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Chapter: Advanced Perspectives on Financial Engineering, Economic Modeling, and Portfolio Optimization

FUZZY TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION APPROACH FOR FINANCIAL EFFICIENCY MEASUREMENT OF THE PRIVATE BANKS

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Annotation. In India, the banking industry has been one of the most rapid growing industries after the government's demonetisation move in 2016. Private banks are doing exceptionally well in terms of their customer relations and financial services compared to the public banks. The main component of a bank is undoubtedly its financial performance. In today's increasingly more competitive market, an appropriate and accurate measurement of financial performance is of great importance for a bank that aims to successfully maintain its market position. The main objectives of this study are to identify the best private bank and to rank the private banks in India. This research paper attempts to propose a Multi-Criteria Decision-Making (MCDM) model to evaluate and compare the financial performance of ten private banks enlisted on the National Stock Exchange (NSE) NIFTY as of 2 September 2023. These ten private banks are evaluated to gain a financial performance score and a ranking by applying a Fuzzy Technique for Order Preference by Similarity to Ideal Solution (F-TOPSIS) methodology, which is based on Euclidean Distance. The results show that the HDFC Bank is the most financially efficient one followed by ICICI Bank and Axis bank.

Keywords: banking sector, financial efficiency, ranking, triangular fuzzy number, F-TOPSIS.

JEL classification: C44, C61, G21, G24.

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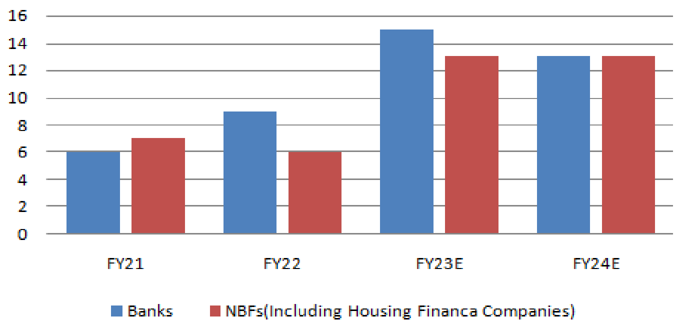
Introduction

The demonetisation move initiated by the Indian government in November 2016 was a monumental decision aimed at curbing black money and counterfeit currency and promoting the digital economy (Singh, 2017). This decision had far-reaching implications, one of which was the significant impact it had on the banking sector, particularly the private banking segment. The growth of the private banking sector post-demonetisation played a pivotal role in the economic landscape of India (Shirley, 2017).

Background of the Study

In recent years, the private banking sector in India has witnessed remarkable growth and transformation. It has fostered financial inclusion, promoted digital literacy, and contributed to the formalisation of the economy. Private banks have become key facilitators in channelling savings into productive investments, thereby stimulating economic growth. Through their innovative approaches, customer-centric focus, and adaptability to technological advancements, private banks not only weathered the challenges but also emerged as dominant players in the Indian banking industry. This growth has not only benefited the banks themselves, but also had a positive ripple effect on the overall economic landscape of the country. It encompasses a select group of financial institutions that offer personalised financial services to high-net-worth individuals and corporate clients. These services range from wealth management and investment advice to customised lending solutions. Key players in the sector include prominent Indian and international banks. With a focus on exclusivity, expertise, and innovation, private banking in India continues to play a pivotal role in managing and growing the wealth of affluent clients (Sivathanu, 2019). *Figure 1* shows the promising credit growth of both banks and non-banking finance companies in recent times and the estimates for the coming year (Goriparthi, Tiwari, 2017).



Source: Goriparthi and Tiwari (2017).

Figure 1. **Credit Growth of Banks and NBFCs**

Seven years after the completion of demonetisation in India, there is a necessity to review the financial health of some selected private banks.

Private Banking Sector in India

The private banking sector in India was dynamic and competitive, with several well-established and emerging players. Private banking refers to banking services tailored for high-net-worth individuals (HNWIs) and ultra-high-net-worth individuals (UHNWIs) who require specialised financial services, personalised advice, and wealth management solutions. Below is a list of some prominent private sector banks in India (Chaudhary, Sharma, 2011):

i. Axis Bank: Axis Bank is one of the largest private sector banks in India.

ii. Bandhan Bank: Bandhan Bank is a Kolkata-based private sector bank.

iii. Federal Bank: Federal Bank is a major private sector commercial bank based in Kochi, Kerala.

iv. HDFC Bank: Housing Development Finance Corporation Limited (HDFC) Bank is one of the largest and most well-known private sector banks in India.

v. ICICI Bank: Industrial Credit and Investment Corporation of India (ICICI) Bank is another major private sector bank in India.

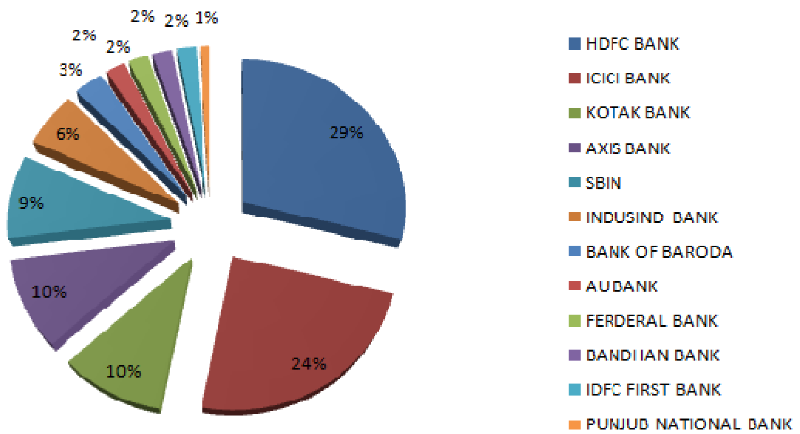
vi. IDFC FIRST Bank: IDFC FIRST Bank is a new-generation private sector bank formed after the merger of IDFC Bank and Capital First.

vii. IndusInd Bank: IndusInd Bank is a Mumbai-based private sector bank.

viii. Kotak Mahindra Bank: Kotak Mahindra Bank is one of the fastest growing private sector banks in India.

ix. RBL Bank: Ratnakar Bank Limited (RBL) is a scheduled commercial bank headquartered in Mumbai.

x. Yes Bank: Yes Bank is a prominent private sector bank in India, although it faced some financial challenges in recent years.



Source: Gupta and Jaiswal (2020).

Figure 2. **Credit Growth of Banks and NBFCs**

In *Figure 2*, the current market share of some prominent private and public sector banks in India is represented (Gupta, Jaiswal, 2020).

Key Factors Driving the Growth of Private Banks

There are some key factors driving the growth of private banks. They are as follows:

- Digitisation and Technological Advancements: Demonetisation served as a stimulus for the widespread acceptance and implementation of digital payment systems and technology-based financial solutions. Private banks, being more agile and tech-savvy, were able to adapt swiftly to this new paradigm (Sardana, Singhania, 2018).
- Enhanced Customer Experience: Private banks invested heavily in improving customer experiences. They introduced personalised services, dedicated relationship managers, and streamlined processes (Sayed, Sayed, 2020).
- Stringent Regulatory Compliance: Post demonetisation, regulatory authorities implemented more stringent compliance measures to track and trace financial transactions. Private banks, equipped with robust compliance frameworks and a culture of transparency, were better positioned to navigate the evolving regulatory landscape (Kanoujiya *et al.,* 2023).
- Expanding Reach and Accessibility: Private banks aggressively expanded their branch networks and ATM coverage, especially in semi-urban and rural areas. This extended reach played a vital role in accessing previously inaccessible markets and catering to a diverse customer base (Maity, Sahu, 2018).
- Tailored Products and Services: Private banks focused on offering specialised financial products and services that catered to the diverse needs of their clientele. This included wealth management solutions, customised investment strategies, and exclusive privileges for high-net-worth individuals (Kamath *et al.,* 2003).
- Risk Management and Asset Quality: Private Banks placed a strong emphasis on effective risk management practices and maintaining a high standard of asset quality. This instilled confidence in investors and depositors, further fuelling the sector's growth (Suresh, Krishnan, 2018).

Multi-Criteria Decision Making

Multi-Criteria Decision Making (MCDM) is a structured approach used in various fields to make complex decisions when multiple criteria or objectives are involved. It helps decision-makers evaluate and rank alternative options based on their performance against multiple criteria, which may have conflicting goals or priorities. MCDM techniques provide a systematic framework for decision-making, ensuring that choices are made based on a comprehensive analysis of all relevant factors. Key components of MCDM are criteria, alternatives, performance evaluation, modelling, aggregation, ranking and selection, and sensitivity analysis. There are some well-known MCDM methods such as Multi-Attribute Utility Theory (MAUT) (Figueira *et al.,* 2005), Analytic Hierarchy Process (AHP) (Saaty, 1980, November), ELECTRE (Elimination and Choice Expressing Reality) (Roy, 1968), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Zavadskas *et al.,* 2016). Some applications of MCDM include project management, environmental management, healthcare, finance, manufacturing, and urban planning. MCDM is a valuable tool for handling complex decisions in various domains. It enables decision-makers to consider multiple criteria and preferences systematically, leading to more informed and objective decisions. As technology and data analytics continue to advance, MCDM methods are likely to become even more sophisticated and widely used in decision-making processes.

Motivation

The private banking sector in India is a dynamic and ever-changing industry that has a significant impact on the country's financial environment. This sector not only drives economic growth, but also serves as a catalyst for wealth creation, investment, and financial inclusion. Engaging in research in this field has the potential to provide significant knowledge that may influence regulatory choices, stimulate innovation, and support the sustainable growth of the financial industry. The research has great importance in several areas such as economic impact, wealth management and client services, technological disruption, regulatory framework and compliance, competitive landscape and market trends, financial inclusion and accessibility, as well as global comparisons and best practices. Conducting research on the private banking sector in India has immense potential to uncover opportunities, address challenges, and contribute to the overall growth and stability of the financial ecosystem. This research endeavour aims to not only to expand our understanding of the sector, but also to provide actionable insights that can drive positive change in the Indian financial landscape. Through this research, we endeavour to create a foundation for informed decision-making, innovation, and sustainable development in the private banking sector.

Beneficiaries

When conducting research on the private banking sector in India, there can be several potential beneficiaries:

a) Academic community: One's research can contribute to the academic knowledge base regarding the private banking sector in India. Professors, students, and researchers in finance, economics, and business studies could use the findings for teaching, reference, and further research.

b) Industry professionals: Professionals working in private banks, financial institutions, or related sectors can benefit from the research. It can provide insights into market trends, customer behaviour, regulatory changes, and best practices.

c) Regulators and policy makers: Government agencies, regulatory bodies, and policymakers are often interested in research that can inform policy decisions. The findings may help them understand the dynamics of the private banking sector, which can be useful for formulating or modifying regulations.

d) Investors and financial analysts: Investors, both domestic and international, may find the research valuable in making informed decisions about investments in the Indian private banking sector. Financial analysts may also use the findings to provide recommendations to their clients.

e) Banking executives and strategists: Executives and strategists within private banks could benefit from such research. It could help them identify areas for improvement, develop better strategies, and understand customer preferences.

f) Customers and clients: Such research might shed light on the operation of private banks, their offered services, and the trends in customer satisfaction. This information can be beneficial for individuals and businesses looking to engage with private banks.

g) Consulting firms: Consulting firms that work with banks, financial institutions, or provide advisory services may find value in such research. It could serve as a resource for them when advising their clients.

h) Media and journalists: Journalists covering finance and banking sectors may use the research as a source of information for their articles and reports. It could also provide them with a deeper understanding of the industry.

i) General public: If the research findings are made publicly available, it can educate the general public about the private banking sector in India. This could be particularly useful for individuals who are considering engaging with private banks.

Organisation of the Work

The remaining sections of the paper are organised in the following manner. Section 1 provides literature review; Section 2, objectives; whereas Section 3, research methodology; and Section 4, numerical illustrations. Section 5 presents the findings, and Section 6 provides the sensitivity analysis. The final part of the paper is the conclusions and the limitations and future scopes.

1. Literature Review

After a thorough literature analysis, this study found several research initiatives in the banking and finance business that have employed different MCDM methodologies to address multi-criteria decision-making challenges. Scientists have tried a wide range of different approaches in an effort to identify the one that works best for their individual investigations.

Table 1. Related Works

Authors	Application Area	Methods Applied
Chowdhury, S., Roy, B.C. (2016)	Institutions for microfinance	Fuzzy AHP
Gupta, K.P., Manrai, R. (2018)	Mobile financial services	Fuzzy AHP
Zaini, S.H.R., Akhtar, A. (2019)	Analysing factors that contribute to financial inclusion	AHP approach
Bardhan, A.K. *et al.* (2021)	Indian microfinance institutions	DEA and SUR (Seemingly Unrelated Regression model)
Chien, F. *et al.* (2021)	Selection of financial leasing companies for Vietnamese small and medium-sized enterprises (SMEs)	FANP and TOPSIS
Roy, P., Patro, B. (2021)	NBFC-MFIs in India	TOPSIS and interval-valuedTOPSIS
Ghosh, A. *et al.* (2021)	Indian life insurance companies	DEA and SEM
Mehta, K. *et al.* (2022)	Venture capital firms in India	fuzzy AHP
Dağıstanlı, H.A. (2023)	Energy Companies in Borsa, Istanbul	Hesitant Fuzzy TOPSIS
Jain, E., Gupta, P.K. (2023)	Indian Microfinance institutions	TOPSIS and DEA
Nandi, B. *et al.* (2023)	Financial market prediction	Machine learning
Jeyapaul, P.P., ST, J.C. (2024)	Housing loan for self-help group women	AHP
Jana, S. *et al.* (2024)	Selection of financial indices	FUZZY AHP
Jana, S. *et al.* (2024)	NIFTY IT companies in India	VIKOR
Rao, S.H. *et al.* (2021)	Commercial banks operating in the private sector in India	ARAS and MOORA
Marjanović, I., Popović, Ž. (2020)	Financial performance of Serbian banks	CRITIC and TOPSIS
Gupta, S. *et al.* (2021)	Govt-owned banks in India	CRITIC and interval-valued TOPSIS
Shaverdi, M. *et al.* (2011)	Iranian private banking sector	FAHP, TOPSIS, VIKOR and ELECTRE
Ünlü, U. *et al.* (2022)	Turkestan commercial banks	SWARA II, MEREC and MARCOS

Table 1 (*continuation*). Related Works

Authors	Application Area	Methods Applied
Gupta, S. *et al.* (2021)	Various Indian private banks	AHP and interval-valued TOPSIS
Abdel-Basset, M. *et al.* (2021)	Commercial banks	AHP, TOPSIS, VIKOR, COPRAS
Kumar, P., Sharma, D. (2024)	Indian private sector banks	CRITIC, interval-valued TOPSIS
Momeni, M. *et al.* (2011)	Private banks in Tehran stock exchange	SAW, VIKOR, and TOPSIS
Sama, H.R. *et al.* (2022)	Indian private sector banks	CRITIC-TOPSIS and CRITIC-GRA
Çelen, A. (2014)	Turkish banking sector	FAHP, TOPSIS
Sedaghat, M. (2013)	Iran's state-owned, partly privatised, and privately held banks	AHP, TOPSIS and VIKOR
Wanke, P. *et al.* (2016)	Islamic banks	DEA, TOPSIS
Kumar, P., Sharma, D. (2023)	Commercial banks in India	AHP and interval-valued TOPSIS
Wanke, P. *et al.* (2022)	Banking Sector	Fuzzy TOPSIS and SWARA
Fazeli, Z. *et al.* (2023)	Private Banks	Fuzzy AHP
Amile, M. *et al.* (2013)	Banks in Iran: state-owned, partially private, and private Banks	Fuzzy AHP and TOPSIS
Aydın, Y. (2020)	Foreign deposit banks	SD and COPRAS
Iç, Y.T. *et al.* (2022)	Turkish commercial banks	AHP and DOE
Tunay, K.B., Akhisar, I. (2015)	Banks that are privately owned in Turkey	AHP and TOPSIS
Hemmati, M. *et al.* (2013)	Banking industry	DEA and TOPSIS
Hassanzadeh, M.R., Valmohammadi, C. (2021)	Financial institutions of the Tehran stock market	Fuzzy AHP and TOPSIS
Guru, S., Mahalik, D. K. (2019)	Public sector banks in India	AHP-TOPSIS and AHP-GRA
Tabriz, A.A. *et al.* (2011)	Private Banks in Iran	FAHP, VIKOR
Yazdi, A.K. *et al.* (2020)	Colombian banks	BSC, SWARA and WASPAS
Salur, M.N., Cıhan, Y. (2020)	Banks of Turkey	TOPSIS
Özçalıcı, M. *et al.* (2022)	Banks operating in Turkey	BWM, ARAS, EDAS, MOORA, OCRA and TOPSIS
Aras, G. *et al.* (2018)	Intermediate institutions in the Turkish capital markets, including both bank-origin and non-bank-origin organisations	TOPSIS
Ünvan, Y.A. *et al.* (2020)	Banking industry in Turkey	TOPSIS and fuzzy TOPSIS
Yeşildağ, E. *et al.* (2020)	Banks listed in Borsa, Istanbul	TOPSIS and GRA
Ozcalici, M., Bumin, M. (2020)	Banks that are listed publicly on Borsa, Istanbul	EDAS, MOORA, OCRA and TOPSIS
Dinçer, H., Yüksel, S. (2018)	Turkish banking industry	Fuzzy AHP, fuzzy ANP and fuzzy VIKOR
Ozdemir, A. (2013)	Turkish commercial banks	ANP & DEA
Aldalou, E., Perçin, S. (2020)	Financial performance of companies listed on the BIST technology index in Turkey	Fuzzy Shannon's entropy and ELECTRE I
Lin, A.J., Chang, H.Y. (2019)	Taiwanese banks	DEMATEL, DANP and SAW
Erdoğan, H.H. (2022)	Banks in Turkey	WASPAS
Karadağ Ak, Ö. et al. (2022)	Banks in Turkey	ARAS
Roy, S., Das, A. (2018)	Banks in Bangladesh	TOPSIS
Özbek, A. (2015)	Banks in Turkey	OCRA and MOORA
Yuksel, S. et al. (2018)	Turkish banking sector	AHP and TOPSIS
Baležentis, A. et al. (2012)	Lithuanian economic sectors	VIKOR, TOPSIS, ARAS
Dash, M. (2017)	Indian banking sector	PROMETHEE
Dudić, B. et al. (2024)	Banks in Vietnam	RAM, PSI, SRP, CAMELS
Chang, S.C., Tsai, P.H. (2016)	Wealth management institutions	AHP, VIKOR
Önder, E. et al. (2013)	Turkish banks	AHP, TOPSIS
Ova, A. (2021)	Turkish deposit banks	TOPSIS
Önder, E., Hepsen, A. (2013)	Banks in Turkey	AHP, TOPSIS
Jayachitra, Geetha (2019)	Public sector banks in India	TOPSIS
Ünlü, U., Yalçın, N. (2023)	Commercial banks traded on Borsa, Istabul	CRITIC and WASPAS
Akkoc, S., Vatansever, K. (2013)	Turkish banking sector	Fuzzy AHP, Fuzzy TOPSIS
Sezer, D. et al. (2018)	Turkish banking sector	GRA
Jana, S. et al. (2025)	Private banks in India	Fuzzy TOPSIS

Source: created by the authors.

2. Objectives

The present study has two objectives. The first is to identify the best private bank. The second objective is concerned with the private bank ranking in India; thus, it has been set to rank the private banks in India.

3. Research Methodology

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a well-recognised approach in the field of Multi-Criteria Decision Making (MCDM) for making decisions. It belongs to a specific category of operations research models that focus on choice issues including many decision criteria. This study presents Fuzzy TOPSIS methodology for ranking the alternatives (Hwang, Yoon, 2012).

3.1 Problem Definition

A hypothetical situation could be proposed that would include someone interested in opening an account in a private bank. The market is overflowing with a number of available private banks. Thus, the problem is how to determine the best private bank for opening an account.

3.2 Fuzzy Set Theory

Fuzzy set theory was introduced by L.A. Zadeh in 1965. This theory is an extension of the classical crisp logic into a multivariate form (Zadeh, 1965). Its definition is as follows:

Set $\breve{\boldsymbol{A}}$ is defined as $\breve{\boldsymbol{A}} = \{(¥, \boldsymbol{\mu}_{\breve{A}}(¥): ¥ \in \breve{\boldsymbol{A}}, \boldsymbol{\mu}_{\breve{A}}(¥) \in (\mathbf{0}, \mathbf{1})\}$, where $\boldsymbol{\mu}_{\breve{A}}(¥)$ represents the membership function of $\breve{\boldsymbol{A}}$.

3.3 Triangular Fuzzy Number (TFN)

The definition of triangular fuzzy number (TFN) is as follows: Triangular Fuzzy Number $\breve{A}_{TFN} = \{(a, b, c), \mu_{\breve{A}}(x)\}$ is defined as TFN if it satisfies the following properties:

$i.\ \mu_{\breve{A}}(x)$ is zero when $x \leq a$

$ii.\ \mu_{\breve{A}}(x)$ is strictly increasing continuous function when $a < x \leq b$

$iii.\ \mu_{\breve{A}}(x)$ has the maximum value, i.e. 1 at $x = b$

$iv.\ \mu_{\breve{A}}(x)$ is strictly decreasing continuous function in $b < x \leq c$

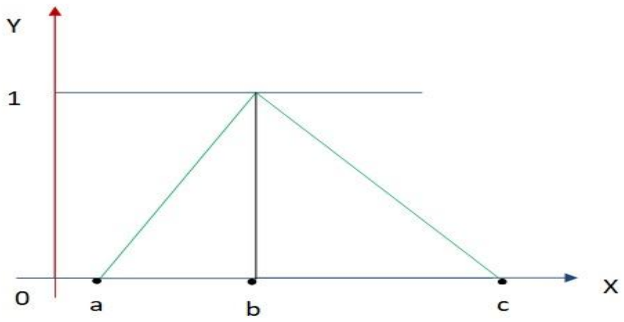
$\boldsymbol{v}.\ \boldsymbol{\mu}_{\breve{A}}(\boldsymbol{x})$ is again zero when $\boldsymbol{x} \geq \boldsymbol{c}$

3.4 The Membership Function of a Symmetric and Linear TFN

$$\mu_{\breve{A}}(x) = \begin{cases} 0; & x \leq a \\ \frac{x-a}{b-a}; & a < x \leq b \\ 1; & x = b \\ \frac{c-x}{c-b}; & b < x \leq c \\ 0; & x \geq c \end{cases} \quad (1)$$

3.5 Graph of TFN

Figure 3 presented below is the representation of the membership function of linear triangular fuzzy number (LTFN).



Source: Zadeh (1965).

Figure 3. **Membership Function of Linear TFN**

In *Figure 3*, the triangular fuzzy number is diagrammed with $\boldsymbol{a} \leq \boldsymbol{b} \leq \boldsymbol{c}$ where a, b, and c are all real numbers.

3.6 Arithmetic Operations of TFN

Let $E = (e_1, e_2, e_3)$ and $F = (f_1, f_2, f_3)$ be two different TFN.

(a) Addition:

$$(E + F) = (e_1 + f_1, e_2 + f_2, e_3 + f_3) \quad (2)$$

(b) Subtraction:

$$(E - F) = (e_1 - f_3, e_2 - f_2, e_3 - f_1) \quad (3)$$

(c) Multiplication:

$$(E \times F) = (e_1 f_1, e_2 f_2, e_3 f_3) \quad (4)$$

(d) Scalar Multiplication:

$$\theta E = (\theta e_1, \theta e_2, \theta e_3) \quad (5)$$

(e) Division:

$$\left(\frac{E}{F}\right) = \left(\frac{e_1}{f_3}, \frac{e_2}{f_2}, \frac{e_3}{f_1}\right) \quad (6)$$

(f) Inverse:

$$E^{-1} = \left(\frac{1}{e_3}, \frac{1}{e_2}, \frac{1}{e_1}\right) \quad (7)$$

(g) Distance measure:

$$d\left(\widetilde{E_d}, \widetilde{F_d},\right) = \sqrt{\frac{1}{3}\left[(e_1 - f_1)^2 + (e_2 - f_2)^2 + (e_3 - f_3)^2\right]} \quad (8)$$

3.7 Linguistic Variable (LV)

A linguistic variable is defined by five components: a variable name, a set of terms, the universe it applies to, a syntactic rule, and a semantic rule. In the context of fuzzy set theory, a transformation scale is essential to convert fuzzy numbers associated with a linguistic variable. In this case, a 1–9 transformation scale is employed to assess both the alternatives and the criteria.

Table 2. Linguistic Variables for Alternatives

LV	MF
Very Lower (VL)	(1, 1, 3)
Lower (L)	(1, 3, 5)
Middle (ML)	(3, 5, 7)
Upper (U)	(5, 7, 9)
Very Upper (VU)	(7, 9, 9)

Source: created by the authors.

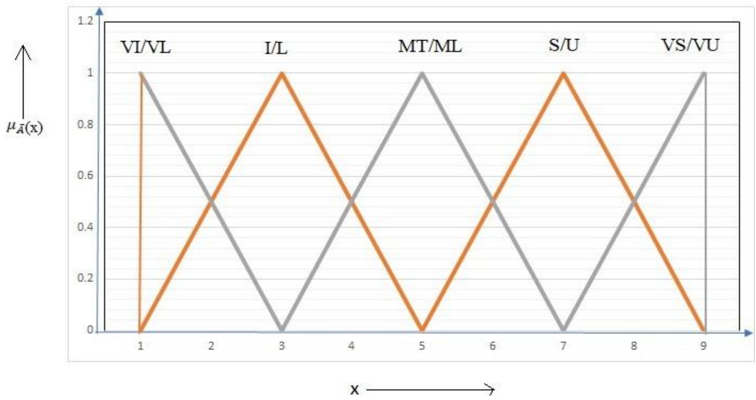
Table 2 illustrates the linguistic variable (LV) for alternatives ratings with membership functions (MF), while *Table 3* outlines the linguistic terms for criteria ratings.

Table 3. Linguistic Variables for Criteria

LV	MF
Very Inferior (VI)	(1, 1, 3)
Inferior (I)	(1, 3, 5)
Moderate (MT)	(3, 5, 7)
Superior (S)	(5, 7, 9)
Very Superior (VS)	(7, 9, 9)

Source: created by the authors.

In *Figure 4*, the membership function of TFN for alternatives and criteria are defined graphically.



Source: Zadeh (1965).

Figure 4. **Graphical Representation of MF for the Alternatives and Criteria**

3.8 Selection of Alternatives

This research paper aims to propose a Multi-Criteria Decision-Making (MCDM) framework evaluate and compare the financial performance of ten private banks listed on the National Stock Exchange (NSE) under the NIFTY index as of 2 September 2023. The evaluation involves assigning a financial performance score and subsequent ranking to these banks. This assessment is conducted utilising the Fuzzy Technique for Order Preference by Similarity to Ideal Solution (F-TOPSIS) methodology, which relies on Euclidean Distance. In *Table 4*, private banks' scrip information is provided.

Table 4. Private Banks' (Alternatives) Scrip Information

SL. No	Private Banks	NSE	BSE	ISIN Code*
A01	Axis Bank	AXISBANK	532215	INE238A01034
A02	Bandhan Bank	BANDHANBANK	541153	INE545U01014
A03	Federal Bank	FEDERALBNK	500469	INE171A01029
A04	HDFC Bank	HDFCBANK	500180	INE040A01034
A05	ICICI Bank	ICICIBANK	532174	INE090A01021
A06	IDFC First Bank	IDFCFIRSTB	539437	INE092T01019
A07	Indusind Bank	INDUSINDBK	532187	INE095A01012
A08	Kotak Mahindra Bank	KOTAKBANK	500247	INE237A01028
A09	RBL Bank	RBLBANK	540065	INE976G01028
A10	YES Bank	YESBANK	532648	INE528G01035

Note: *An ISIN Code, or International Securities Identification Number, serves as a unique identifier for a particular securities offering. It is assigned by the National Numbering Agency (NNA) of a given country to distinguish it from other financial instruments within that jurisdiction.

Source: created by the authors.

3.9 Selection of Criteria

The nine financial ratios of ten private banks which were listed on NIFTY of National Stock Exchange (NSE) on 2 September 2023 are analysed in this study. Among these, seven were identified as belong to the beneficiary criterion, including Quick Ratio, Current Ratio, Return on Capital Employed, Return on Net Worth, Return on Total Assets, Earnings per Share, and Dividend Yield. The remaining two, Debt-Equity Ratio and Price-Earnings Ratio, were considered as non-beneficiary criterion. *Table 5* outlines formulas for financial ratios and defines beneficiary and non-beneficiary criteria (Lev, Sunder, 1979).

Table 5. Formulas for Financial Ratios (Criteria)

SL. No	Ratios	Formulas	Criteria
C01	Quick Ratio	$Quick\ Ratio = \frac{Current\ Assests - Inventories}{Current\ Liabilities}$	Beneficiary
C02	Current Ratio	$Current\ Ratio = \frac{Current\ Assests}{Current\ Liabilities}$	Beneficiary
C03	Debt to Equity Ratio	$Debt\ to\ Equity\ Ratio = \frac{Total\ Debt}{Total\ Shareholders'Equity}$	Non-Beneficiary
C04	Return on Capital Employed	$Return\ on\ Capital\ Employed = \frac{Net\ Profit}{Total\ Capital\ Employed}$	Beneficiary
C05	Price Earnings Ratio	$Price\ Earnings\ Ratio = \frac{Market\ Price\ Per\ Share}{Earnings\ Per\ Share}$	Non-Beneficiary

Table 5 (*continuation)*. Formulas for Financial Ratios (Criteria)

SL. No	Ratios	Formulas	Criteria
C06	Return on Total Assets	$Return\ on\ Total\ Assets\ = \frac{Net\ Profit}{Total\ Assest}$	Beneficiary
C07	Earnings per Share	$Earnings\ per\ Share = \frac{Net\ Profit}{Number\ of\ Equity\ Share}$	Beneficiary
$C08$	Return on Net Worth	$Return\ on\ Net\ Worth = \frac{Net\ Profit}{Total\ Shareholders'Equity}$	Beneficiary
$C09$	Dividend Yield	$Dividend\ Yield = \frac{Dividend\ Per\ Share}{Market\ Price\ Per\ Share}$	Beneficiary

Source: created by the authors.

3.10 Fuzzy TOPSIS

The employed MCDM method is known as Fuzzy TOPSIS (Hwang, Yoon, 1981), which aids in the selection of the optimal private bank based on pre-defined weighted criteria. TOPSIS works by identifying the alternative that is farthest from the Negative Ideal Solution (NIS) while being very close to the Positive Ideal Solution (PIS). The NIS comprises the minimum values for each alternative, whereas the PIS comprises the maximum values for each alternative (Salih, *et al.,* 2019). The different stages of fuzzy TOPSIS are outlined below:

Step 1: Performance evaluation assignment to the criteria and alternatives

Consider that n is the set of alternatives, where $A = (A1, A2, A3, \dots\dots\dots, An)$ and m is a set of criteria, where $C = (C1, C2, C3, \dots\dots\dots, Cm)$ and k is the number of decision makers, where $Dk\ (k = 1, 2, 3, \dots\dots\dots, k)$. The values of the alternatives are to be calculated with reference to the criteria. The weight for each criterion is represented by $CWi\ (i = 1,2,3, \dots\dots\dots, m)$. The performance assignment of each decision maker for each alternative with reference to each criterion is represented by $\tilde{p}_k = \tilde{y}_{ijk}\ (i = 1, 2, 3, \dots..m; j = 1, 2, 3, \dots\dots n; k = 1, 2, 3 \dots\dots, k)$ with membership function $\tilde{p}_k(x)$.

Step 2: Calculation of the aggregate fuzzy assignment to the criteria and alternatives

TFN is used to represent the fuzzy assignment of all decision makers $\tilde{p}_k = (x_k, y_k, z_k), k = 1,2, \dots\dots, k$.

The aggregated fuzzy rating is calculated as $\tilde{p} = (x, y, z)$, where

$$\begin{cases} x = \min_k\{x_k\} \\ y = \frac{1}{k}\sum_1^k y_k \\ z = \max_k\{z_k\} \end{cases} \quad (9)$$

If the effective weight of the k_{th} decision maker and fuzzy assignment are $\widetilde{CW}_{ijk} = (cw_{jk1}, cw_{jk2}, cw_{jk3})$ and $\tilde{y}_{ijk} = (x_{ijk}, y_{ijk}, z_{ijk})$ respectively, then the aggregated fuzzy ratings $(\tilde{y}_{ij})$ of alternatives, with respect to each criterion, are given by $\tilde{y}_{ij} = (x_{ij}, y_{ij}, z_{ij})$ and

$$\begin{cases} x_{ij} = \min_k\{x_{ijk}\} \\ y_{ij} = \frac{1}{k}\sum_1^k y_{ijk} \\ z_{ij} = \max_k\{z_{ijk}\} \end{cases} \quad (10)$$

The aggregated fuzzy weights $(\widetilde{CW}_{ij})$ of each criterion are calculated as $\widetilde{CW}_j = (cw_{j1}, cw_{j2}, cw_{j3})$, where

$$\begin{cases} cw_{j1} = \min_k\{cw\} \\ cw_{j2} = \frac{1}{k}\sum_1^k cw_{jk2} \\ cw_{j3} = \max_k\{cw_{jk3}\} \end{cases} \tag{11}$$

Step 3: Calculation of fuzzy decision matrix

Decision matrix can be formed under fuzzy environment as follows:

$$\widetilde{Decision\ Matrix}(DM) = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & & \tilde{x}_{2n} \\ \vdots & & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \tag{12}$$

Where $i = 1, 2, 3, \ldots\ldots, m; j = 1, 2, 3, \ldots\ldots, n$

$$Criteria\ \widetilde{Weights}\ (CW) = [\widetilde{cw}_1 \quad \widetilde{cw}_2 \ldots\ldots.. \quad \widetilde{cw}_n] \tag{13}$$

Step 4: Calculation of normalised fuzzy decision matrix

Normalised decision matrix is denoted by $\tilde{P}$ and defined by

$$\tilde{P} = \begin{bmatrix} \tilde{p}_{11} & \tilde{p}_{12} & \cdots & p_{1n} \\ p_{21} & \tilde{p}_{22} & & \tilde{p}_{2n} \\ \vdots & & \ddots & \vdots \\ \tilde{p}_{m1} & \tilde{p}_{m2} & \cdots & \tilde{p}_{mn} \end{bmatrix} \tag{14}$$

where $i = 1, 2, 3, \ldots\ldots, m; j = 1, 2, 3, \ldots\ldots, n$.

$$\tilde{p}_{ij} = \left(\frac{x_{ij}}{z_j^*}, \frac{y_{ij}}{z_j^*}, \frac{z_{ij}}{z_j^*}\right), z_j^* = \max_i(z_{ij}) \tag{15}$$

$$\tilde{p}_{ij} = \left(\frac{x_j^-}{z_{ij}}, \frac{x_j^-}{y_{ij}}, \frac{x_j^-}{x_{ij}}\right), x_j^- = \min_i(x_{ij}) \tag{16}$$

Equations (15) and (16) are used to calculate the beneficiary and non-beneficiary criteria, respectively.

Step 5: Calculation of weighted normalised fuzzy decision matrix

The weighted normalised decision matrix is denoted by $\widetilde{WC}$. It is calculated by multiplying the criteria weights $(cw_j)(\tilde{p}_{ij})$ with the normalised fuzzy decision matrix.

$$\widetilde{WC} = \begin{bmatrix} \tilde{p}_{11} * w_1 & \tilde{p}_{12} * w_2 & \cdots & p_{1n} * w_n \\ p_{21} * w_1 & \tilde{p}_{22} * w_2 & & \tilde{p}_{2n} * w_n \\ \vdots & & \ddots & \vdots \\ \tilde{p}_{m1} * w_1 & \tilde{p}_{m2} * w_2 & \cdots & \tilde{p}_{mn} * w_n \end{bmatrix} \tag{17}$$

where $i = 1, 2, 3, \ldots\ldots, m;\ j = 1, 2, 3, \ldots\ldots, n$.

Step 6: Calculation of FPIS and FNIS

$$F^+ = (wc_1{}^+, wc_2{}^+, \ldots\ldots, wc_n{}^+) \text{where } wc_j{}^+ = \max_i(wc_{ij}) \tag{18}$$

$$F^- = (wc_1{}^-, wc_2{}^-, \ldots\ldots, wc_n{}^-) \text{ where } wc_j{}^- = \min_i(wc_{ij}) \tag{19}$$

where $i = 1, 2, 3, \dots \dots, m;\ j = 1, 2, 3, \dots \dots, n$.

By using equations (18) and (19), it is possible to calculate Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS).

Step 7: Distance Calculation from FPIS and FNIS for each alternative

$$v_i^+ = \sum_{j=1}^{n} v_t\left(\tilde{t}_{ij}, t_j^+\right) \quad (20)$$

$$v_i^- = \sum_{j=1}^{n} v_t\left(\tilde{t}_{ij}, t_j^-\right) \quad (21)$$

where $i = 1, 2, 3, \dots \dots, m;\ j = 1, 2, 3, \dots \dots, n$

Equations (20) and (21) are used to calculate the distance from Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS), respectively, for each alternative.

Step 8: Calculation of closeness coefficient of each alternative

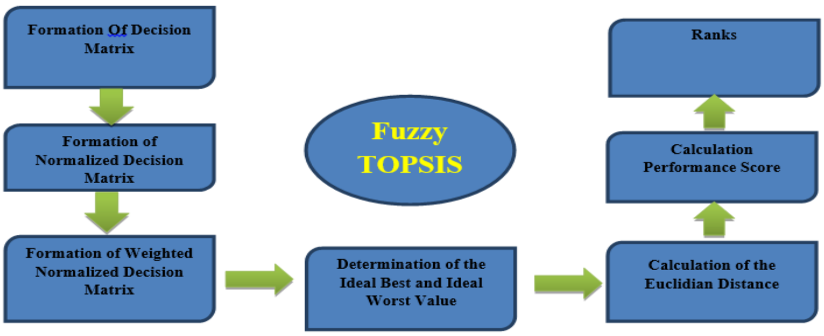
$$S_i = \frac{v_i^-}{v_i^- + v_i^+} \quad (22)$$

where $i = 1,2,3, \dots \dots, m$.

The closeness coefficient is denoted by S_i and defined by equation (22).

Step 9: Ranking of the alternatives

The alternatives are prioritised based on their closeness coefficient (S_i)values, with the highest values taking precedence. Select the top alternatives with the highest (S_i) values. *Figure 5* illustrates diagrammatic steps of TOPSIS.



Source: Hwang and Yoon (1981).

Figure 5. **Diagrammatic Steps of TOPSIS**

3.11 Respondents

The study involved interviewing 300 account holders (250 men and 50 women) from various private banks in Kolkata, North 24 Parganas, South 24 Parganas, and Howrah. Participants were informed about the study's purpose and provided their responses. Those who agreed to participate were given the questionnaire during the interview, and it took a maximum of 10 minutes to complete.

To analyse the socio-demographic profiles of male and female account holders, the study used the T-test for interval scale data and the Chi-square test for nominal scale data. The higher number of male respondents can be attributed to the fact that approximately 83.3% of account holders in private banks are men. Most male account holders were urban natives, while women were primarily from semi-urban areas. Both male and female account holders from rural areas were limited in number. The female account holders tended to be slightly older than their male counterparts and held higher qualifications. About 21.5% of the account holders had no job experience, while the rest had up to forty years of experience. Both male and female account holders were predominantly from nuclear families that range in size from 1 to 5 members, with a few coming from joint/extended families. The average annual income of male and female account holders did not show significant differences. On average, the annual income ranged from 10 thousand to 60 lakh Indian rupees, as shown in *Table 6*.

Table 6. Sampling Profile

Characteristics	Descriptive Statistics	Men	Women	t	χ^2
Sex	N (%)	250 (83.34)	50 (16.76)		
Birth Area					
➢ Urban	N (%)	135 (54)	24 (48)		5.99 (0.05%)
➢ Semi-Urban	N (%)	69 (27.6)	22 (44)		9.21 (0.01%)
➢ Rural	N (%)	46 (18.4)	4 (8)		
Age	M(SD)	20.81 (4.50) [98]	23.61 (3.97) [22]	3.94	
Qualifications	M(SD)	14.99 (3.06) [88]	17.73 (3.52) [14]	3.11	
Job Experience	M(SD)	0.64 (2.81) [130]	1.02 (1.93) [38]	1.97	
Family Members	M(SD)	4.67 (1.85) [120]	4.69 (1.34) [30]	0.11	
Income	M(SD)	466399 (771448) [182]	530888 (988621) [43]	149974.42	

Note: *p < 0.05; **p < 0.01; ***p < 0.001.

Source: created by the authors.

3.12 Judgment Committee

A judgment committee is established, with three judges named J1, J2, and J3, to make the optimal decision. Various options for assessing financial efficiency are outlined in *Table 3*. The effectiveness of each decision is measured applying several criteria as outlined in *Table 4*. The committee consisting of three judges assesses the linguistic quality of the 10 options using the grading scale specified in *Table 1*, as well as the nine criteria established by private banks for each decision, as outlined in *Table 2*.

4. Numerical Illustrations

Linguistic judgments from three judges for the criteria are defined in *Table 7*.

Table 7. Linguistic Judgment for the Criteria

Criteria	J1	J2	J3
C01	S	S	VS
C02	VS	VS	VS
C03	VS	S	VS
C04	S	VS	VS
C05	VS	VS	VS
C06	S	S	VS
C07	MT	S	S
C08	MT	S	MT
C09	MT	MT	MT

Source: created by the authors.

Table 8 shows the transformation from linguistic judgments to fuzzy membership function for criteria, as defined in *Table 2*.

Table 8. Linguistic Judgment for the Criteria

Criteria	J1	J2	J3
C01	$(5,7,9)$	$(5,7,9)$	$(7,9,9)$
C02	$(7,9,9)$	$(7,9,9)$	$(7,9,9)$
C03	$(7,9,9)$	$(5,7,9)$	$(7,9,9)$
C04	$(5,7,9)$	$(7,9,9)$	$(7,9,9)$
C05	$(7,9,9)$	$(7,9,9)$	$(7,9,9)$
C06	$(5,7,9)$	$(5,7,9)$	$(7,9,9)$
C07	$(3,5,7)$	$(5,7,9)$	$(5,7,9)$
C08	$(3,5,7)$	$(5,7,9)$	$(3,5,7)$
C09	$(3,5,7)$	$(3,5,7)$	$(3,5,7)$

Source: created by the authors.

By using equation (11), the aggregated fuzzy weight for each criteria can be calculated, as shown in *Table 9*.

For the criteria C01, the following calculation is applied:

$$\begin{cases} cw_{j1} = \min_k\{5,5,7\} = 5 \\ cw_{j2} = \frac{1}{3}\sum_{1}^{3}(7+7+9) = \frac{23}{3} = 7.67 \\ cw_{j3} = \max_k\{9,9,9\} = 9 \end{cases}$$

This way, it is possible to find out the fuzzy aggregated value for the remaining the criteria.

Table 9. Aggregated Fuzzy weights for criteria

Criteria	J1	J2	J3	Aggregated Fuzzy Weights
C01	$(5,7,9)$	$(5,7,9)$	$(7,9,9)$	$(\mathbf{5},\mathbf{7.67},\mathbf{9})$
C02	$(7,9,9)$	$(7,9,9)$	$(7,9,9)$	$(\mathbf{7},\mathbf{9},\mathbf{9})$
C03	$(7,9,9)$	$(5,7,9)$	$(7,9,9)$	$(\mathbf{5},\mathbf{8.33},\mathbf{9})$
C04	$(5,7,9)$	$(7,9,9)$	$(7,9,9)$	$(\mathbf{5},\mathbf{8.33},\mathbf{9})$
C05	$(7,9,9)$	$(7,9,9)$	$(7,9,9)$	$(\mathbf{7},\mathbf{9},\mathbf{9})$
C06	$(5,7,9)$	$(5,7,9)$	$(7,9,9)$	$(\mathbf{5},\mathbf{7.67},\mathbf{9})$
C07	$(3,5,7)$	$(5,7,9)$	$(5,7,9)$	$(\mathbf{3},\mathbf{6.33},\mathbf{9})$
C08	$(3,5,7)$	$(5,7,9)$	$(3,5,7)$	$(\mathbf{3},\mathbf{5.67},\mathbf{9})$
C09	$(3,5,7)$	$(3,5,7)$	$(3,5,7)$	$(\mathbf{3},\mathbf{5},\mathbf{7})$

Source: created by the authors.

Linguistic judgments for the alternatives from the three judges are defined in *Table 10*.

Table 10. Linguistic Judgments for the Alternatives

	J	A01	A02	A03	A04	A05	A06	A07	A08	A09	A10
	J1	ML	VU	U	U	U	U	U	ML	U	VU
C01	J2	U	U	VU	VU	VU	VU	U	U	ML	U
	J3	U	VU	U	VU	U	U	U	U	U	U
	J1	L	U	ML	U	VU	L	U	U	L	ML
C02	J2	ML	ML	U	ML	U	L	ML	U	L	U
	J3	L	U	U	U	VU	L	U	VU	VL	U
	J1	U	ML	U	U	ML	U	U	ML	U	VU
C03	J2	U	U	VU	ML	U	ML	U	L	VU	U
	J3	ML	ML	U	ML	U	U	VU	ML	U	VU
	J1	U	U	U	U	ML	ML	ML	U	U	ML
C04	J2	U	U	VU	VU	U	U	ML	ML	ML	ML
	J3	VU	ML	VU	VU	U	U	ML	U	U	U
	J1	ML	ML	U	U	U	U	VU	U	VU	U
C05	J2	U	U	VU	VU	VU	VU	U	U	U	U
	J3	U	U	VU	VU	VU	U	VU	ML	VU	VU
	J1	ML	U	U	ML	U	U	ML	U	ML	U
C06	J2	U	ML	ML	ML	ML	ML	ML	ML	ML	ML
	J3	U	U	ML	U	ML	ML	ML	ML	U	ML
	J1	U	ML	ML	U	ML	VU	U	ML	ML	ML
C07	J2	ML	U	U	U	U	U	ML	U	U	ML
	J3	ML	ML	ML	ML	U	U	ML	U	ML	U
	J1	U	U	ML	U	U	U	U	VL	VL	VU
C08	J2	U	U	U	U	U	U	U	VL	VL	U
	J3	ML	U	U	U	U	U	U	VL	VL	U
	J1	U	ML	U	ML	ML	ML	ML	U	U	U
C09	J2	ML	ML	U	ML	ML	ML	ML	U	U	U
	J3	U	ML	U	ML	ML	ML	ML	U	U	VU

Source: created by the authors.

Table 11. Transformation of Linguistic Judgment to Membership Function for Alternatives

	J	A01	A02	A03	A04	A05	A06	A07	A08	A09	A10
	J1	(3, 5, 7)	(7, 9, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(7, 9, 9)
C01	J2	(5, 7, 9)	(5, 7, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)
	J3	(5, 7, 9)	(7, 9, 9)	(5, 7, 9)	(7, 9, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)
	J1	(1, 3, 5)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(7, 9, 9)	(1, 3, 5)	(5, 7, 9)	(5, 7, 9)	(1, 3, 5)	(3, 5, 7)
C02	J2	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(1, 3, 5)	(3, 5, 7)	(5, 7, 9)	(1, 3, 5)	(5, 7, 9)
	J3	(1, 3, 5)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(7, 9, 9)	(1, 3, 5)	(5, 7, 9)	(7, 9, 9)	(1, 1, 3)	(5, 7, 9)
	J1	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(7, 9, 9)
C03	J2	(5, 7, 9)	(5, 7, 9)	(7, 9, 9)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(1, 3, 5)	(7, 9, 9)	(5, 7, 9)
	J3	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(7, 9, 9)	(3, 5, 7)	(5, 7, 9)	(7, 9, 9)
	J1	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)
C04	J2	(5, 7, 9)	(5, 7, 9)	(7, 9, 9)	(7, 9, 9)	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)
	J3	(7, 9, 9)	(3, 5, 7)	(7, 9, 9)	(7, 9, 9)	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)
	J1	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(7, 9, 9)	(5, 7, 9)	(7, 9, 9)	(5, 7, 9)
C05	J2	(5, 7, 9)	(5, 7, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)
	J3	(5, 7, 9)	(5, 7, 9)	(7, 9, 9)	(7, 9, 9)	(7, 9, 9)	(5, 7, 9)	(7, 9, 9)	(3, 5, 7)	(7, 9, 9)	(7, 9, 9)
	J1	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)
C06	J2	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)
	J3	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)
	J1	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(7, 9, 9)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)
C07	J2	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)
	J3	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)
	J1	(5, 7, 9)	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(1, 1, 3)	(1, 1, 3)	(7, 9, 9)
C08	J2	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(1, 1, 3)	(1, 1, 3)	(5, 7, 9)
	J3	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(1, 1, 3)	(1, 1, 3)	(5, 7, 9)
	J1	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)
C09	J2	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)
	J3	(5, 7, 9)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(7, 9, 9)

Source: created by the authors.

Table 11 shows the transformation from linguistic judgments to fuzzy membership function for the alternatives, as defined in *Table 3*.

By using equation (10), the aggregated fuzzy weight for each alternative can be calculated, as shown in *Table 12*. Suppose taking the criterion C06 and alternative A03:

$$\begin{cases} x_{ij} = \min_k\{5,3,3\} = 3 \\ y_{ij} = \frac{1}{3}\sum_{1}^{3} 7+5+5 = \frac{17}{3} = 5.66 \\ z_{ij} = \max_k\{9,7,7\} = 9 \end{cases}$$

This way, it is possible to find out the fuzzy aggregated value for the rest of the alternatives.

Table 12. Aggregated Fuzzy Weights for the Alternatives

	A01	A02	A03	A04	A05	A06	A07	A08	A09	A10
C01	(3, 6.33, 9)	(5, 8.33, 9)	(5, 7.66, 9)	(5, 8.33, 9)	(5, 7.66, 9)	(5, 7.66, 9)	(5, 7, 9)	(3, 6.33, 9)	(3, 6.33, 9)	(5, 7.66, 9)
C02	(1, 3.66, 7)	(3, 6.33, 9)	(3, 6.33, 9)	(3, 6.33, 9)	(5, 8.33, 9)	(1, 3, 5)	(3, 6.33, 9)	(5, 7.66, 9)	(1, 2.33, 5)	(3, 6.33, 9)
C03	(3, 6.33, 9)	(3, 5.66, 9)	(5, 7.66, 9)	(3, 5.66, 9)	(3, 6.33, 9)	(3, 6.33, 9)	(5, 7.66, 9)	(1, 4.33, 7)	(5, 7.66, 9)	(5, 8.33, 9)
C04	(5, 7.66, 9)	(3, 6.33, 9)	(5, 8.33, 9)	(5, 8.33, 9)	(3, 6.33, 9)	(3, 6.33, 9)	(3, 5, 7)	(3, 6.33, 9)	(3, 6.33, 9)	(3, 5.66, 9)
C05	(3, 6.33, 9)	(3, 6.33, 9)	(5, 8.33, 9)	(5, 8.33, 9)	(5, 8.33, 9)	(5, 7.66, 9)	(5, 8.33, 9)	(3, 6.33, 9)	(5, 8.33, 9)	(5, 7.66, 9)
C06	(3, 6.33, 9)	(3, 6.33, 9)	(3, 5.66, 9)	(3, 5.66, 9)	(3, 5.66, 9)	(3, 5.66, 9)	(3, 5, 7)	(3, 5.66, 9)	(3, 5.66, 9)	(3, 5.66, 9)
C07	(3, 5.66, 9)	(3, 5.66, 9)	(3, 5.66, 9)	(3, 6.33, 9)	(3, 6.33, 9)	(5, 7.66, 9)	(3, 5.66, 9)	(3, 6.33, 9)	(3, 5.66, 9)	(3, 5.66, 9)
C08	(3, 6.33, 9)	(5, 7, 9)	(3, 6.33, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)	(1, 1, 3)	(1, 1, 3)	(5, 7.66, 9)
C09	(3, 6.33, 9)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(5, 7, 9)	(5, 7, 9)	(5, 7.66, 9)

Source: created by the authors.

By taking transpose of the above matrix (*Table 12*), we can get the fuzzy decision matrix, as shown in *Table 13*.

Table 13. Fuzzy Decision Matrix

Criteria Type	B	B	NB	B	NB	B	B	B	B
	C01	C02	C03	C04	C05	C06	C07	C08	C09
A01	(3, 6.33, 9)	(1, 3.66, 7)	(3, 6.33, 9)	(5, 7.66, 9)	(3, 6.33, 9)	(3, 6.33, 9)	(3, 5.66, 9)	(3, 6.33, 9)	(3, 6.33, 9)
A02	(5, 8.33, 9)	(3, 6.33, 9)	(3, 5.66, 9)	(3, 6.33, 9)	(3, 6.33, 9)	(3, 6.33, 9)	(3, 5.66, 9)	(5, 7, 9)	(3, 5, 7)
A03	(5, 7.66, 9)	(3, 6.33, 9)	(5, 7.66, 9)	(5, 8.33, 9)	(5, 8.33, 9)	(3, 5.66, 9)	(3, 5.66, 9)	(3, 6.33, 9)	(5, 7, 9)
A04	(5, 8.33, 9)	(3, 6.33, 9)	(3, 5.66, 9)	(5, 8.33, 9)	(5, 8.33, 9)	(3, 5.66, 9)	(3, 6.33, 9)	(5, 7, 9)	(3, 5, 7)
A05	(5, 7.66, 9)	(5, 8.33, 9)	(3, 6.33, 9)	(3, 6.33, 9)	(5, 8.33, 9)	(3, 5.66, 9)	(3, 6.33, 9)	(5, 7, 9)	(3, 5, 7)
A06	(5, 7.66, 9)	(1, 3, 5)	(3, 6.33, 9)	(3, 6.33, 9)	(5, 7.66, 9)	(3, 5.66, 9)	(5, 7.66, 9)	(5, 7, 9)	(3, 5, 7)
A07	(5, 7, 9)	(3, 6.33, 9)	(5, 7.66, 9)	(3, 5, 7)	(5, 8.33, 9)	(3, 5, 7)	(3, 5.66, 9)	(5, 7, 9)	(3, 5, 7)
A08	(3, 6.33, 9)	(5, 7.66, 9)	(1, 4.33, 7)	(3, 6.33, 9)	(3, 6.33, 9)	(3, 5.66, 9)	(3, 6.33, 9)	(1, 1, 3)	(5, 7, 9)
A09	(3, 6.33, 9)	(1, 2.33, 5)	(5, 7.66, 9)	(3, 6.33, 9)	(5, 8.33, 9)	(3, 5.66, 9)	(3, 5.66, 9)	(1, 1, 3)	(5, 7, 9)
A10	(5, 7.66, 9)	(3, 6.33, 9)	(5, 8.33, 9)	(3, 5.66, 9)	(5, 7.66, 9)	(3, 5.66, 9)	(3, 5.66, 9)	(5, 7.66, 9)	(5, 7.66, 9)

Source: created by the authors.

Maximum and minimum values which will require the normalised fuzzy decision matrix for the calculation of the beneficiary and non-beneficiary criteria are presented in *Table 14*.

Table 14. Maximum Values (z_j^*) and Minimum Values (x_j^-)

Criteria Type	B	B	NB	B	NB	B	B	B	B
	C01	C02	C03	C04	C05	C06	C07	C08	C09
z_j^*	9	9	9	9	9	9	9	9	9
x_j^-	3	1	1	3	3	3	3	1	3

Source: created by the authors.

The equations (15) and (16) are used for beneficiary and non-beneficiary criteria, respectively, to calculate the normalised fuzzy decision matrix, as presented in *Table 15*.

For beneficiary criteria:

Taking the junction of A03 and C02:

$$z_2^* = \max_3(z_{32}) = 9, \tilde{p}_{32} = \left(\frac{x_{32}}{z_2^*}, \frac{y_{32}}{z_2^*}, \frac{z_{32}}{z_2^*}\right) = \left(\frac{3}{9}, \frac{6.33}{9}, \frac{9}{9}\right) = (0.33, 0.70, 1)$$

For non-beneficiary criteria:

Supposing the junction of A06 and C05:

$$x_5^- = \min_6(x_{65}) = 3, \tilde{p}_{65} = \left(\frac{x_5^-}{z_{65}}, \frac{x_5^-}{y_{65}}, \frac{x_5^-}{x_{65}}\right) = \left(\frac{3}{9}, \frac{3}{7.66}, \frac{3}{5}\right) = (0.33, 0.39, 0.60)$$

Table 15. Normalised Fuzzy Decision Matrix

Criteria Type	B	B	NB	B
	C01	C02	C03	C04
A01	(0.33, 0.70, 1)	(0.11, 0.40, 0.78)	(0.11, 0.16, 0.33)	(0.56, 0.85, 1)
A02	(0.56, 0.92, 1)	(0.33, 0.70, 1)	(0.11, 0.18, 0.33)	(0.33, 0.70, 1)
A03	(0.56, 0.85, 1)	(0.33, 0.70, 1)	(0.11, 0.13, 0.20)	(0.55, 0.92, 1)
A04	(0.56, 0.92, 1)	(0.33, 0.70, 1)	(0.11, 0.18, 0.33)	(0.55, 0.92, 1)
A05	(0.56, 0.85, 1)	(0.56, 0.92, 1)	(0.11, 0.16, 0.33)	(0.33, 0.70, 1)
A06	(0.56, 0.85, 1)	(0.11, 0.33, 0.56)	(0.11, 0.16, 0.33)	(0.33, 0.70, 1)
A07	(0.56, 0.78, 1)	(0.33, 0.70, 1)	(0.11, 0.13, 0.20)	(0.33, 0.56, 0.78)
A08	(0.33, 0.70, 1)	(0.56, 0.85, 1)	(0.14, 0.23, 1)	(0.33, 0.70, 1)
A09	(0.33, 0.70, 1)	(0.11, 0.26, 0.56)	(0.11, 0.13, 0.20)	(0.33, 0.70, 1)
A10	(0.56, 0.85, 1)	(0.33, 0.70, 1)	(0.11, 0.12, 0.20)	(0.33, 0.63, 1)

NB	B	B	B	B
C05	C06	C07	C08	C09
(0.33, 0.47, 1)	(0.33, 0.70, 1)	(0.33, 0.63, 1)	(0.33, 0.70, 1)	(0.33, 0.70, 1)
(0.33, 0.47, 1)	(0.33, 0.70, 1)	(0.33, 0.63, 1)	(0.56, 0.78, 1)	(0.33, 0.56, 0.78)
(0.33, 0.36, 0.60)	(0.33, 0.63, 1)	(0.33, 0.63, 1)	(0.33, 0.70, 1)	(0.56, 0.78, 1)
(0.33, 0.36, 0.60)	(0.33, 0.63, 1)	(0.33, 0.70, 1)	(0.56, 0.78, 1)	(0.33, 0.56, 0.78)
(0.33, 0.36, 0.60)	(0.33, 0.63, 1)	(0.33, 0.70, 1)	(0.56, 0.78, 1)	(0.33, 0.56, 0.78)
(0.33, 0.39, 0.60)	(0.33, 0.63, 1)	(0.56, 0.85, 1)	(0.56, 0.78, 1)	(0.33, 0.56, 0.78)
(0.33, 0.36, 0.60)	(0.33, 0.56, 0.78)	(0.33, 0.63, 1)	(0.56, 0.78, 1)	(0.33, 0.56, 0.78)
(0.33, 0.47, 1)	(0.33, 0.63, 1)	(0.33, 0.70, 1)	(0.11, 0.11, 0.33)	(0.56, 0.78, 1)
(0.33, 0.36, 0.60)	(0.33, 0.63, 1)	(0.33, 0.63, 1)	(0.11, 0.11, 0.33)	(0.56, 0.78, 1)
(0.33, 0.39, 0.60)	(0.33, 0.63, 1)	(0.33, 0.63, 1)	(0.56, 0.85, 1)	(0.56, 0.85, 1)

Source: created by the authors.

In this step, it is necessary to calculate the weighted normalised fuzzy decision matrix, as presented in *Table 16*, by using equation (17). The aggregated weights for criteria are taken from *Table 9*.

Supposing for the junction A06 and C03:

$\widetilde{WC}_{63} = (0.11, 0.16, 0.33) * (5, 8.33, 9) = (0.55, 1.33, 3)$.

Similarly, we can calculate the value for all junctions of *Table 16*.

Table 16. Weighted Normalised Fuzzy Decision Matrix

Criteria Weight	(5,7.67,9)	(7,9,9)	(5,8.33,9)	(5,8.33,9)
	C01	C02	C03	C04
A01	(1.67, 5.40, 9)	(0.78, 3.67, 7)	(0.56, 1.32, 3)	(2.78, 7.10, 9)
A02	(2.78, 7.10, 9)	(2.33, 6.33, 9)	(0.56, 1.47, 3)	(1.67, 5.86, 9)
A03	(2.78, 6.54, 9)	(2.33, 6.33, 9)	(0.56, 1.09, 1.80)	(2.78, 7.72, 9)
A04	(2.78, 7.10, 9)	(2.33, 6.33, 9)	(0.56, 1.48, 3)	(2.78, 7.72, 9)
A05	(2.78, 6.54, 9)	(3.89, 8.33, 9)	(0.56, 1.32, 3)	(1.67, 5.86, 9)
A06	(2.78, 6.54, 9)	(0.78, 3, 5)	(0.56, 1.33, 3)	(1.67, 5.86, 9)
A07	(2.78, 5.96, 9)	(2.33, 6.33, 9)	(0.56, 1.09, 1.80)	(1.67, 4.63, 7)
A08	(1.67, 5.40, 9)	(3.89, 7.67, 9)	(0.71, 1.92, 9)	(1.67, 5.86, 9)
A09	(1.67, 5.40, 9)	(0.78, 2.33, 5)	(0.56, 1.09, 1.80)	(1.67, 5.86, 9)
A10	(2.78, 6.54, 9)	(2.33, 6.33, 9)	(0.56, 1, 1.80)	(1.67, 5.25, 9)

Criteria Weight	(7,9,9)	(5,7.67,9)	(3,6.33,9)	(3,5.67.9)	(3,5,7)
	C05	C06	C07	C08	C09
A01	(2.33, 4.27, 9)	(1.67, 5.40, 9)	(1, 3.99, 9)	(1, 3.99, 9)	(1, 3.52, 7)
A02	(2.33, 4.27, 9)	(1.67, 5.40, 9)	(1, 3.99, 9)	(1.67, 4.41, 9)	(1, 2.78, 5.44)
A03	(2.33, 3.25, 5.40)	(1.67, 4.83, 9)	(1, 3.99, 9)	(1, 3.99, 9)	(1.67, 3.89, 7)
A04	(2.33, 3.25, 5.40)	(1.67, 4.83, 9)	(1, 4.46, 9)	(1.67, 4.41, 9)	(1, 2.78, 5.44)
A05	(2.33, 3.25, 5.40)	(1.67, 4.83, 9)	(1, 4.46, 9)	(1.67, 4.41, 9)	(1, 2.78, 5.44)
A06	(2.33, 3.25, 5.40)	(1.67, 4.83, 9)	(1.67, 5.40, 9)	(1.67, 4.41, 9)	(1, 2.78, 5.44)
A07	(2.33, 3.25, 5.40)	(1.67, 4.26, 7)	(1, 3.99, 9)	(1.67, 4.41, 9)	(1, 2.78, 5.44)
A08	(2.33, 4.27, 9)	(1.67, 4.83, 9)	(1, 4.46, 9)	(0.33, 0.63, 3)	(1.67, 3.89, 7)
A09	(2.33, 3.25, 5.40)	(1.67, 4.83, 9)	(1, 3.99, 9)	(0.33, 0.63, 3)	(1.67, 3.89, 7)
A10	(2.33, 3.25, 5.40)	(1.67, 4.83, 9)	(1, 3.99, 9)	(1.67, 4.41, 9)	(1.67, 3.89, 7)

Source: created by the authors.

By using equations (18) and (19), it is necessary to calculate Fuzzy Positive Ideal Solution (FPIS/$\boldsymbol{F}^{+}$) and Fuzzy Negative Ideal Solution (FNIS/$\boldsymbol{F}^{-}$), as presented in *Table 17*.

Table 17. Calculations of $\boldsymbol{F}^{+}$ and $\boldsymbol{F}^{-}$

	C01	C02	C03	C04	C05	C06	C07	C08	C09
F^{+}	(9, 9, 9)	(9, 9, 9)	(9, 9, 9)	(9, 9, 9)	(9, 9, 9)	(9, 9, 9)	(9, 9, 9	(9, 9, 9)	(7, 7, 7
F^{-}	(1.67, 1.67, 1	(0.78, 0.78, 0	(0.56, 0.56, 0	(1.67, 1.67, 1	(2.33, 2.33, 2	(1.67, 1.67, 1	(1, 1, 1	(0.33, 0.33, 0	(1, 1, 1

Source: created by the authors.

Table 18 illustrates the calculations of the distance from $\boldsymbol{F}^{+}$ for each alternative by using equation (20).

Table 18. Distance Calculation from $F^{+}$for Each Alternative

	C01	C02	C03	C04	C05	C06	C07	C08	C09
$v_t, A_1{}^+$	4.72	5.78	7.45	3.76	4.72	4.72	5.45	5.45	4.01
$v_t, A_2{}^+$	3.76	4.14	7.39	4.60	4.72	4.72	5.45	5.01	4.33
$v_t, A_3{}^+$	3.86	4.15	7.87	3.67	5.50	4.87	5.45	5.45	3.56
$v_t, A_4{}^+$	3.76	4.14	7.39	3.67	5.50	4.87	5.31	5.01	4.33
$v_t, A_5{}^+$	3.87	2.98	7.45	4.60	5.50	4.87	5.31	5.01	4.33
$v_t, A_6{}^+$	3.86	6.31	7.45	4.60	5.40	4.87	4.72	5.00	4.33
$v_t, A_7{}^+$	4.00	4.14	7.87	5.06	5.50	5.17	5.45	5.01	4.33
$v_t, A_8{}^+$	4.72	3.05	6.29	4.60	4.72	4.87	5.32	7.78	3.56
$v_t, A_9{}^+$	4.72	6.53	7.87	4.60	5.50	4.87	5.45	7.78	3.56
$v_t, A_{10}{}^+$	3.86	4.14	7.90	4.76	5.40	4.87	5.45	4.87	3.46

Source: created by the authors.

Table 19 illustrates the calculation of the distance from $F^{-}$for each alternative by using equation (21).

Table 19. Distance Calculation from $F^{-}$for Each Alternative

	C01	C02	C03	C04	C05	C06	C07	C08	C09
$v_t, A_1{}^-$	4.75	3.96	1.48	5.31	4.01	4.75	4.93	5.44	3.76
$v_t, A_2{}^-$	5.31	5.80	1.51	4.88	4.01	4.75	4.93	5.58	2.76
$v_t, A_3{}^-$	5.12	5.80	0.78	5.52	1.85	4.61	4.93	5.44	3.86
$v_t, A_4{}^-$	5.31	5.80	1.51	5.52	1.85	4.61	5.03	5.58	2.76
$v_t, A_5{}^-$	5.12	6.70	1.48	4.88	1.85	4.61	5.03	5.58	2.76
$v_t, A_6{}^-$	5.12	2.75	1.48	4.88	1.90	4.61	5.28	5.58	2.76
$v_t, A_7{}^-$	4.95	5.80	0.78	3.52	1.85	3.42	4.93	5.58	2.76
$v_t, A_8{}^-$	4.75	6.45	4.94	4.88	4.01	4.61	5.03	1.55	3.86
$v_t, A_9{}^-$	4.75	2.60	0.78	4.88	1.85	4.61	4.93	1.54	3.86
$v_t, A_{10}{}^-$	5.12	5.80	0.76	4.71	1.90	4.61	4.93	5.69	3.96

Source: created by the authors.

The *Table 20* below presents the results obtained on the calculations of closeness coefficients (S_i) and the rankings by using equation (22).

Table 20. Calculation of Closeness Coefficients (S_i) and Rankings

	Private Banks	$v_i{}^-$	$v_i{}^+$	$S_i = \frac{v_i{}^-}{v_i{}^- + v_i{}^+}$	**Rankings**
A01	*Axis Bank*	44.42	47.12	0.486	**3**
A02	*Bandhan Bank*	44.37	47.43	0.483	**4**
A03	*Federal Bank*	41.45	50.49	0.451	**7**
A04	*HDFC Bank*	46.22	47.10	0.495	**1**
A05	*ICICI Bank*	45.62	48.10	0.487	**2**
A06	*IDFC First Bank*	40.05	49.57	0.447	**8**
A07	*Indusind Bank*	43.60	48.20	0.475	**6**
A08	*Kotak Mahindra Bank*	45.67	49.21	0.482	**5**
A09	*RBL Bank*	33.95	56.46	0.376	**10**
A10	*YES Bank*	40.17	50.69	0.442	**9**

Source: created by the authors.

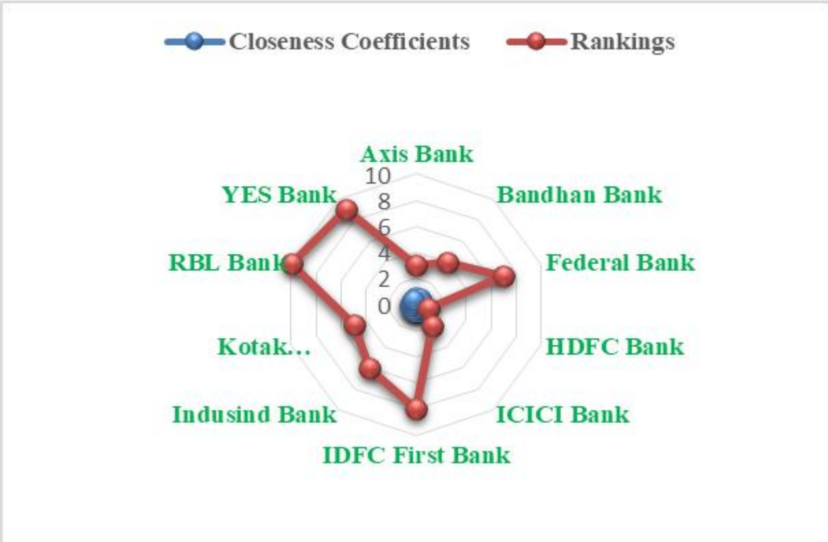
5. Findings

The relative closeness value of A04 (HDFC Bank) is maximum with the value of 0.495. Thus A04 (HDFC Bank) ranks first followed by the A05 (ICICI Bank), A01 (Axis Bank), A02 (Bandhan Bank), A08 (Kotak

Mahindra Bank), A07 (Indusind Bank), A03 (Federal Bank), A06 (IDFC First Bank), A10 (Yes Bank) and A09 (RBL Bank). Therefore, the ranking is as follows:

$A04 > A05 > A01 > A02 > A08 > A07 > A03 > A06 > A10 > A09.$

The results show that the HDFC Bank has the best ranking while ICICIBank and Axis Bank are the second and third best, respectively, according to the Fuzzy TOPSIS technique. In the following *Figure 6*, ranks are presented graphically according to distance measures.



Source: created by the authors.

Figure 6. **Distance Measure and Rankings of Private Banks**

6. Sensitivity Analysis

The sensitivity analysis is conducted to find the influence of weights of criteria on the best private bank. For this reason, 15 experiments have been conducted, and the results are presented in *Table 21*.

The experiments are as follows:

- 1 and 2: all the criteria weights are assigned to (7, 9, 9) and (5, 7, 9).
- 3 and 4: C01 = (7, 9, 9) and rests are taken (5, 7, 9) and (3, 5, 7).
- 5, 6, and 7: C01 = (5, 7, 9) and rests are taken as (3, 5, 7).
- 8 and 9: C01 = (5, 7, 9), C02 = (3, 5, 7), C03 = (1, 3, 5) and C04 = (1, 1, 3).
- 10, 11, 12, and 13: all criteria are taken as (5, 7, 9) expect non-beneficiary criteria C03 and C05
- 14 and 15: weights of the criteria C03 and C05 are taken as (1, 3, 5) and (1, 1, 3), respectively.

Out of 15 experiments, the alternative A04, i.e. HDFC Bank, has been scored as best private bank in first eight experiments. However, the alternative A05, i.e. ICICI Bank, and the alternative A01, i.e. Axis Bank, have performed as best private banks in the last 5 and 2 experiments, respectively.

Table 21. Experimental Results of Sensitivity Analysis

No of Exp.	A01	A02	A03	A04	A05	A06	A07	A08	A09	A10
1	0.5051	0.5058	0.5090	**0.5195**	0.5097	0.4660	0.4657	0.4926	0.3836	0.4787
2	0.5142	0.5253	0.5038	**0.5288**	0.5228	0.4776	0.4792	0.4950	0.3937	0.4922
3	0.5241	0.5257	0.5009	**0.5372**	0.5227	0.4903	0.4939	0.4977	0.4046	0.5068
4	0.5341	0.5463	0.5264	**0.5520**	0.5468	0.5024	0.5083	0.4996	0.4138	0.5213
5	0.4729	0.4603	0.4698	**0.4782**	0.4606	0.4355	0.4325	0.4570	0.3698	0.4472
6	0.4785	0.4759	0.4615	**0.4818**	0.4705	0.4445	0.4436	0.4659	0.3793	0.4581
7	0.4864	0.4740	0.4849	**0.4994**	0.4820	0.4550	0.4559	0.4671	0.3890	0.4705
8	0.4936	0.5015	0.4880	**0.5034**	0.4930	0.4645	0.4673	0.4670	0.3968	0.4821
9	0.4711	0.4701	0.4637	0.4717	**0.4738**	0.4401	0.4592	0.4388	0.3825	0.4534
10	0.4788	0.4821	0.4681	0.4741	**0.4858**	0.4505	0.4515	0.4585	0.3915	0.4665
11	0.4840	0.4817	0.4820	0.4824	**0.4995**	0.4447	0.4445	0.4719	0.3743	0.4533
12	0.4856	0.4819	0.4772	0.4827	**0.4876**	0.4462	0.4497	0.4795	0.3749	0.4584
13	0.4625	0.4623	0.4587	0.4585	**0.4679**	0.4283	0.4250	0.4512	0.3712	0.4395
14	**0.4491**	0.4329	0.4331	0.4324	0.4375	0.4186	0.4144	0.4421	0.3729	0.4287
15	**0.4183**	0.4133	0.4052	0.4040	0.4009	0.3825	0.3789	0.4052	0.3416	0.3929

Source: created by the authors.

Conclusions

Utilising the Fuzzy TOPSIS technique, HDFC Bank has the highest ranking, followed by ICICI Bank and Axis Bank. The sensitivity analysis ranks HDFC Bank as the top choice, with ICICI Bank and Axis Bank ranking second and third, respectively. When both techniques are considered collectively, HDFC Bank, ICICI Bank, and Axis Bank emerge as the top-ranked private banks.

It is imperative to acknowledge that these rankings are based on specific techniques and may not reflect the opinions or preferences of all individuals. Individuals may have differing preferences based on their specific needs and objectives. The financial ranking of prominent players in the Indian private banks sector (HDFC, ICICI, Axis, Bandhan etc.) provides valuable insights into their respective financial positions. HDFC Bank emerges as the frontrunner, securing the top position with a financial ranking of 1, indicating robust financial health and strategic positioning. ICICI Bank follows in second place, reinforcing its strength in the industry. Axis Bank is in third position, showcasing its stability and financial resilience. Bandhan Bank and Kotak Mahindra Bank follow in fourth and fifth positions, respectively, demonstrating a solid but slightly lower financial standing compared to their counterparts. Indusind Bank, in sixth place, indicates potential for improvement in its financial performance. The comprehensive analysis on the rankings presented in this study offers valuable benchmarks for stakeholders and investors to assess and navigate the dynamic landscape of the Indian private banks sector, enabling informed decision making for future endeavours and investments.

Limitations

The present study is limited to the discussion of the financial efficiency of ten private banks and nine factors, i.e. financial ratios. The private banks chosen for this study are limited to the Indian financial market. The study employs only two techniques: the MCDM method and the F-TOPSIS method.

Future Scopes

The study can be extended in future by considering a greater number of private banks and choosing a more extensive range of factors and sub-factors for analysis. The methodology could be expanded to include other MCDM methods, thereby refining the results. In addition, to broaden the spectrum of results, the analysis could be expanded to include private banks from other countries.

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NEAPIBRĖŽTAS ARTUMO IDEALIAM TAŠKUI METODAS, SKIRTAS ĮVERTINTI PRIVAČIŲ BANKŲ FINANSINĮ EFEKTYVUMĄ

Subrata Jana, Bibhas Chandra Giri, Anirban Sarkar, Edmundas Kazimieras Zavadskas

Santrauka. Bankininkystės sektorius Indijoje – viena sparčiausiai augančių pramonės šakų šalyje po to, kai 2016 m. Indijos vyriausybė įvedė demonetizaciją. Palaikyti santykius su klientais ir teikti finansines paslaugas labiau sekasi privatiems nei valstybiniams bankams. Pagrindinė banko dalis – jo finansiniai rezultatai. Šiuolaikinėje nuolat didėjančios konkurencijos rinkoje tinkamas ir tikslus finansinių rezultatų vertinimas itin reikšmingas bankui, užsibrėžusiam tikslą sėkmingai išlaikyti savo padėtį rinkoje. Tyrimo metu siekta nustatyti geriausią privatų banką ir sudaryti privačių Indijos bankų reitingą. Šiuo tyrimu norima įvertinti ir palyginti dešimties privačių bankų, 2023 m. rugsėjo 2 d. įtrauktų į NIFTY sąrašą Nacionalinėje vertybinių popierių biržoje (angl. NSE), finansinius rezultatus. Tyrime pasitelktas daugiakriteris sprendimų priėmimo metodas (angl. *Multi-Criteria Decision Making*, MCDM). Šie dešimt privačių bankų vertinami siekiant nustatyti finansinės veiklos rezultatų balą ir reitingą, taikant neapibrėžtą artumo idealiam taškui metodą (F-TOPSIS), kuris pagrįstas euklidiniu atstumu. Rezultatai atskleidė, kad HDFC bankas yra finansiškai efektyviausias, o ICICI ir Axis bankai užima antrąją ir trečiąją vietas.

Reikšminiai žodžiai: bankininkystė sektorius; finansinis efektyvumas; reitingai; numanomas neapibrėžtasis skaičius; F-TOPSIS.