysal, and Meleke (2003) [17], Denizer, Dinç, and Tarmclar (2000) [18], and Bauer, Berger, Ferrier, and Humphrey (1998) [16], other researchers have used DEA. In the study, Mercan, Reisman, Yolalan, and Emel (2003) [20] used the DEA method to investigate how bank ownership and growth affected performance during 1989-1999. Astarcoglu and Demir (2007) [21] analyzed the performance of Turkish commercial banks with DEA by examining their total commercials, interest income and expenses, and credits they granted. Frei and Harker (1999) [22] measured bank performance using the AHP approach as an alternative to the DEA and examined the relationship between financial and operating performance. Based on a sample of 737 European banks between 1995 and 2000, Beccalli (2007) [23] examined whether IT investments impacted bank performance. Based on standard accounting ratios and alternative profit efficiency measures, this study investigated whether IT expenditures contributed to better performance. In order to estimate banks' financial performances using financial data, Ravi, Kurniawan, Thai, and Kumar (2008) proposed a few models. These models were integrated with neural networks and statistical approaches. Using particle swarm optimization (PSO), Lin (2009) [25] determined appropriate SVM and DT parameter settings and selected a subset of useful features without affecting classification accuracy. A study by Hopkins and Hopkins (1997) [30] investigated the relationship between strategic planning and financial performance and identified the factors that affected performance measurement. An analysis of the performance of European Union banks and the influence of environmental factors on performance was performed by Vigas, Pastor, and Hasan (2001) [31]. Cinar (2010) [26] proposed a decision support model to assist the bank in choosing the best branch among all branches of three banks. Yurdakul, M., İ ç, Y. T. (2004) [32] analyzed the bank performances using AHP with the financial and non-financial performance criteria in credit risk assessment. Using fuzzy AHP, Albayrak, and Erensal (2005) [33] assessed the financial and non-financial performance standards for the performance assessment of Turkish banks. Secme (2009) [34] proposed a fuzzy multicriteria decision model for assessing banks' operational effectiveness. TOPSIS and fuzzy AHP are incorporated into the proposed model. Results demonstrate that performance other than financial success should also be considered in a competitive environment. For evaluating banking performance, Wu (2009) [35] introduced Fuzzy Multiple Criteria Decision Making (FMCDM). Based on the fuzzy analytic hierarchy process and fuzzy TOPSIS technique, Sun (2010) [36] proposed a performance evaluation model for industrial practitioners in a fuzzy environment. This approach allows decision analysts to understand the entire evaluation process and produce more precise, efficient, and organized decision support tools. TOPSIS is used by some scholars to address decision-making issues in the financial industry, particularly banking. Various study fields have used the TOPSIS and fuzzy TOPSIS for entity ranking [19], [34], [37], [38].

III. METHODOLOGY

For FAHP, we collected data for pairwise comparison matrix from experts in business fields, where the expert must meet the following three criteria:

1) Business graduate with knowledge of CAMELS.
2) Professionals in banks with experience on CAMELS.
3) CAMELS criterion researcher.

Fig. 1 demonstrates the methodology of the proposed model. In the initial phase of FAHP, we gathered experts' fuzzified pairwise comparison matrices based on linguistic value. Following that, we identified the fuzzified CAMELS criteria weight vectors for each expert. In order to identify the crisp weight vector for the CAMELS criteria, we used a defuzzification procedure.

After applying the defuzzification method, eight experts find eight crisp weights for each CAMELS criterion. Then, we calculated the mean weight based on eight experts' crisp weights for each CAMELS criterion. After that, a weight vector was found for the CAMELS criteria.

For the fiscal year 2021, we selected ten banks. For this study, we analyzed the annual reports of ten banks to determine their CAMELS scores. Using CAMELS weight vectors, we run the TOPSIS method on the financial analysis of 10 banks to provide each bank's rank.

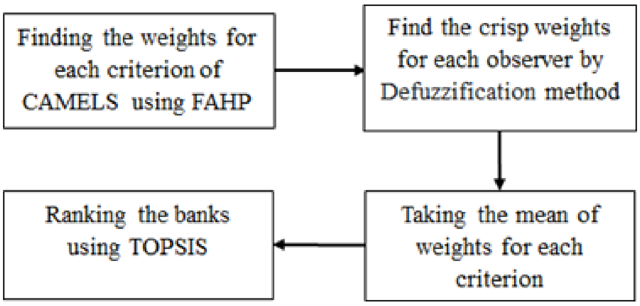

Fig. 1: The Proposed Model for Ranking Banks using FAHP and TOPSIS

IV. THE CAMEL'S CRITERION

According to the stated criteria, bank regulators use the internationally accepted CAMELS rating system to assign scores to financial organizations. Supervisory authorities grade each bank based on its performance on a scale. The best score for each factor is one, while the worst score is five (Jordan, Peek, Rosengren, 1999) [39].

4.1. Capital Adequacy

A bank's ability to pay up its standing liabilities. In order to assess capital adequacy, two layers of capital must be present (Eubanks, 2010) [40]. The capital adequacy ratio is calculated by dividing bank capital by risk-weighted assets (King Tarbert, 2011) [41].

$$CAR = (Equity\ Capital)/(Total\ Assets)$$

4.2 Asset Quality

When a potential demand arises, the asset liquidation value should be liquid enough to meet it. Therefore, banks should maintain adequate provisions to cover future withdrawal demands (Kadioglu Ocal, 2017) [42].

$$Asset\ Quality = \frac{Total\ Non\ performing\ loan - Provision\ for\ non\ performing\ Assets}{Total\ loans}$$

4.3 Management quality

The ability of a management team to recognize and respond to financial stress is measured by their management competence (Valová, 2007) [43]. The category is based on the effectiveness of a bank's internal controls, its financial performance, and its business strategy [44-48]. This result indicates how efficient the management is at keeping them in the system.

$$Management\ quality = \frac{Personal\ Expenses}{Average\ assets}$$

4.4 Earnings

Although interest from advances is the primary source of income, in Bangladesh, bank earnings are heavily weighted on operating income. Where Return on assets represents the weightage of earnings compared to total assets, on the other hand, return on equity represents the weightage of the bank's Return compared to the investor. We find earnings from Return on assets and Return on Equity.

4.5 Liquidity

Liquidity refers to the ease with which an asset can be purchased, sold, and converted into cash or cash equivalents. We decide liquidity from

$$\frac{Net\ Loans}{Deposite\ and\ Short\ Term\ fund\ /\ asstes} \text{ and } \frac{Liquid\ assets}{Deposite\ and\ Short\ Term\ fund\ /\ asstes}$$

4.5 Sensitivity

Sensitivity analysis examines how different risk exposures could affect an institution. Examiners can determine an institution's sensitivity to market risk by observing how credit concentrations are managed. In this way, examiners can see how lending to particular industries affects a particular institution.

$$Sensitivity = (Total\ securities\ Total\ )/Aassets$$

V. FUZZY ANALYTIC HIERARCHY PROCESS (FAHP)

A quantitative and qualitative approach is required to determine the weights for each CAMELS criterion. In AHP, qualitative and quantitative factors are considered in making judgments. Furthermore, expert judgments are based on individual judgments, so fuzzy numbers rather than crisp data are preferred. For the analysis, scientists agreed to use triangle fuzzy numbers [51].

An AHP approach based on fuzzy numbers was developed in order to reduce ambiguity when determining the weights of the CAMELS criteria [49]. Due to the nature and character of people, respondents' linguistic judgments of the same aspect may differ. Therefore, in order to make a safer decision, it is essential to consider uncertainty. Therefore, fuzzy AHP increases calculations' accuracy.

In the current study, triangle fuzzy numbers were calculated based on the numerical assessments offered by the experts. Often, triangular fuzzy numbers are used to determine the best approach to addressing real-world issues. Triangular fuzzy number *M* is represented by (a, b, c), and the membership function of the fuzzy number is defined by the following equation.

$$\int_{\widetilde{M}}(x) = \begin{cases} \frac{x-a}{b-a}, & if\ a \le x \le b; \\ \frac{c-x}{c-b}, & if\ b \le x \le c; \\ 0, & \text{otherwise.} \end{cases}$$

where $-inf < a \le b \le c < +inf$;

$\int_{\widetilde{M}}(x))$ is a membership function of the triangular fuzzy number $\widetilde{M}$. And a, b, c represents the lower bound of the best possible value, the best possible value given by experts, and the upper bound of the best possible value, respectively.

In the FAHP technique, experts compare each CAMELS criterion with another. To analyze expert opinions, we built a triangular fuzzy-number scale using a triangle fuzzy membership function shown in Table 1 [50].

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

TABLE 1: Fuzzy Pairwise Comparison Scale

Meaning of Fuzzy number	Fuzzy number, $\widetilde{M}_{ij}$	Triangular Fuzzy numbers
If the j^{th} element is equally as important as i^{th} element	$\tilde{1}$	(1,1,1)
If the j^{th} element is moderately important than i^{th} element	$\tilde{3}$	(2,3,4)
If the j^{th} element is strongly important than i^{th} element	$\tilde{5}$	(4,5,6)
If the j^{th} element is very strongly important than i^{th} element	$\tilde{7}$	(6,7,8)
If the j^{th} element is extremely important than i^{th} element	$\tilde{9}$	(8,9,9)
Intermediate values	$\tilde{2}$, $\tilde{4}$, $\tilde{6}$, $\tilde{8}$	(1,2,3), (3,4,5), (5,6,7), (7,8,9)

To create the pairwise comparison matrix given by the equation, each expert must perform $n(n-1)/2$ comparisons.

$$\widetilde{M} = \widetilde{m}_{ij}$$

$$\widetilde{m}_{ji} = \frac{1}{\widetilde{m}_{ij}}$$

the aggregated experts' assessment is calculated using a formula that is based on geometric mean [24].

$$\widetilde{m}_{ij}^{A} = (\widetilde{m}_{i1} \otimes \widetilde{m}_{i2} \otimes \dots \dots \dots \otimes \widetilde{m}_{in})^{\frac{1}{n}}$$

Where, $\widetilde{m}_{ij}^{A}$ =Evaluation of an aggregated element belonging to i^{th} row and j^{th} column.

n = number of times each expert developed pairwise comparison matrices.

The fuzzy weights of the CAMELS criterion are derived from following the calculation of the aggregated experts' assessments [24].

$$\widetilde{\omega}_i = \widetilde{m}_{ij}^{A} \otimes (\widetilde{m}_{i1} \otimes \widetilde{m}_{i2} \otimes \dots \dots \dots \otimes \widetilde{m}_{in})^{\frac{1}{n}}$$

$$D = \begin{matrix} & C_1 & \dots & C_n \\ A_1 & \\ \vdots & \\ A_m & \end{matrix} \begin{pmatrix} x_{11}\dots & x_{in} \\ \vdots & \vdots \\ x_{m1}\dots & x_{mn} \end{pmatrix}$$

VI. TOPSIS

Consider the CAMELS criteria and alternatives (private banks of Bangladesh) in the decision matrix D given by where $A1, A2, \dots\dots, Am$ are alternatives (private banks of Bangladesh) and $C1, C2, \dots, Cn$ are CAMELS criteria, x_{ij} indicates the rating of the alternative A_i according to criteria C_j The weight vector of CAMELS criteria $W = (W1, W2, \dots, Wn)$ is composed of the individual weights $w_j (j = 1, \dots, n)$ for each criterion C_j satisfying $\sum_{j=1}^{n} W_j = 1$. The two categories into which the criteria are frequently separated are benefit and cost. Greater values are preferred for the benefit criterion, but the opposite is true for the cost criterion. The decision matrix D's data come from numerous sources, so normalizing them is necessary to create a dimensionless matrix that allows for comparison of the different criteria. In this study, the normalized decision matrix is used as follows.

$R = [r_{ij}], R_{m\times n})$, with i=1,2, . . . , m and j=1,2,. . . ,n

The normalized value r_{ij} is calculated as:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}} \text{, with } i = 1,2,\dots m$$

The relative ranking of the choices is represented by the normalized decision matrix R. We compute the weighted normalized decision matrix following normalization. $P = [p_{ij}]_{m\times n}$ with i=1,2,. . . ,m and j=1,2,. . . ,n by multiplying the normalized decision matrix by its associated weights. The weighted normalized value p_{ij} is calculated as: $p_{ij} = w_i.r_{ij}$ with i=1,2,. . . ,m and j=1,2,. . . ,n The steps that follow the following given description of TOPSIS:

1) Finding the ideal solutions A^+ (benefits) and negative ideal solutions A^- (costs) as follows

$$A^+ = (p_1^+, p_2^+, \dots, p_m^+)$$

$$A^- = (p_1^-, p_2^-, \dots, p_m^-)$$

Where,

$p^+ = (max_i\ p_{ij}\ j \in J_1; min_i\ p_{ij}\ j \in J_2)$

$p^- = (min_i\ p_{ij}\ \ j \in J_1; max_i\ p_{ij}\ \ j \in J_2)$

Where J_1 and J_2 represent the criteria benefit and cost, respectively

2) Calculate the Euclidean distances from the positive ideal solution A^+ (benefits) and negative ideal solution A^- (costs) of each alternative A_i respectively as follows:

3)

$$e_i^+ = \sqrt{\sum_{j=1}^{n} (e_{ij}^+)^2}$$

$$e_i^- = \sqrt{\sum_{j=1}^{n} (e_{ij}^-)^2}$$

Where,

$$e_{ij}^+ = p_j^+ - p_{ij} \text{ with } i = 1,2,\dots,m$$

$$e_{ij}^- = p_j^- - p_{ij} \text{ with } i = 1,2,\dots,m$$

4) Determine α_i, where α_i is the parameter which expressing how much each alternative A_i is close to the positive ideal solution Calculate the relative closeness $_i$ for each alternative A_i with respect to positive ideal solution as given by

$$\alpha_i = \frac{e_i^+}{e_i^+ + e_i^-}$$

Retrieval Number: 100.1/ijrte.D73221111422
DOI: 10.35940/ijrte.D7322.0512123
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

5) Rank the options in order of how closely they are related. The best options are those that have higher α_i and picked because they are nearer the positive ideal solution.

VII. DATA AND FINDINGS

All Bangladeshi private banking activity has been considered in the modeling [2]. A total of ten Bangladeshi commercial banks provided financial information for the study. The banks are Jamuna Bank, City Bank Limited, Southeast Bank Limited, Dhaka Bank Limited, AB Bank, Bank Asia, National Credit and Commerce, Eastern Bank, MTB, and Social Islami Bank Limited. A total of six criteria were considered: Capital Adequacy, Asset Quality, Management Efficiency, Earnings, Liquidity, and Sensitivity to Market Risk. This study integrated the Fuzzy AHP and TOPSIS to create the proposed model. The weight vectors for each criterion were initially obtained using the Fuzzy AHP approach.

The Fuzzy AHP procedure consists of two stages:

7.1. Stage I Fuzzy Triangular membership pair-wise comparison matrix

The financial experts compare linguistic criteria and chooses the linguistic variable that best reflects the weight of the factors. In a scale, three values are assigned to each variable using a triangular fuzzy number. An example of a fuzzy comparison matrix for six basic criteria determined by one expert is shown in Table 2.

Table 2: Fuzzy Pairwise Comparison Matrix of One Expert

Criteria	Capital Adequacy	Asset Quality	Management Efficiency	Earnings	Liquidity	Sensitivity to Market Risk
Capital Adequacy	1,1,1	1,2,3	1,1,1	1,2,3	1,2,3	1,2,3
Asset Quality	1/3,1/2,1	1,1,1	1,1,1	1,2,3	1,2,3	2,3,4
Management Efficiency	1,1,1	1,1,1	1,1,1	1,2,3	1,1,1	2,3,4
Earnings	1/3,1/2,1	1/3,1/2,1	1/3,1/2,1	1,1,1	1,1,1	1,2,3
Liquidity	1/3,1/2,1	1/3,1/2,1	1,1,1	1,1,1	1,1,1	1,2,3
Sensitivity to Market Risk	1/3,1/2,1	1/4,1/3,1/2	1/4,1/3,1/2	1/3,1/2,1	1/3,1/2,1	1,1,1

Fuzzy AHP is used to determine the priority weights for each criterion. For experts, comparing CAMELS criteria has been made easier with the use of linguistic measures of importance [51]. Using linguistic terminology to portray people's views is only reasonable since verbal expressions make up human speech [2]. Instead of numbers, fuzzy AHP uses linguistic variables whose values are words. Linguistic variables can be defined and converted to fuzzy integers. In this situation, we use a scale of five categories: equally important, moderately important, strongly important, very strongly important, and extremely important. In order to meet CAMELS criteria, we conducted a survey. Table 3 shows the fuzzy and crisp weights of the CAMELS criteria, which were determined after consulting one financial expert.

Table 3: Fuzzy Weight of CAMELS criteria form Table-2

Criteria	fuzzy weight from one observer			Crisp weight after defuzzification
	Weight1	Weight2	Weight3	
Capital Adequacy	0.1162	0.2458	0.4434	0.2383
Asset Quality	0.1086	0.2087	0.3873	0.2085
Management Efficiency	0.1304	0.2087	0.3225	0.1958
Earnings	0.0671	0.1229	0.256	0.132
Liquidity	0.0806	0.1379	0.256	0.1404
Sensitivity to Market Risk	0.0423	0.0759	0.1692	0.085

Table 4: Crisp Weights of Eight Financial Experts.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8
Capital Adequacy	0.1276	0.1216	0.1789	0.0769	0.1195	0.1467	0.1835	0.2083
Asset Quality	0.2205	0.1506	0.1842	0.0211	0.2527	0.1026	0.1879	0.2167
Management Efficiency	0.0951	0.0997	0.1072	0.1614	0.1515	0.4182	0.1239	0.2037
Earnings	0.2076	0.2106	0.3111	0.0926	0.0893	0.1068	0.1856	0.1371
Liquidity	0.2493	0.3403	0.0882	0.1846	0.1452	0.1312	0.0195	0.1459
Sensitivity to Market Risk	0.0999	0.0772	0.1304	0.2733	0.2417	0.0945	0.1239	0.0883

Table-4 is showing the crisp weights of CAMELS criteria after counselling of eight experts. For each CAMELS criterion, we took the normalized mean value of the weights of eight financial experts. The final weight vector of CAMELS criteria is shown in Table-5.

Table 5: Final weights of CAMELS criteria

Criterions	Normalized mean weights (Mean of 8 crisp Weights finding from experts)
Capital Adequacy	0.145377
Asset Quality	0.167047
Management	0.170096
Earning	0.167581
Liquidity	0.163022
Sensitivity	0.141159

7.1 Stage-II [2]

Our study aims to determine the Rank of private Banks of Bangladesh.". A bank's performance is assessed based on its capital adequacy, asset quality, management efficiency, earnings, liquidity, and market risk sensitivity. Our data came from the ten commercial banks in Bangladesh: City Bank Limited, Southeast Bank Limited, Dhaka Bank Limited, AB Bank, Bank Asia, National Credit and Commerce, Eastern Bank, MTB, and Social Islami Bank Limited. Table 6 shows all the values in BDT. Table 6 shows CAMELS criteria values of these IO private banks of Bangladesh.

Table 6: Data table for the 10 private local banks according to CAMELS criteria.

Criteria → Bank ↓	Capital Adequacy	Asset Quality	Management Efficiency	Earnings,	Liquidity,	Sensitivity to Market Risk
City Bank Limited	0.001663	0.001356	0.188804	0.001663	0.214363	0.108095
AB Bank	0.001541	0.062195	0.001514	0.001541	0.450504	0.169354
Bank Asia	0.000346	0.008529	0.249945	0.000346	0.173128	0.181833
Dhaka Bank Limited	0.001458	0.031971	0.003158	0.001458	0.515409	0.150401
Eastern bank	0.001881	0.025639	0.29596	0.001881	0.336605	0.18038
MTB	0.00028	0.016023	0.376925	0.00028	0.388871	0.154229
National Credit and commerce	0.001873	0.005398	0.29875	0.001873	0.329986	0.182139
Southeast Bank Limited	0.001414	0.038924	0.131975	0.001414	0.198637	0.228801
Social Islami Bank Limited	9.58E-05	0.996271	0.251261	9.58E-05	0.003071	0.786702
Jamuna Bank	0.999992	0.002964	0.7088	0.999992	0.178091	0.341526

Table 7: Rank of ten local Commercial Bank using TOPSIS

Bank Name	e_i^+	e_i^-	α_i	Rank
Jamuna Bank	0.138696604	0.288704451	0.675488391	1
City Bank Limited	0.245826779	0.215574129	0.467216526	2
Southeast Bank Limited	0.238386654	0.208839345	0.46696602	3
Dhaka Bank Limited	0.253265593	0.218860437	0.463563589	4
AB Bank	0.249165174	0.214523515	0.462645564	5
Bank Asia	0.242958511	0.207904856	0.461126078	6
National Credit and commerce	0.248420231	0.199908786	0.445897496	7
Eastern bank	0.248673833	0.197228125	0.442312759	8
MTB	0.255341988	0.194621012	0.432526701	9
Social Islami Bank Limited	0.280417305	0.114199637	0.289393649	10

In order to rate banks using CAMELS standards, we suggest using the TOPSIS approach. The TOPSIS calculation begins by normalizing the decision matrix. The weighted normalized matrix is obtained by multiplying the normalized matrix by the Fuzzy AHP weight vectors. The steps in the TOPSIS approach are to find the closest distance to the PIS (Positive Ideal Solution) and the farthest distance from the NIS (Negative Ideal Solution). Table 7 displays the rank using the performance score generated from PIS and NIS.

VIII. CONCLUSIONS

The business environment is changing quickly in the age of globalization, especially in the financial sector, which calls for constant improvement in bank efficiency. It can be accomplished by using performance measurements and managing them for Banks. Performance evaluation is a matter of judgment for decision-makers; hence it cannot be determined analytically. As a result, we suggest in this study a fuzzy model that may integrate different decision-maker judgments as well as the ambiguity and uncertainty of linguistic data. As it can be considered that experts have specific preferences if it is related to CAMELS criteria, the FAHP framework is used to find fuzzified CAMELS criteria because it is near to how humans think. The weight vector of the CAMELS criterion that we discovered after the FAHP and defuzzification processes were employed in the final section of this paper's TOPSIS technique to rank the ten commercial banks of Bangladesh.

Retrieval Number: 100.1/ijrte.D73221111422
DOI: 10.35940/ijrte.D7322.0512123
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

According to the findings of this study, Jamuna Bank is the best among the ten commercial banks in Bangladesh, and the importance of each CAMELS criterion is relatively close to one an- other. We can observe from the CAMELS weight vector that management has the most significant impact on banking performance. The major conclusion of the suggested approach is to determine how banks rank according to CAMELS criteria. Such insights helped banks' management to improve their management practices, organizational structures, and market position. Such a study can also help investors, regulators, shareholders, and clients select the best solutions from a large pool of banks. In the future, we will integrate the proposed model with non-financial performance measurements.

DECLARATION

Funding/ Grants/ Financial Support	No, We did not receive.
Conflicts of Interest/ Competing Interests	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	K.K; conceived, designed, and implemented the experiments and analyzed the data. K.K., M.A.R., N.I; wrote the paper, K.K, M.A.R., S.M.R., N.I., and M.F.K.; reviewed, supervised and funding acquisition. All the authors contributed in this paper. All authors have read and agreed to the published version of the manuscript.

REFERENCES

1. T. BOZDOG˘ AN, A. ODABAS, and A. H. SHEGIWAL, "Analysis of financial performance of foreign banks having branches in turkey by topsis and electre methods," *Alanya Akademik Bakıs,*, vol. 5, no. 2, pp. 1049–1067, 2021. [CrossRef]
2. M. M. Hossain, M. R. Islam, and M. Z. Islam, "A hybrid fuzzy ahp and topsis method for analyzing the performance of public commercial banks: a case study on bangladesh," *Mechanical, Industrial and Materials Engineering*, 2020.
3. C. Valmohammadi and S. Roshanzamir, "The guidelines of improvement: Relations among organizational culture, tqm and performance," *International Journal of Production Economics*, vol. 164, pp. 167–178, 2015. [CrossRef]
4. M. Shaverdi, I. Ramezani, R. Tahmasebi, and A. A. A. Rostamy, "Combining fuzzy ahp and fuzzy topsis with financial ratios to design a novel performance evaluation model," *International Journal of Fuzzy Systems*, vol. 18, no. 2, pp. 248–262, 2016. [CrossRef]
5. G.-S. Liang and M.-J. J. Wang, "Personnel selection using fuzzy mcdm algorithm," *European journal of operational research*, vol. 78, no. 1, pp. 22–33, 1994. [CrossRef]
6. H. D. Sherman and F. Gold, "Bank branch operating efficiency: Evaluation with data envelopment analysis," *Journal of banking & finance*, vol. 9, no. 2, pp. 297–315, 1985. [CrossRef]
7. M. Oral and R. Yolalan, "An empirical study on measuring operating efficiency and profitability of bank branches," *European Journal of Operational Research*, vol. 46, no. 3, pp. 282–294, 1990. [CrossRef]
8. Rahman, M.A., Hamada, M. and Shin, J., 2021. The impact of state-of-the-art techniques for lossless still image compression. *Electronics*, *10*(3), p.360. [CrossRef]
9. Rahman, M.A. and Hamada, M., 2021. PCBMS: A Model to Select an Optimal Lossless Image Compression Technique. *IEEE Access*, *9*, pp.167426-167433. [CrossRef]
10. Rahman, M.A. and Hamada, M., 2023. A prediction-based lossless image compression procedure using dimension reduction and Huffman coding. *Multimedia Tools and Applications*, *82*(3), pp.4081-4105. [CrossRef]
11. S. Li, F. Liu, S. Liu, and G. Whitmore, "Comparative performance of chinese commercial banks: Analysis, findings and policy implications," *Review of Quantitative Finance and Accounting*, vol. 16, no. 2, pp. 149–170, 2001. [CrossRef]
12. H. To¨ zu¨ m, "Performance evaluation of banks," *Active: Journal of Banking and Finance*, vol. 27, no. 1, pp. 1–9, 2002.
13. C. Zopounidis, A. Pouliezos, and D. Yannacopoulos, "Designing a dss for the assessment of company performance and viability," *Computer Science in Economics and Management*, vol. 5, no. 1, pp. 41–56, 1992. [CrossRef]
14. Y. Siskos, C. Zopounidis, and A. Pouliezos, "An integrated dss for financing firms by an industrial development bank in greece," *Decision Support Systems*, vol. 12, no. 2, pp. 151–168, 1994. [CrossRef]
15. S. Gu¨ ven and E. Persentili, "A linear programming model for bank balance sheet management," *Omega*, vol. 25, no. 4, pp. 449–459, 1997. [CrossRef]
16. Y. Kaya, "Camels analysis in turkish banking sector," *BRSA MSPD working report*, vol. 6, 2001.
17. I. Isik, D. Uysal, and U. Meleke, "Post-entry performance of de novo banks in turkey," in *10th Annual conference of the ERF*, 2003.
18. C. Denizer, M. Dinc, and M. Tarimcilar, *Measuring banking efficiency in the pre-and post-liberalization environment: evidence from the Turkish banking system*. World Bank Publications, 2000, vol. 2476.
19. P. W. Bauer, A. N. Berger, G. D. Ferrier, and D. B. Humphrey, "Consistency conditions for regulatory analysis of financial institutions: a comparison of frontier efficiency methods," *Journal of Economics and business*, vol. 50, no. 2, pp. 85–114, 1998. [CrossRef]
20. M. Mercan, A. Reisman, R. Yolalan, and A. B. Emel, "The effect of scale and mode of ownership on the financial performance of the turkish banking sector: results of a dea-based analysis," *Socio-Economic Planning Sciences*, vol. 37, no. 3, pp. 185–202, 2003. [CrossRef]
21. A. Demirgu¨ c¸-Kunt and H. Huizinga, "Determinants of commercial bank interest margins and profitability: some international evidence," *The World Bank Economic Review*, vol. 13, no. 2, pp. 379–408, 1999. [CrossRef]
22. F. X. Frei and P. T. Harker, "Measuring aggregate process performance using ahp," *European Journal of Operational Research*, vol. 116, no. 2, pp. 436–442, 1999. [CrossRef]
23. E. Beccalli, "Does it investment improve bank performance? evidence from europe," *Journal of banking & finance*, vol. 31, no. 7, pp. 2205–2230, 2007. [CrossRef]
24. V. Ravi, H. Kurniawan, P. N. K. Thai, and P. R. Kumar, "Soft computing system for bank performance prediction," *Applied soft computing*, vol. 8, no. 1, pp. 305–315, 2008. [CrossRef]
25. X. Lin and Y. Zhang, "Bank ownership reform and bank performance in china," *Journal of Banking & Finance*, vol. 33, no. 1, pp. 20–29, 2009. [CrossRef]
26. N. Cinar and S. S. Ahiska, "A decision support model for bank branch location selection," *International Journal of Mechanical, Industrial Science and Engineering*, vol. 3, no. 12, pp. 26–31, 2009.
27. C.-S. Yu, "A gp-ahp method for solving group decision-making fuzzy ahp problems," *Computers & Operations Research*, vol. 29, no. 14, pp. 1969–2001, 2002. [CrossRef]
28. Z. Tao, H. Chen, L. Zhou, and J. Liu, "A generalized multiple attributes group decision making approach based on intuitionistic fuzzy sets." *International Journal of Fuzzy Systems*, vol. 16, no. 2, 2014.
29. Q.-J. Yeh, "The application of data envelopment analysis in conjunction with financial ratios for bank performance evaluation," *Journal of the operational research society*, vol. 47, no. 8, pp. 980–988, 1996. [CrossRef]
30. W. E. Hopkins and S. A. Hopkins, "Strategic planning–financial performance relationships in banks: a causal examination," *Strategic management journal*, vol. 18, no. 8, pp. 635–652, 1997. [CrossRef]
31. A. Lozano-Vivas, J. T. Pastor, and I. Hasan, "European bank performance beyond country borders: What really matters?" *Review of Finance*, vol. 5, no. 1-2, pp. 141–165, 2001. [CrossRef]

32. M. Yurdakul and Y. T. İç, "Ahp approach in the credit evaluation of the manufacturing firms in turkey," *International journal of production economics*, vol. 88, no. 3, pp. 269–289, 2004. [CrossRef]
33. E. Albayrak and Y. C. Erensal, "A study bank selection decision in turkey using the extended fuzzy ahp method," in *35th International conference on computers and industrial engineering, Istanbul, Turkey*, 2005.
34. N. Y. Seçme, A. Bayrakdaroğlu, and C. Kahraman, "Fuzzy performance evaluation in turkish banking sector using analytic hierarchy process and topsis," *Expert systems with applications*, vol. 36, no. 9, pp. 11 699–11 709, 2009. [CrossRef]
35. H.-Y. Wu, G.-H. Tzeng, and Y.-H. Chen, "A fuzzy mcdm approach for evaluating banking performance based on balanced scorecard," *Expert systems with applications*, vol. 36, no. 6, pp. 10 135–10 147, 2009. [CrossRef]
36. C.-C. Sun, "A performance evaluation model by integrating fuzzy ahp and fuzzy topsis methods," *Expert systems with applications*, vol. 37, no. 12, pp. 7745–7754, 2010. [CrossRef]
37. T. Kaya and C. Kahraman, "Multicriteria decision making in energy planning using a modified fuzzy topsis methodology," *Expert Systems with Applications*, vol. 38, no. 6, pp. 6577–6585, 2011. [CrossRef]
38. D. Tadic, A. T. Gumus, S. Arsovski, A. Aleksic, and M. Stefanovic, "An evaluation of quality goals by using fuzzy ahp and fuzzy topsis methodology," *Journal of Intelligent & Fuzzy Systems*, vol. 25, no. 3, pp. 547–556, 2013. [CrossRef]
39. J. S. Jordan, J. Peek, E. S. Rosengren *et al.*, *The impact of greater bank disclosure amidst a banking crisis*. Federal Reserve Bank of Boston, 1999, vol. 2.
40. W. W. Eubanks, *Status of the Basel III Capital Adequacy Accord*. DIANE Publishing, 2010.
41. P. King and H. Tarbert, "Basel iii: an overview," *Banking & financial services policy report*, vol. 30, no. 5, pp. 1–18, 2011.
42. E. Kadioglu, N. Ocal *et al.*, "Effect of the asset quality on the bank profitability," *International Journal of Economics and Finance*, vol. 9, no. 7, pp. 60–68, 2017. [CrossRef]
43. I. Valová, "New capital rules according to basel ii," *Banks & bank systems*, no. 2, Iss. 2, pp. 14–21, 2007.
44. T. Mashamba, "The effects of basel iii liquidity regulations on banks' profitability," 2018. [CrossRef]
45. Rahman, M.A. and Hamada, M., 2020. Burrows–wheeler transform based lossless text compression using keys and Huffman coding. *Symmetry*, *12*(10), p.1654. [CrossRef]
46. Rahman, M.A. and Hamada, M., 2019. Lossless image compression techniques: A state-of-the-art survey. *Symmetry*, *11*(10), p.1274. [CrossRef]
47. Rahman, M.A. and Hamada, M., 2021. Lossless text compression using GPT-2 language model and Huffman coding. In *SHS Web of Conferences* (Vol. 102, p. 04013). EDP Sciences. [CrossRef]
48. P. Laarhoven and W. PEDRYCZ, "A fuzzy extension of saaty's priority theory, fuzzy sets and systems," *Fuzzy Sets and Systems*, vol. 11, pp. 1–3. [CrossRef]
49. A. Ishizaka and N. H. Nguyen, "Calibrated fuzzy ahp for current bank account selection," *Expert systems with applications*, vol. 40, no. 9, pp. 3775–3783, 2013. [CrossRef]
50. Z. Huang, W. Zhao, Z. Shao, Y. Gao, Y. Zhang, Z. Li, J. Li, and Q. Xixi, "Entropy weight-logarithmic fuzzy multiobjective programming method for evaluating emergency evacuation in crowded places: A case study of a university teaching building," *IEEE Access*, vol. 8, pp. 122 997–123 012, 2020. [CrossRef]
51. E. Önder, N. Taş, and A. Hepsen, "Performance evaluation of turkish banks using analytical hierarchy process and tops is methods," *Journal of International Scientific Publication: Economy & Business*, vol. 7, no. Part 1, pp. 470–503, 2013.

AUTHORS PROFILE

I am **Khadijatul Kobra** Working as an innovative lecturer at Daffodil International University for the past 8 years, I have been teaching undergraduate students in a variety of departments, including CSE, EEE, TE, SWE, and others. compassionate and dedicated to imparting crucial knowledge to students while fostering learning through various lesson plans and teaching strategies. Fuzzy mathematics is my area of study, and I enjoy applying fuzzy mathematics to a variety of research topics. I would absolutely love to use my research to benefit this world. a committed and enthusiastic researcher who takes pleasure in discovering new information and drawing connections between various subjects.

Md. Atiqur Rahman is working as a faculty member in the Computer Science and Engineering department at Daffodil International University in Dhaka, Bangladesh. He Completed his B.Sc. and M.Sc. degrees in Computer Science and Engineering from the University of Rajshahi, Rajshahi, Bangladesh, and PhD degree in Computer Science and Engineering from the University of Aizu in Japan. His primary areas of research are Machine Learning, Deep Learning, Image Processing, and Computer Vision. He has published several works in major conferences and journals and has also served as a reviewer for various international journals.

Syeda Maria Rahman is working as a Senior Lecturer in the Department of Business Administration at Daffodil International University in Dhaka, Bangladesh. He Completed his Bachelor of Business Administration (BBA) from Daffodil International University, Dhaka, Bangladesh. His primary area of research is finance and banking. He has published several works in major conferences and journals.

Mr. Nafees Imran is working as a lecturer in the Department of Information Technology & Management (ITM) at Daffodil International University in Dhaka, Bangladesh. He Completed his Bachelor of Business Administration (BBA) from Bangladesh University of Business and Technology, Dhaka, Bangladesh, and MBA from Bangladesh University of Professionals. His primary area of research is Education. He has published several works in major conferences and journals and has also served as a reviewer for various international journals.

Md Faisal Kabir, Civil Engineer, faculty, researcher, and construction entrepreneur with 11+ years of academic and industrial experiences. Organized equitable educational and social programs to reach the unreached populations in Bangladesh. Ambitious and looking forward to exploring new learning opportunities, playing a vital role in decision-making utilizing research and applied science knowledge, and adding significant value to diverse organizations with long-term prospects.