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INTEGRATED NEUTROSOPHIC DEMATEL, TOPSIS, AND GRA APPROACH FOR FINANCIAL RATIO PERFORMANCE EVALUATION OF NASDAQ EXCHANGE

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Accounting and economic-based financial metrics play a crucial role in stock selection or stock ranking by providing objective and quantifiable measures of a company's financial health and performance. These metrics are used by investors, analysts, and portfolio managers to assess the potential risks and returns associated with investing in a particular stock. This study aims to contribute to stock selection and ranking methodologies by proposing a novel Multi-Criteria Decision-Making (MCDM) model. The model integrates the Decision-Making Trial and Evaluation Laboratory (DEMATEL), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and Grey Relational Analysis (GRA) approaches within a neutrosophic environment. Focusing on companies listed on the NASDAQ stock exchange, the research evaluates financial metrics from June 2018 to May 2022, specifically in the Information Technology sector across eight industries. The financial metrics are categorized into two groups: accounting-based financial measures (AFM) and economic value-based financial measures (EFM). Two experts assess the data, and the neutrosophic DEMATEL approach is employed to calculate the weights of the criteria. Subsequently, companies are ranked using neutrosophic TOPSIS and GRA methods. In conclusion, the study conducts a sensitivity analysis using the neutrosophic GRA method to validate the efficiency of the ranking. This research significantly contributes to the field by introducing a comprehensive MCDM model that amalgamates various decision-making techniques within a neutrosophic framework. The results not only provide valuable insights into stock ranking on the NASDAQ stock exchange but also demonstrate the efficacy of the proposed methodology. The integration of DEMATEL, TOPSIS, and GRA in a neutrosophic environment adds originality to the existing literature on financial metrics and MCDM models in stock selection.

Keywords: Neutrosophic set, Neutrosophic DEMATEL, TOPSIS, GRA, Financial Ratio.

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1. INTRODUCTION

Evaluating a company's financial success is of great significance in today's dynamic global economy. Company performance assessment is typically performed within the framework of financial exploration. The financial ratio performance review process is very useful in all businesses and relevant industries. Numerous research (Çaloglu Buyukselçuk*et al.*,2022) demonstrated that financial ratios are important gauges of a company's financial strength. They give consumers the ability to evaluate and examine pertinent data in order to deliver a helpful piece of information for decision-making. (Sim *et al.*,2011) have shown that the value of the financial ratios also illustrates the strengths and weaknesses of the company in terms of flexibility, productivity, and profitability. The stock price movement is influenced by the financial ratios, which also measure the stock's numerous funding characteristics (Lee *et al.*, 2011).

The company's efficiency and competitiveness are demonstrated by the financial performance measurement. One of the widely accepted techniques in group decision-making is the MCDM technique. Many MCDM methods are used in the literature. Each one has its own merits and demerits. The DEMATEL and TOPSIS approaches are powerful tools for ranking complex problems. Nowadays, hybrid methods have been successfully used to analyze a company's performance in

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the financial stock market. The DEMATEL and ANP are combined to investigate the interdependence of stock investment decision-making factors (Badhotiya*et al.*,2022; Golcuk and Baykasoglu, 2016).

The decision-makers (DMs) assess various alternatives and criteria linguistically. These kinds of situations have been successfully handled by fuzzy MCDM techniques. A new DEMATEL approach is proposed for the Priority Investment project, based on estimating the likelihood of reducing the international trade deficit and generating new investments simultaneously (Altuntas *et al.*,2015; Mills*et al.*,2000). These findings showed that the primary criterion: return, financial ratios, dividends, and risk are the most important variables for achieving high benefits of stock portfolio selection in the Shanghai Stock Exchange. Rezaeian and Akbari (2015) combined the ANP and DEMATEL for optimal stock selection in the fuzzy environment. The causal relationship between the item classes has been examined using the fuzzy DEMATEL approach, which is utilized for a variety of applications. To determine a set of reliable attributes in the stock market. Wu *et al.* (2007) have used the fuzzy and gray Delphi approach. The several criteria that are employed in portfolio development and the causal relationships between the criteria have been examined by Varma and Kumar (2012) and Tabrizi *et al.*(2016). A fuzzy DEMATEL system has been created to handle interactions between evaluation parameters Rostamkhani and Abbasi (2021). They proposed the fuzzy ANP method to calculate the relative importance of each criterion, which was applied to evaluate the quality of service in Turkey's airline achievement. Pineda *et al.*(2018) have proposed integrated DRSA, DEMATEL, DANP, and VIKOR methods to rank and evaluate the financial ratios in airlines. Yalcin *et al.* (2012) have investigated a new procedure to order the two groups in the financial ratios in the Turkish manufacturing industry of the Istanbul Stock Exchange by using fuzzy TOPSIS and Fuzzy VIKOR. Aldalou and Perçin (2020) have combined fuzzy Shannon's entropy and the fuzzy ELECTRE I approach to decide the weights of the criteria and rank companies. The financial performance of businesses listed on Turkey's BIST Technology Index has been assessed using this approach.

Recently, many authors have used the idea of neutrosophic sets in MCDM methods. The concept of the neutrosophic set was introduced by Smarandache (2010). Seyfullahogullari and Ergul (2012) which is distinguished by the role of truth, indeterminacy, and falsity membership functions. Therefore, the neutrosophic set theory has been used to explain the confusion associated with ambiguity in human thought, which handles the linguistic terms as distributions of possibilities in terms of membership functions. Basset *et al.* (2019) have presented a navel hybrid multiple criteria group decision-making framework for the project selection under the neutrosophic environment. Altuntas and Dereli (2015) studied a novel approach based on a process called DEMATEL and patent quote analysis to prioritize investment project portfolios. Bolturk and Kahraman (2018) introduced a new interval-valued neutrosophic AHP based on cosine similarity measures. Liang *et al.* (2018) developed a single-valued trapezoidal neutrosophic normalized weighted Bonferroni mean operator, which was used to solve the multi-criteria group decision-making problems. Hence, the objective of this paper is to evaluate the comparative significance of the financial ratios of two groups (AFM and EFM) using the DEMATEL, TOPSIS, and approach under the neutrosophic environment. Comparison of the proposed work with the existing literature review is shown in Table 1.

Table 1. Literature Review

S.No	Author	Methods	Problem
1	Visalakshmi *et al*.(2015)	FDEMATEL-FTOPSIS	Financial performance evaluation
2	Abdel-Basset *et al*.(2020)	TOPSIS-AHP	Financial performance evaluation
3	Yalcin *et al*.(2012)	FAHP-FTOPSIS	Financial performance evaluation
4	Ho *et al*.(2011)	DEMATEL-ANP	Portfolio selection
5	Mandic *et al*.(2014)	FTOPSIS-FAHP	Financial performance evaluation
6	Yuksel *et al*.(2017)	DEMATEL-GRA	Financial performance in the Turkish banking sector
7	Eceand Uludag (2017)	FTOPSIS	Portfolio Selection
8	Varma and Kumar (2012)	DEMATEL	Portfolio Selection
9	Lee *et al*.(2011)	DEMATEL-ANP	Portfolio Selection
10	Shaverdi,*et al*.(2016)	FTOPSIS	Financial performance evaluation
12	Amiri*et al*.(2010)	TOPSIS	Portfolio Selection
13	Lin *et al*.(2007)	TOPSIS	Mutual funds’ performance evaluation
14	Wang (2014)	FTOPSIS	Financial performance
15	Joshi and Kumar (2014)	Intuitionistic fuzzy entropy and TOPSIS	Portfolio Selection
16	Veeramani *et al*.(2022)	Neutrosophic DEMATEL	Financial performance evaluation
17	Veeramani *et al*.(2022)	FTOPSIS, FVIKOR, FAHP, FARAS, FCOPRAS, FWPM	Financial performance evaluation

S.No	Author	Methods	Problem
18	Aldalouand Perçin(2020)	FTOPSIS	Financial performance evaluation
19	Moghimiand Anvari (2014)	FTOPSIS	Financial performance evaluation
20	Altuntasand Dereli(2015)	DEMATEL	Portfolio Selection
21	Altuntas *et al.*(2015)	DEMATEL	Portfolio Selection
22	Rezaeian and Akbari(2015)	FuzzyANP and Fuzzy DEMATEL	Portfolio Selection
23	**Proposed model**	Neutrosophic DEMATEL, TOPSIS, and GRA	Financial performance evaluation

1.1 Research Hap and Contributions

The integration of AFM and EFM presents a comprehensive approach to assessing a company's financial health. AFM metrics delve into specific financial aspects like revenue, expenses, and profits, offering a detailed view of the company's financial position. In contrast, EFM metrics consider broader economic factors such as interest rates, inflation, and macroeconomic trends, recognizing their potential impact on a company's performance. However, traditional financial ratio measures have been criticized for overlooking the cost of capital resources, leading to an incomplete evaluation of a company's true financial performance. To address this, there is a growing consensus in favor of economic value-based measures, which factor in the cost of capital resources, providing a more accurate representation of a company's value and potential for long-term success (Singh and Schmidgall, 2002; Wu *et al.*,2017).

In the realm of forecasting securities' performance in unpredictable contexts, the application of fuzzy set theory has been a valuable tool. Nevertheless, it has its limitations as it primarily considers the truth-membership function and neglects non-membership and indeterminacy. Intuitionist fuzzy set theory was developed to address this by incorporating both truth and falsity degrees. Despite this improvement, it still falls short in handling indeterminacy, a crucial factor in real-world scenarios. Neutrosophic set theory is proposed as a solution, extending and generalizing intuitionistic fuzzy sets, providing a more precise handling of uncertain environments. By comprehensively considering all relevant factors in decision-making situations, neutrosophic sets offer an accurate simulation of real-world issues (Abdel Basset *et al.*,2018).

In the domain of MCDM, the distinction between traditional and Hybrid MCDM is paramount. Traditional MCDM assigns weights to criteria and evaluates options based on these weights, often utilizing techniques like weighted scoring or pair-wise comparisons. On the other hand, Hybrid MCDM combines various decision-making methods, such as quantitative models and expert opinions, for a more accurate evaluation. In this paper, to construct the pair-wise comparison matrix, we collect linguistic information from the two experts. Then, we design a range of values for each linguistic expression based on the (DM) expert evaluation. It is more adaptable in handling uncertainties and complex relationships effectively, integrating both quantitative and qualitative factors. Moreover, Hybrid MCDM exhibits greater flexibility and can be customized for changing decision contexts, while traditional MCDM relies on predefined models that are less easily adjusted.

This study introduces a novel hybrid investment decision model that integrates DEMATEL, TOPSIS, and GRA under a neutrosophic environment. By leveraging the strengths of these methodologies, the model excels in identifying causal relationships, ranking alternatives with consideration for both positive and negative deviations, and effectively handling data uncertainty. This integrated approach contributes significantly to the field of investment decision-making by providing a comprehensive and adaptable framework that accommodates uncertainties and captures the intricate dynamics of real-world scenarios. This research not only enhances the accuracy of investment decisions but also offers a valuable tool for investors seeking a more holistic understanding of the financial landscape.

1.2 The Proposed Model Framework

The developed model provides decision-makers (DMs) with a comprehensive framework for making informed choices in situations characterized by uncertainty. It seamlessly integrates historical data, expert assessments, and advanced neutrosophic methodologies, offering a nuanced approach to MCDM, as depicted in Figure 1.

The organization of the research paper is as follows: Section 2 delves into the fundamental concepts of neutrosophic sets, establishing the theoretical foundation for the proposed methodology. Section 3 elaborates on the stepwise approach employed in the proposed method, emphasizing the application of neutrosophic sets in decision-making. Section 4 applies the methodology in a real-world context, offering insights into its practical implications. Section 5 critically analyzes the outcomes of the NASDAQ Exchange case study, providing a comprehensive discussion of the findings. Finally, section 6 summarizes key discoveries and contributions, outlining potential future directions for this research.

2. NEUTROSOPHIC SETS

The definitions of the neutrosophic sets and arithmetic operations of the triangular neutrosophic numbers are explored in this section.

2.1 Definition(Smarandache, 2010)

Let E be be an universe of discourse and $\xi \in E$. A neutrosophic set X in E is characterized by a truth truth-membership function $T_X\,(\xi)$ an indeterminacy-membership function $I_X\,(\xi)$ and a falsity membership function $F_X\,(\xi)$. $T_X\,(\xi)$, $I_X\,(\xi)$ and $F_X\,(\xi)$are real standard or real nonstandard subsets of]-0, 1+[. That is $T_X(\xi): E \rightarrow]-0,1+[I_X\,(\xi): E \rightarrow]-0,1+[$and $F_X(\xi): E \rightarrow]-0,$ 1+[. There is no restriction on the sum of $T_X\,(\xi), I_X\,(\xi)$ and $F_X\,(\xi)$, so $0 \leq\ sup\, T_X(\xi) + sup\, I_X(\xi) + sup\, F_X(\xi) \leq\ 3$.

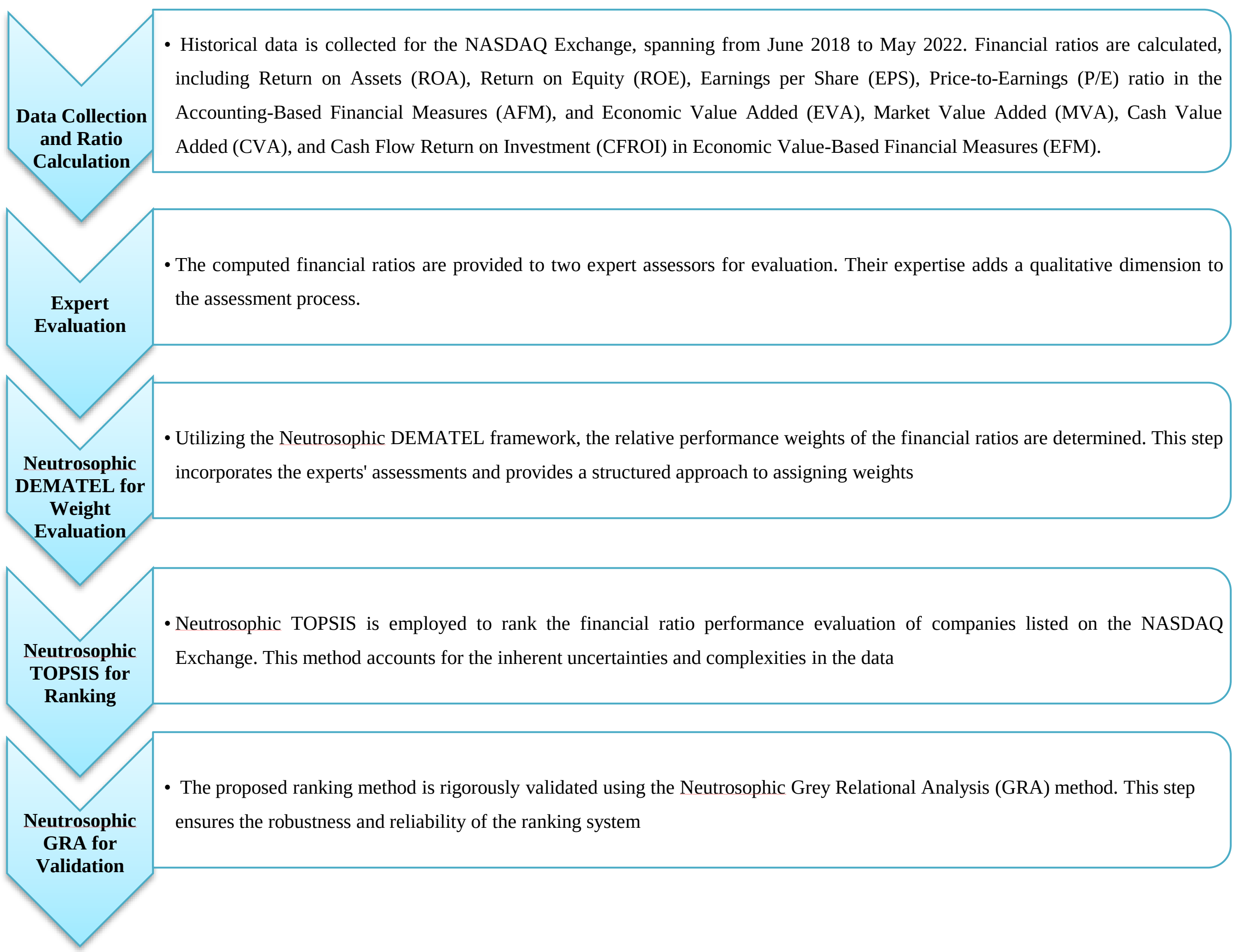

Figure 1. The framework of the proposed method

2.2 Definition (Smarandache, 2010)

Let E be be a space of points. A single valued neutrosophic set X over E is an object taking the form $\{\langle\, \xi, T_X\,(\xi), I_X\,(\xi), F_X\,(\xi)\,, \rangle : \xi \in E\}$, where $T_X(\xi): E \rightarrow [0,1], I_X(\xi): E \rightarrow [0,1]$ and $F_X(\xi): E \rightarrow [0,1]$ with $0 \leq T_X(\xi) + I_X(\xi) + F_X(\xi) \leq 3$ for all $\xi \in E$. The intervals $T_X\,(\xi), I_X\,(\xi)$ and $F_X\,(\xi)$ represent the truth, indeterminacy, falsity membership degree of x to, respectively.

2.3 Definition(Nabeeh *et al.*,2019)

Suppose $\alpha_l, \theta_l, \beta_l \in [0,1]$ and $l^{(1)}, l^{(2)}, l^{(3)} \in R$ where $l^{(1)} \leq l^{(2)} \leq l^{(3)}$. Then single value triangular neutrosophic number $\tilde{l} = \langle (l^{(1)}, l^{(2)}, l^{(3)}); \alpha_l, \theta_l, \beta_l \rangle$ is a special neutrosophic set on the real line set R, whose truth, indeterminacy and falsity functions are defined as:

$$T_l(\xi) = \begin{cases} \alpha_l\left(\dfrac{\xi - l^{(1)}}{l^{(2)} - l^{1}}\right), l^{(1)} \leq \xi \leq l^{(2)} \\ \alpha_l,\ \xi = l^{(2)} \\ \alpha_l\left(\dfrac{l^{(3)} - \xi}{l^{(3)} - l^{(2)}}\right), l^{(2)} \leq \xi \leq l^{(3)} \\ 0, \quad otherwise \end{cases} \tag{1}$$

$$I_l(\xi) = \begin{cases} \left(\dfrac{l^{(2)} - \xi + \theta_l\left(\xi - l^{(1)}\right)}{l^{(2)} - l^{1}}\right), l^{(1)} \leq \xi \leq l^{(2)} \\ \theta_l,\ \xi = l^{(2)} \\ \left(\dfrac{\xi - l^{(2)} + \theta_l\left(l^{(3)} - \xi\right)}{l^{(3)} - l^{(2)}}\right), l^{(2)} \leq \xi \leq l^{(3)} \\ 0, \quad otherwise \end{cases} \tag{2}$$

$$F_l(\xi) = \begin{cases} \left(\dfrac{l^{(2)} - \xi + \beta_l\left(\xi - l^{(1)}\right)}{l^{(2)} - l^{1}}\right), l^{(1)} \leq \xi \leq l^{(2)} \\ \beta_l,\ \xi = l^{(2)} \\ \left(\dfrac{\xi - l^{(2)} + \beta_l\left(l^{(3)} - \xi\right)}{l^{(3)} - l^{(2)}}\right), l^{(2)} \leq \xi \leq l^{(3)} \\ 0, \quad otherwise \end{cases} \tag{3}$$

2.4 Definition (Nabeeh *et al.*,2019)

Suppose that $l = \langle (l^{(1)}, l^{(2)}, l^{(3)}); \alpha_l, \theta_l, \beta_l \rangle$ and $m = \langle (m^{(1)}, m^{(2)}, m^{(3)}); \alpha_m, \theta_m, \beta_m \rangle$ are two single-valued triangular neutrosophic numbers, and $\gamma \neq 0$ be any real number. Then, the arithmetic operations are defined as follows:

- $l + m = \langle (l^{(1)} + m^{(1)}, l^{(2)} + m^{(2)}, l^{(3)} + m^{(3)}); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m \rangle$
- $l - m = \langle \left(l^{(1)} - m^{(3)}, l^{(2)} - m^{(2)}, l^{(3)} - m^{(1)}\right); \alpha_l \wedge \alpha_m \}, \theta_l \vee \theta_l, \beta_l \vee \beta_m \rangle$
- $\gamma^l = \begin{cases} \langle \left(\gamma\, l^{(1)}, \gamma\, l^{(2)}, \gamma\, l^{(3)}\right); \alpha_l, \theta_l, \beta_l \rangle, & if\ \gamma > 0 \\ \langle \left(\gamma\, \mathrm{l}^{(3)}, \gamma\, \mathrm{l}^{(2)}, \gamma\, \mathrm{l}^{(1)}\right); \alpha_l, \theta_l, \beta_l \rangle, & \text{of}\ \gamma < 0 \end{cases}$
- $l.m = \begin{cases} \langle \left(l^{(1)}m^{(1)}, l^{(2)}m^{(2)}, l^{(3)}m^{(3)}\right); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m \rangle, & \text{if}\ l^{(3)} > 0, m^{(3)} > 0 \\ \langle \left(l^{(1)}m^{(3)}, l^{(2)}m^{(2)}, l^{(3)}m^{(1)}\right); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m \rangle, & \text{if}\ l^{(3)} < 0, m^{(3)} > 0 \\ \langle \left(l^{(3)}m^{(3)}, l^{(2)}m^{(2)}, l^{(1)}m^{(1)}\right); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m \rangle, & \text{if}\ l^{(3)} < 0, m^{(3)} < 0 \end{cases}$
- $l^{-1} = \langle \left(\frac{1}{l^{(3)}}, \frac{1}{l^{(2)}}, \frac{1}{l^{(1)}}\right); \alpha_l, \theta_l, \beta_l \rangle, where\ \ l \neq 0$
- $\frac{l}{m} = \begin{cases} \langle \left(\frac{l^{(1)}}{m^{(3)}}, \frac{l^{(2)}}{m^{(2)}}, \frac{l^{(3)}}{m^{(1)}}\right); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m \rangle, \text{if}\ l^{(3)} > 0, m^{(3)} > 0 \\ \langle \left(\frac{l^{(3)}}{m^{(3)}}, \frac{l^{(2)}}{m^{(2)}}, \frac{l^{(1)}}{m^{(1)}}\right); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m \rangle, \text{if}\ l^{(3)} < 0, m^{(3)} > 0 \\ \langle \left(\frac{l^{(3)}}{m^{(3)}}, \frac{l^{(2)}}{m^{(2)}}, \frac{l^{(1)}}{m^{(1)}}\right); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m \rangle, \text{if}\ l^{(3)} < 0, m^{(3)} < 0 \end{cases}$

3. METHODOLOGY

This study aims to identify the best stock selection under a neutrosophic Environment in the NASDAQ stock exchange. To rank the companies, we follow the two stages: (i) Criteria weights are evaluated by using the neutrosophic DEMATEL technique (ii)The companies are ranked by using the TOPSIS and GRA methods.

3.1 Neutrosophic DEMATEL Framework for Determining Weights of The Criteria

DEMATEL has been recommended as a crucial tool for establishing the cause-and-effect chain components of a complicated system by Fontela and Gabus (1976).In order to address internal relationships between criteria and create a casual graph between them for the financial performance ratio assessment, the neutrosophic DEMATEL model is applied. Following is a quick explanation of the neutrosophic DEMATEL technique, and Figure 2 depicts the DEMATEL framework's flowchart.

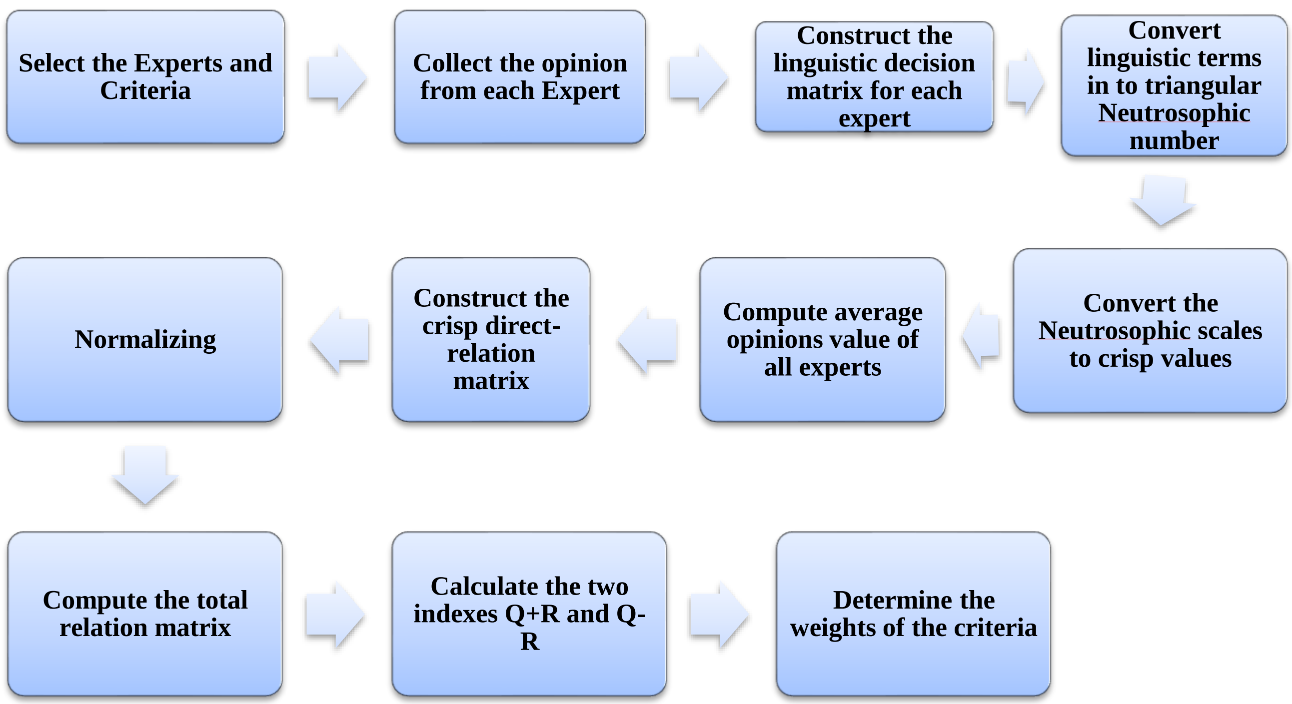

Figure 2. The framework of neutrosophic DEMATEL method for calculating weights of the criteria

Step 1: Identify the professionals with the most experience in the investment sector.

Step 2: Choose the criterion that will have the greatest influence on the given problem.

Step 3: Construct the linguistic direct-relation Matrix. This shows the degree of effect that each criterion has on other criteria. To collect the opinion from each expert. Then, create the pair-wise comparison matrix for each expert, whose elements are the linguistic terms such as Equally important, Slightly important, Strongly important, very strongly important, Absolutely important, etc., which is shown in Table 2. This matrix is called the linguistic direct-relation matrix, which is a $n \times n$ matrix whose elements t_{ij} indicates the degree of effect between criteria i and criteria j, where,t_{ij} takes any one the linguistic terms like equally important, slightly important, strongly important, very strongly important, and absolutely important.

Table 2. Linguistic direct relation matrix

	C_1	C_2	…	C_n
C_1	t_{11}	t_{12}	…	t_{1n}
C_2	t_{21}	t_{22}	…	t_{2n}
. . .	. . .	. . .	. . .	. . .
C_n	t_{n1}	t_{n2}	…	t_{nn}

Step 4: Translate the linguistic direct-relation terms into the triangular neutrosophic number, which is presented in Table 3.

Table 3. Neutrosophic Direct relation matrix

	C_1	C_2	…	C_n
C_1	$\langle(t_{11}^{(1)}, t_{11}^{(2)}, t_{11}^{(3)}); \alpha_{11}, \theta_{11}, \beta_{11}\rangle$	$\langle(t_{12}^{(1)}, t_{12}^{(2)}, t_{12}^{(3)}); \alpha_{12}, \theta_{12}, \beta_{12}\rangle$	…	$\langle(t_{1n}^{(1)}, t_{1n}^{(2)}, t_{1n}^{(3)}); \alpha_{1n}, \theta_{1n}, \beta_{1n}\rangle$
C_2	$\langle(t_{21}^{(1)}, t_{21}^{(2)}, t_{21}^{(3)}); \alpha_{21}, \theta_{21}, \beta_{21}\rangle$	$\langle(t_{22}^{(1)}, t_{22}^{(2)}, t_{22}^{(3)}); \alpha_{22}, \theta_{22}, \beta_{22}\rangle$	…	$\langle(t_{2n}^{(1)}, t_{2n}^{(2)}, t_{2n}^{(3)}); \alpha_{2n}, \theta_{2n}, \beta_{2n}\rangle$
. . .	. . .	. . .	. . .	. . .
C_n	$\langle(t_{n1}^{(1)}, t_{n1}^{(2)}, t_{nj}^{(3)}); \alpha_{n1}, \theta_{n1}, \beta_{n1}\rangle$	$\langle(t_{n2}^{(1)}, t_{n2}^{(2)}, t_{n2}^{(3)}); \alpha_{n2}, \theta_{n2}, \beta_{n2}\rangle$	…	$\langle(t_{nn}^{(1)}, t_{nn}^{(2)}, t_{nn}^{(3)}); \alpha_{nn}, \theta_{nn}, \beta_{nn}\rangle$

The triangular neutrosophic scale is in the form of $t_{ij} = \langle \left(t_{ij}^{(1)}, t_{ij}^{(2)}, t_{ij}^{(3)};\ \alpha_{ij}, \theta_{ij}, \beta_{ij}\right)\rangle$ such that $t_{ij}^{(1)}, t_{ij}^{(2)}, t_{ij}^{(3)}$ are the lower, median and upper bound of neutrosophic number of i^{th} over j^{th} criteria, $\alpha_{ij}, \theta_{ij}, \beta_{ij}$ are the truth-membership, indeterminacy and falsity membership functions of i^{th} over j^{th} criteria.

Step 5: Convert the neutrosophic scales to crisp values by using the Equation (4):

$$r(t_{ij}) = \left|(t_{ij}^{(1)} \times t_{ij}^{(2)} \times t_{ij}^{(3)}) \frac{\alpha_{ij} + \theta_{ij} + \beta_{ij}}{9}\right| \tag{4}$$

Step 6: Combine all expert opinions into a single integration matrix by determining the average value of the expert opinion. According to Equation (5), each expert's average value is calculated by dividing each value by the total number of experts (n), and the average values of all the experts are then added.

$$s_{ij} = \frac{\sum_{k=1}^{m} r^k}{n} \tag{5}$$

where s_{ij} represents the average opinions value of i^{th} criteria and j^{th} criteria and r^k indicates the opinions crisp value of i^{th} criteria and j^{th} criteria for the $k^{th}(k = 1, \ldots, m)$ decision maker.

Step 7: Construct the crisp direct-relation matrix S. This matrix is obtained from previous step 6, i.e., the integrating of all averaged opinions of experts. The initial direct-relation matrix denoted as S, which is a $n \times n$ matrix whose elements t_{ij}Indicates the degree of effect between criteria i and criteria j.

$$S = \begin{bmatrix} 1 & s_{12} \ldots & s_{1n} \\ s_{21} & 1 \ldots & s_{2n} \\ \vdots & \vdots \ddots & \vdots \\ s_{n1} & s_{n2} \ldots & 1 \end{bmatrix}$$

Step 8: Normalizing the direct relation matrix by using the Equations (6) and (7).

$$U = K \times S \tag{6}$$

$$K = Min\left(\frac{1}{Max\sum_{i=1}^{n} s_{ij}}, \frac{1}{Max\sum_{j=1}^{n} s_{ij}}\right), 1 \le i \le n, 1 \le j \le n \tag{7}$$

Step 9: Computing the total-relation matrix P by using the following Equation.

$$P = U \times (1 - U)^{-1} \tag{8}$$

Step 10: Draw the causal diagram after computing the two indices Q+R and Q-R for each criterion. The first step is to calculate the total of each criterion's row and column independently (Q and R). The vector (Q) and (R) is calculated using the Equations (9) and (10), where $P = [z_{ij}],\ i, j \in 1,2, \dots, n$

$$Q = \sum_{j=1}^{n} z_{ij}, \text{ for all } i = 1,2, \dots, n \tag{9}$$
$$R = \sum_{j=1}^{n} z_{ij}, \text{ for all } j = 1,2, \dots, n \tag{10}$$

3.2 Ranking The Alternatives by Neutrosophic TOPSIS and GRA Approach

After measuring the weight of the criteria, we use the neutrosophic TOPSIS and GRA method to rank the alternatives set of companies with the set of weighted criteria obtained from the neutrosophic DEMANTEL process. The proposed framework of neutrosophy TOPSIS and GRA method is shown in Figure 2. Moreover, selecting the best company from seven companies using neutrosophy TOPSIS and GRA is discussed as follows:

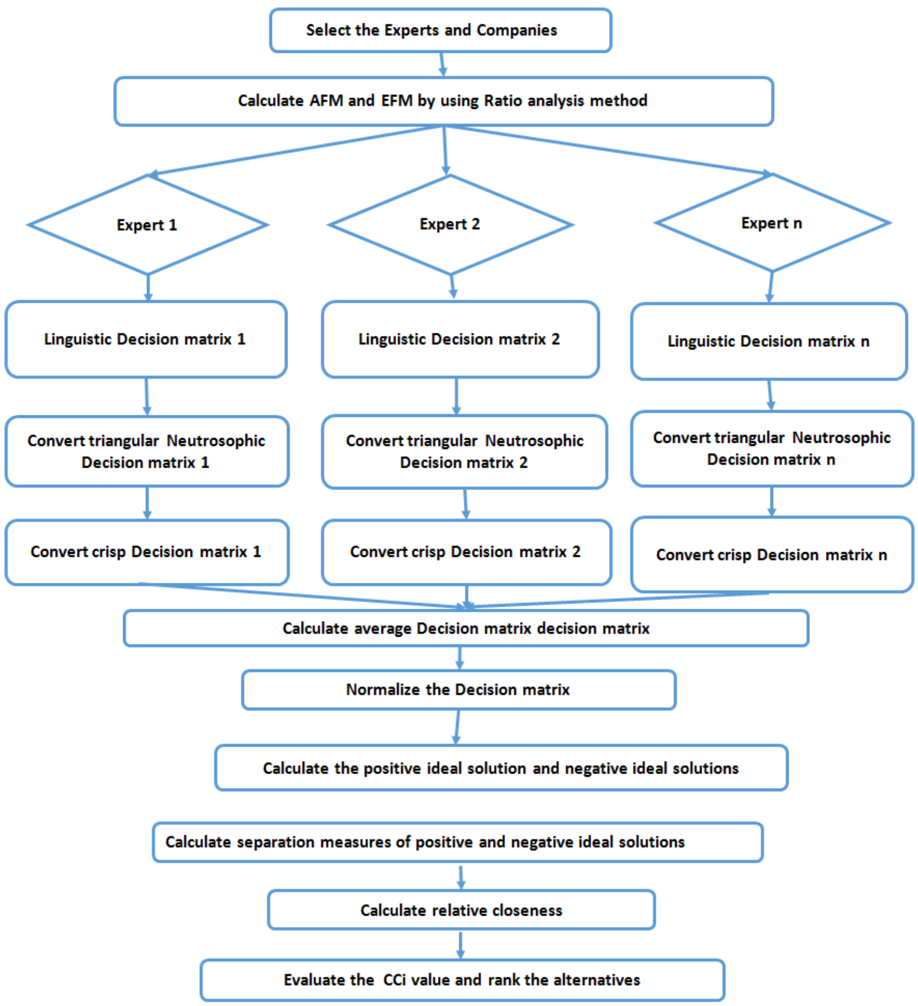

Figure 2. The framework of neutrosophic TOPSIS and GRA for ranking the alternatives

Step 1: Calculate the criteria values of each firm based on the Balance Sheet by using the ratio analysis method. After founding the criteria values, these values are given to different experts. Experts are given their opinion in terms of linguistic variables such as Equally important, Slightly important, Strongly important, very strongly important, Absolutely important, etc. Convert the linguistic terms into the triangular neutrosophic scale, which is shown in Table 2. Convert the neutrosophic scales to crisp values by using Equation 4. To formulate the decision matrix take the average value for the expert's opinion crisp values. The decision matrix is as follows:

$$X = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \vdots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix} \tag{11}$$

Step 2: Make use of Equation (12) to normalize the decision matrix X.

$$Y = y_{ij} = \frac{a_{ij}}{\sqrt{\sum_{j=1}^{n} a_{ij}^2}}, \quad j = 1,2, \ldots n; i = 1,2, \ldots m \tag{12}$$

Step 3: Using the Equation (13), obtain the weighted normalized decision matrix v_{ij}taking into account the fact that each criterion has a different weight (obtained from steps 1 to 9 in neutrosophic DEMATEL).

$$v_{ij} = y_{ij} \times W_{j,} \quad j = 1,2, \ldots n; i = 1,2, \ldots m \tag{13}$$

Step 4: Find the positive ideal solution (PIS) and negative ideal solutions (NIS)

$$A^+ = \{v_1^+, v_2^+, \ldots, v_n^+\}\{({}^{max}{}_j v_{ij} |\ i \in I), ({}^{max}{}_j v_{ij} |\ i \in I^c)\} \tag{14}$$

$$A^- = \{v_1^-, v_2^-, \ldots, v_n^-\}\{({}^{max}{}_j v_{ij} |\ i \in I), ({}^{max}{}_j v_{ij} |\ i \in I^c)\} \tag{15}$$

Step 5: Use both the positive and negative ideal solutions to compute the separation measures.

$$S(v_{0j}^+, v_{ij}) = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_i^+)^2} \tag{16}$$

$$S(v_{0j}^-, v_{ij}) = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_i^-)^2} \tag{17}$$

Step 6: Calculate the grey relational coefficient (GRC) values between each reference alternative and other compared alternatives after getting the positive ideal and negative ideal alternatives.

$$\gamma(v^\alpha{}_{0j}, v_{ij}) = \frac{\min_i \min_j S(v^\alpha{}_{0j}, v_{ij}) + \lambda \min_i \min_j S(v^\alpha{}_{0j}, v_{ij})}{S(v^\alpha{}_{0j}, v_{ij}) + \max_i max_j\, S(v^\alpha{}_{0j}, v_{ij})} \tag{18}$$

Step 7: Calculate the grey relational coefficient of each alternative from a positive ideal solution and negative ideal solution using the following Equation, respectively.

$$S^+(x_j) = \sum_{i=1}^{m} \gamma(v_{0j}^+, v_{ij}) \tag{19}$$

$$S^-(x_j) = \sum_{i=1}^{m} \gamma(v_{0j}^-, v_{ij}) \tag{20}$$

Step 8: Then the closeness coefficient CC_i is determined.

$$CC_i = \frac{S_i^+(x)}{S_i^+(x) + S_i^-(x)} \tag{21}$$

Step 9: Alternatives are ranked in the decreasing order of CC_i value. The greater the value of CC_i, the higher the alternative is preferred.

4. CASE STUDY IN NASDAQ EXCHANGE

Accounting-based financial measures offer a fundamental assessment of a company's historical financial performance and are crucial for regulatory compliance and reporting. On the other hand, economic value-based measures provide a forward-looking perspective, focusing on value creation for shareholders and aligning with long-term strategic objectives. Both sets of measures play complementary roles in evaluating different dimensions of a company's financial performance. In this paper, we consider the following AFM and EFM:

4.1 Accounting-Based Financial Measures

4.1.1 Return on Assets (ROA)

ROA assesses a company's efficiency in utilizing its total assets to generate profits. It is calculated by dividing net income by total assets and is expressed as a percentage.

4.1.2 Return on Equity (ROE)

ROE measures the return generated for shareholders' equity. It evaluates how effectively a company is using shareholders' investments to generate profits, calculated by dividing net income by shareholders' equity.

4.1.3 Earnings per Share (EPS)

EPS quantifies the portion of a company's profit allocated to each outstanding share of common stock. It is a key indicator for investors, reflecting a company's profitability on a per-share basis.

4.1.4 Price to Earnings (P/E) Ratio

The P/E ratio compares the current market price of a company's stock to its earnings per share. It provides insights into how the market values a company's earnings potential and growth prospects.

4.2 Economic Value-Based Financial Measures

4.2.1 Economic Value Added

EVA is a measure of a company's true economic profit, accounting for the cost of capital. It indicates whether a company generates returns above and beyond its required rate of return for investors.

4.2.2 Market Value Added

MVA represents the difference between the total market value of a company's outstanding shares and the total capital invested in the company. It assesses whether a company has created value for its shareholders over time.

4.2.3 Cash Value Added (CVA)

CVA evaluates the value created by a company through its operating activities. It considers the excess of cash generated from operations over the cost of capital employed.

4.2.4 Cash Flow Return on Investment (CFROI)

CFROI measures the return a company generates from its operating cash flows in relation to the capital invested. It helps in assessing the efficiency of capital utilization and the overall financial health of the company.

These financial measures play critical roles in evaluating different aspects of a company's financial performance. AFM provides insights into historical performance and profitability, while EFM focuses on assessing value creation and efficiency in capital utilization. Integrating both sets of measures offers a comprehensive view of a company's financial health and its ability to generate sustainable value for stakeholders.

This section shows the method of assessing many companies and uses neutrosophic TOPSIS-DEMATEL to identify the best companies over the measure of financial ratio in the NASDAQ stock market. Neutrosophic DEMATEL is used to measuring the various requirements affecting the business assessment process. The neutrosophic TOPSIS is used to rank alternative companies. We found eight companies in the NASDAQ stock market. After that, we consider four important AFM criteria and four important EFM criteria that affect the performance of the selection of companies.

4.3 NEUTROSOPHIC DEMATEL TECHNIQUE

First, we use the neutrosophic DEMATEL technique to weigh the four key criteria in AFM and four criteria in EFM for this issue. We follow the following steps for more details:

Step 1: Select the field for expectations in the stock market: We take into account eight firms, including Apple, Microsoft, Google, Intel, Adobe, NVIDIA, Micron Technology, Inc., and Cognizant Technology Solutions Corp. Two experts (i) investors in the NASDAQ market (DM1) and (ii) a professor of finance (DM2) interviewed each other in-depth to gather their thoughts on the data for the performance of eight sectors in the IT sector over one year period (June 2018 to May 2022). Two different groups of financial measures were gathered for consideration by the decision-maker: accounting-based financial measures (AFM) and economic value-based financial measures (EFM).

Step 2: Identify the most important criteria in financial ratio measure: AFM based on four criteria: Return On Assets (ROA), Return On Equity (ROE), Earnings per share (EPS), price to earnings Ratio (P/E) Ratio, and EFM based four criteria such that Economic Value Added (EVA), Market Value Added (MVA), Cash Value Added (CVA), Cash Flow Return on Investment (CFROI)Yalcin et al. (2012) which is shown in Figure 3.

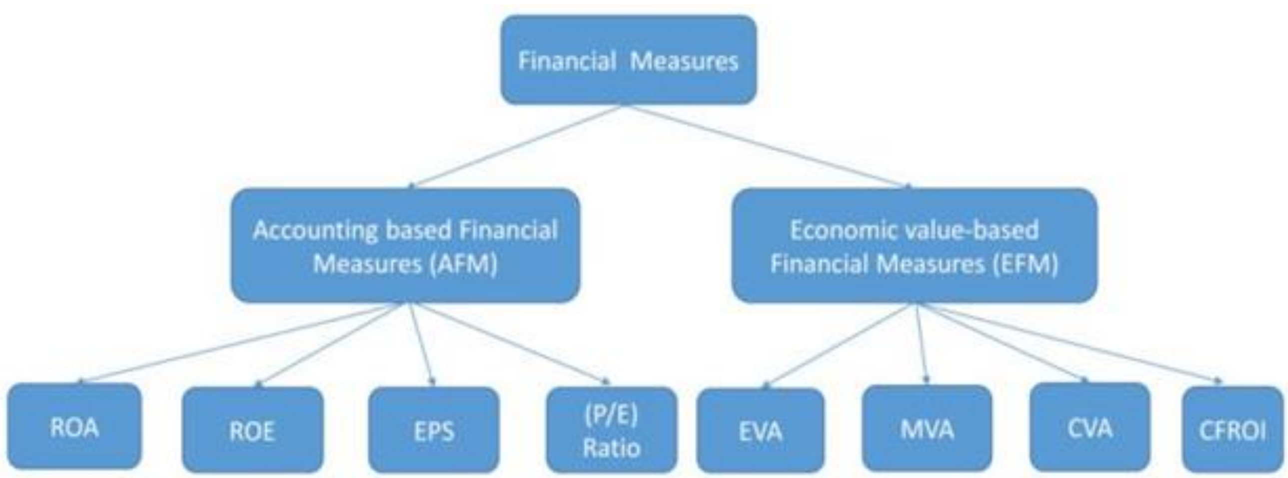

Figure 3: Financial Measures

Step 3: Construct the pairwise comparison matrix: To compare the interrelation between the four criteria such as ROA, ROE, EPS, and P/E Ratio in AFM, and four criteria such as EVA, MVA, CVA, CFROI in EVA, we collect the linguistic information from the ‘two experts. Then, we design a range of values for each linguistic expression based on the (DM) expert evaluation as represented as A 5-point Likert’s scale (see Table 4), which is given in Tables 5, 6, 7, and 8.

Table 4.The neutrosophic triangular scale value

Explanation		Neutrosophic Triangular Scale
Equally important	1	$\langle(1,1,1); 0.5,0.5,0.5\rangle$
Slightly important	3	$\langle(2,3,4); 0.30,0.75,0.70\rangle$
Strongly important	5	$\langle(4,5,6); 0.80,0.15,0.20\rangle$
Very strongly important	7	$\langle(6,7,8); 0.90,0.10,0.10\rangle$
Absolutely important	9	$\langle(9,9,9); 1.00,0.00,0.00\rangle$
sporadic values between two close scales	2	$\langle(1,2,3); 0.40,0.60,0.65\rangle$
	4	$\langle(3,4,5); 0.35,0.60,0.40\rangle$
	6	$\langle(5,6,7); 0.70,0.25,0.30\rangle$
	8	$\langle(7,8,9); 0.85,0.10,0.15\rangle$

Table 5. The pair-wise neutrosophic comparison matrix of AFM's criteria given by expert 1

	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio
C_1 (ROA)	(1,1,1;0.5,0.5,0.5)	(2,3,4;0.3,0.75,0.7)	(6,7,8;0.9,0.1,0.1)	(9,9,9;1,0,0)
C_2(ROE)	(4,5,6;0.8,0.15,0.2)	(1,1,1;0.5,0.5,0.5)	(7,8,9;0.85,0.1,0.15)	(6,7,8;0.9,0.1,0.1)
C_3(EPS)	(2,3,4;0.3,0.75,0.7)	(3,4,5;0.35,0.6,0.4)	(1,1,1;0.5,0.5,0.5)	(4,5,6;0.8,0.15,0.2)
C_4 (P/E) Ratio	(1,2,3;0.4,0.6,0.65)	(2,3,4;0.3,0.75,0.7)	(5,6,7;0.7,0.25,0.3)	(1,1,1;0.5,0.5,0.5)

Table 6. The pairwise neutrosophic comparison matrix of AFM's criteria given by expert 2

	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio
C_1 (ROA)	(1,1,1;0.5,0.5,0.5)	(2,3,4;0.3,0.75,0.7)	(9,9,9;1,0,0)	(4,5,6;0.8,0.15,0.2)
C_2(ROE)	(4,5,6;0.8,0.15,0.2)	(1,1,1;0.5,0.5,0.5)	(1,2,3;0.4,0.6,0.65)	(6,7,8;0.9,0.1,0.1)
C_3(EPS)	(6,7,8;0.9,0.1,0.1)	(3,4,5;0.35,0.6,0.4)	(1,1,1;0.5,0.5,0.5)	(4,5,6;0.8,0.15,0.2)
C_4 (P/E) Ratio	(1,2,3;0.4,0.6,0.65)	(2,3,4;0.3,0.75,0.7)	(7,8,9;0.85,0.1,0.15)	(1,1,1;0.5,0.5,0.5)

Table 7. The pair-wise neutrosophic comparison matrix of EFM's criteria given by expert 1

	E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)
E_1 (EVA)	(1,1,1;0.5,0.5,0.5)	(5,6,7;0.7,0.25,0.3)	(5,6,7;0.7,0.25,0.3)	(9,9,9;1,0,0)
E_2(MVA)	(6,7,8;0.9,0.1,0.1)	(1,1,1;0.5,0.5,0.5)	(6,7,8;0.9,1,1)	(7,8,9;0.8,0.1,0.15)
E_3 (CVA)	(4,5,6;0.8,0.15,0.2)	(5,6,7;0.7,0.25,0.3)	(1,1,1;0.5,0.5,0.5)	(7,8,9;0.8,0.1,0.15)
E_4 (CFROI)	(1,2,3;0.4,0.6,0.65)	(9,9,9;1,0,0)	(9,9,9;1,0,0)	(1,1,1;0.5,0.5,0.5)

Table 8. The pair-wise neutrosophic comparison matrix of EFM's criteria given by expert 2

	E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)
E_1 (EVA)	(1,1,1;0.5,0.5,0.5)	(5,6,7;0.7,0.25,0.3)	(3,4,5;0.35,0.6,0.4)	(9,9,9;1,0,0)
E_2 (MVA)	(2,3,4;0.3,0.75,0.7)	(1,1,1;0.5,0.5,0.5)	(6,7,8;0.9,1,1)	(5,6,7;0.7,0.2,0.35)
E_3 (CVA)	(4,5,6;0.8,0.15,0.2)	(3,4,5;0.35,0.6,0.4)	(1,1,1;0.5,0.5,0.5)	(5,6,7;0.7,0.2,0.35))
E_4 (CFROI)	(5,6,7;0.7,0.25,0.3)	(6,7,8;0.9,0.1,0.1)	(6,7,8;0.9,0.1,0.1)	(1,1,1;0.5,0.5,0.5)

Step 4: Convert the neutrosophic AFM and EFM matrices into crisp matrix by using Equation (4), which is shown in Tables 9 and 10.

Table 9. The crisp values of the pair-wise comparison matrix for AFM

	Expert-1				Expert-2			
	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4(P/E) Ratio	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio
C_1 (ROA)	1.0000	4.6667	41.0667	81.0000	1.0000	4.6667	81.0000	15.3333

Expert-1					Expert-2			
	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4(P/E) Ratio	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio
C_2(ROE)	15.3333	1.0000	61.6000	41.0667	15.3333	1.0000	1.1000	41.0667
C_3(EPS)	4.6667	9.0000	1.0000	15.3333	41.0667	9.0000	1.0000	15.3333
C_4 (P/E) Ratio	1.1000	4.6667	29.1667	1.0000	1.1000	4.6667	61.6000	1.0000

Table 10. The crisp values of the pair-wise comparison matrix for EFM

Expert-1					Expert-2			
	E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)	E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)
E_1 (EVA)	1.0000	29.1667	29.1667	81.0000	1.0000	29.1667	9.0000	81.0000
E_2 (MVA)	108.2667	1.0000	108.2667	58.8000	4.6667	1.0000	41.0667	29.1667
E_3 (CVA)	15.3333	29.1667	1.0000	58.8000	15.3333	9.0000	1.0000	29.1667
E_4 (CFROI)	1.1000	0.0000	0.0000	1.0000	29.1667	41.0667	41.0667	1.0000

Step 5: In order to construct the initial direction relation matrix, measure the average opinions of the experts by using Equation (5). The initial direction relation matrix is shown in Table 11.

Table 11. Direct-relation matrix for AFM and EFM

AFM					EFM				
	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio		E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)
C_1 (ROA)	1.0000	4.6667	61.0333	48.1667	E_1 (EVA)	1.0000	29.1667	19.0833	81.0000
C_2(ROE)	15.3333	1.0000	31.3500	41.0667	E_2 (MVA)	56.4667	1.0000	74.6667	43.9833
C_3(EPS)	22.8667	9.0000	1.0000	15.3333	E_3 (CVA)	15.3333	19.0833	1.0000	43.9833
C_4 (P/E) Ratio	1.1000	4.6667	45.3833	1.0000	E_4 (CFROI)	15.1333	20.5333	20.5333	1.0000

Step 6: Normalizing the initial direct relation matrix by using Equations (6) and (7). The normalized matrix is presented in Table 12.

Table 12. Normalized decision matrix for AFM and EFM ratio

AFM					EFM				
	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio		E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)
C_1 (ROA)	0.0348	0.1625	2.1254	1.6773	E_1 (EVA)	0.0227	0.6624	0.4334	1.8397
C_2(ROE)	0.5340	0.0348	1.0917	1.4301	E_2 (MVA)	1.2825	0.0227	1.6958	0.9990
C_3(EPS)	0.7963	0.3134	0.0348	0.5340	E_3 (CVA)	0.3483	0.4334	0.0227	0.9990
C_4 (P/E) Ratio	0.0383	0.1625	1.5804	0.0348	E_4 (CFROI)	0.3437	0.4664	0.4664	0.0227

Step 7: Compute the total-relation matrix by using Equation (8). The total relation matrix is given in Table 13.

Table 13. Total relation matrix

AFM					EFM				
	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio		E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)
C_1 (ROA)	0.0071	-0.0501	-1.6525	-0.8965	E_1 (EVA)	0.0060	-0.1977	-0.2637	-0.7966

AFM					EFM				
	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio		E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)
C_2(ROE)	-0.2348	0.0209	-1.0010	-0.5474	E_2 (MVA)	-0.4555	0.0026	-0.7370	-0.9952
C_3(EPS)	-0.1016	-0.0350	-0.0021	-0.2244	E_3 (CVA)	-0.0972	-0.0908	0.0081	-0.3740
C_4 (P/E) Ratio	-0.0105	-0.0153	-0.4471	0.0091	E_4 (CFROI)	-0.0723	-0.0701	-0.1170	0.0049

Step 8: By using Equations (9) and (10), calculate the indexes Q+R and Q-R for each criterion, which is shown in Table 14. Finally, draw the causal diagram between Q+R as a vertical axis and Q-R as a horizontal axis for financial measures, which is shown in Figures 4 and 5.

Table 14. Neutrosophic DEMATEL technique result

AFM			EFM		
Criteria	Q+R	Q-R	Criteria	Q+R	Q-R
C_1 (ROA)	-2.9319	-2.2521	E_1 (EVA)	-1.8711	-0.6329
C_2(ROE)	-1.8418	-1.6829	E_2 (MVA)	-2.5412	-1.8291
C_3(EPS)	-3.4657	2.7395	E_3 (CVA)	-1.6634	0.5557
C_4 (P/E) Ratio	-2.1230	1.1955	E_4 (CFROI)	-2.4153	1.9063

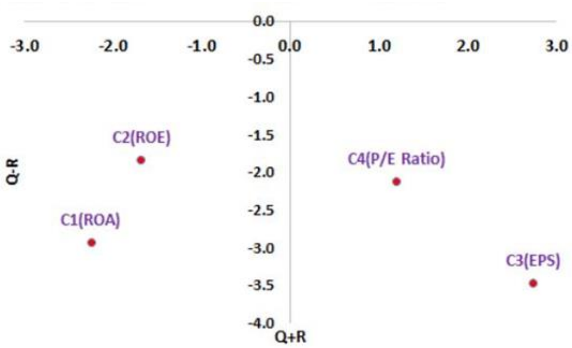

Figure 4. The causal diagram for accounting-based financial measures criteria

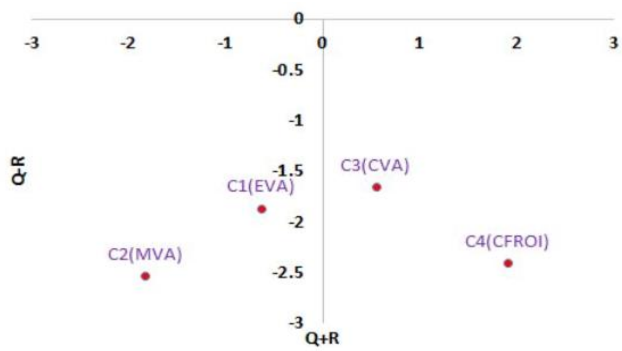

Figure 5. The causal diagram for economic value-based financial measures criteria

Step 9: From the values of Q+R, the weights of the criteria of AFM and EFM are 0.2829, 0.1777, 0.3344, and 0.2048 (ROA, ROE, EPS, P/E ratio, respectively) and 0.2203, 0.2992, 0.1958, 0.2844 (EVA, MVA, CVA, and CFROI respectively) respectively.

4.4 Neutrosophic TOPSIS and GRA approach

Now, the neutrosophic TOPSIS and GRA methods are applied to rank the eight companies and pick the best one.

Step 1: In this paper, to create the decision matrix, the financial data of 8 companies which are listed in the NASDAQ Exchange (http://www.nasdaq.com/Markets/) for a year between (June 2018 and May 2019) are used. Eight financial ratios were categorized into two groups such as four in AFM (ROA, ROE, EPS, and P/E ratio) and another four in EFM (EVA, MVA, CVA, and CFROI). These values are calculated from the Balance Sheet for each firm by using the ratio analysis method. After that, the calculated values are given to the two experts: one from the NASDAQ stock market investor and another one from the professor in Finance. They have given their opinion in terms of linguistic terms. The linguistic variables are converted into the triangular neutrosophic number, which is shown in Tables 15-18.

Table 15. Neutrosophic decision matrix DM1 to provide intangible criteria for AFM

DM1				
	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio
AAPL	(1,1,1;0.5,0.5,0.5)	(4,5,6;0.8,0.15,0.2)	(5,6,7;0.7,0.25,0.3)	(7,8,9;0.85,0.1,0.15)
ADBE	(1,2,3;0.4,0.6,0.65)	(1,1,1;0.5,0.5,0.5)	(2,3,4;0.3,0.75,0.7)	(5,6,7;0.7,0.25,0.3)
CTSH	(4,5,6;0.8,0.15,0.2)	(6,7,8;0.9,0.1,0.1,0.1)	(1,1,1;0.5,0.5,0.5)	(5,6,7;0.7,0.25,0.3)
GOOGL	(6,7,8;0.9,0.1,0.1,0.1	(1,1,1;0.5,0.5,0.5)	(6,7,8;0.9,0.1,0.1,0.1)	(7,8,9;0.85,0.1,0.15)
INTC	(6,7,8;0.9,0.1,0.1,0.1)	(6,7,8;0.9,0.1,0.1,0.1)	(1,2,3;0.4,0.6,0.65)	(8,9,9;1,0,0)
MSFT	(1,1,1;0.5,0.5,0.5)	(1,1,1;0.5,0.5,0.5)	(1,1,1;0.5,0.5,0.5)	(4,5,6;0.8,0.15,0.2)
MU	(8,9,9;1,0,0)	(2,3,4;0.3,0.75,0.7)	(6,7,8;0.9,0.1,0.1,0.1)	(2,3,4;0.3,0.75,0.7)
NVDA	(8,9,9;1,0,0)	(1,1,1;0.5,0.5,0.5)	(8,9,9;1,0,0)	(7,8,9;0.85,0.1,0.15)

Table 16. Neutrosophic decision matrix DM2 to provide intangible criteria for AFM

DM2				
	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio
AAPL	(1,1,1;0.5,0.5,0.5)	(2,3,4;0.3,0.75,0.7)	(4,5,6;0.8,0.15,0.2)	(1,1,1;0.5,0.5,0.5)
ADBE	(1,1,1;0.5,0.5,0.5)	(6,7,8;0.9,0.1,0.1,0.1)	(6,7,8;0.9,0.1,0.1,0.1)	(6,7,8;0.9,0.1,0.1,0.1)
CTSH	(3,4,5;0.35,0.6,0.4)	(8,9,9;1,0,0)	(5,6,7;0.7,0.25,0.3)	(8,9,9;1,0,0)
GOOGL	(4,5,6;0.8,0.15,0.2)	(6,7,8;0.9,0.1,0.1,0.1)	(1,2,3;0.4,0.6,0.65)	(1,1,1;0.5,0.5,0.5)
INTC	(6,7,8;0.9,0.1,0.1,0.1)	(2,3,4;0.3,0.75,0.7)	(2,3,4;0.3,0.75,0.7)	(2,3,4;0.3,0.75,0.7)
MSFT	(8,9,9;1,0,0)	(4,5,6;0.8,0.15,0.2)	(6,7,8;0.9,0.1,0.1,0.1)	(1,2,3;0.4,0.6,0.65)
MU	(6,7,8;0.9,0.1,0.1,0.1)	(4,5,6;0.8,0.15,0.2)	(3,4,5;0.35,0.6,0.4)	(6,7,8;0.9,0.1,0.1,0.1)
NVDA	(8,9,9;1,0,0)	(8,9,9;1,0,0)	(8,9,9;1,0,0)	(5,6,7;0.7,0.25,0.3)

Table 17. The DM-1 to provided intangible criteria for EFM

DM2				
	E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)
AAPL	(1,1,1;0.5,0.5,0.5)	(4,5,6;0.8,0.15,0.2)	(3,4,5;0.35,0.6,0.4)	(5,6,7;0.7,0.25,0.3)
ADBE	(1,2,3;0.4,0.6,0.65)	(5,6,7;0.7,0.25,0.3)	(4,5,6;0.8,0.15,0.2)	(6,7,8;0.9,0.1,0.1,0.1)
CTSH	(3,4,5;0.35,0.6,0.4)	(2,3,4;0.3,0.75,0.7)	(8,9,9;1,0,0)	(7,8,9;0.85,0.1,0.15)
GOOGL	(7,8,9;0.85,0.1,0.15)	(6,7,8;0.9,0.1,0.1,0.1)	(8,9,9;1,0,0)	(8,9,9;1,0,0)
INTC	(1,1,1;0.5,0.5,0.5)	(2,3,4;0.3,0.75,0.7)	(6,7,8;0.9,0.1,0.1,0.1)	(2,3,4;0.3,0.75,0.7)
MSFT	(2,3,4;0.3,0.75,0.7)	(4,5,6;0.8,0.15,0.2)	(7,8,9;0.85,0.1,0.15)	(1,2,3;0.4,0.6,0.65)
MU	(6,7,8;0.9,0.1,0.1,0.1)	(3,4,5;0.35,0.6,0.4)	(2,3,4;0.3,0.75,0.7)	(1,1,1;0.5,0.5,0.5)
NVDA	(7,8,9;0.85,0.1,0.15)	(2,3,4;0.3,0.75,0.7)	(6,7,8;0.9,0.1,0.1,0.1)	(4,5,6;0.8,0.15,0.2)

Table 18. The DM-2 to provided intangible criteria for EFM

DM2				
	E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)
AAPL	(7,8,9;0.85,0.1,0.15)	(8,9,9;1,0,0)	(6,7,8;0.9,0.1,0.1,0.1)	(8,9,9;1,0,0)
ADBE	(5,6,7;0.7,0.25,0.3)	(2,3,4;0.3,0.75,0.7)	(6,7,8;0.9,0.1,0.1,0.1)	(7,8,9;0.85,0.1,0.15)
CTSH	(1,1,1;0.5,0.5,0.5)	(4,5,6;0.8,0.15,0.2)	(7,8,9;0.85,0.1,0.15)	(3,4,5;0.35,0.6,0.4)
GOOGL	(7,8,9;0.85,0.1,0.15)	(6,7,8;0.9,0.1,0.1,0.1)	(8,9,9;1,0,0)	(8,9,9;1,0,0)
INTC	(5,6,7;0.7,0.25,0.3)	(1,2,3;0.4,0.6,0.65)	(5,6,7;0.7,0.25,0.3)	(2,3,4;0.3,0.75,0.7)
MSFT	(2,3,4;0.3,0.75,0.7)	(8,9,9;1,0,0)	(3,4,5;0.35,0.6,0.4)	(6,7,8;0.9,0.1,0.1,0.1)
MU	(4,5,6;0.8,0.15,0.2)	(3,4,5;0.35,0.6,0.4)	(2,3,4;0.3,0.75,0.7)	(4,5,6;0.8,0.15,0.2)
NVDA	(1,2,3;0.4,0.6,0.65)	(3,4,5;0.35,0.6,0.4)	(5,6,7;0.7,0.25,0.3)	(1,2,3;0.4,0.6,0.65)

Step 2: Convert the neutrosophic AFM and EFM decision matrices into crisp matrix by using Equation (4), which is shown in Tables 19 and 20.

Table 19. Crisp-value for AFM decision-matrix

	DM1				DM2			
	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio
AAPL	0.1667	15.3333	29.1667	61.6000	0.1667	4.6667	15.3333	1.1000
ADBE	1.1000	0.1667	4.6667	29.1667	0.1667	41.0667	41.0667	41.0667
CTSH	15.3333	41.0667	0.1667	15.3333	9.0000	72.0000	41.0667	29.1667
GOOGL	41.0667	0.1667	41.0667	4.6667	15.3333	41.0667	9.0000	0.1667
INTC	41.0667	41.0667	1.1000	61.6000	41.0667	4.6667	72.0000	4.6667
MSFT	0.1667	0.1667	0.1667	29.1667	72.0000	15.3333	29.1667	0.1667
MU	72.0000	4.6667	41.0667	72.0000	41.0667	15.3333	1.1000	41.0667
NVDA	72.0000	0.1667	72.0000	61.6000	72.0000	72.0000	4.6667	72.0000

Table 20. Crisp-value for EFM decision-matrix

	DM1				DM2			
	E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)	E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)
AAPL	0.1667	15.3333	9.0000	29.1667	61.6000	72.0000	41.0667	72.0000
ADBE	1.1000	29.1667	15.3333	41.0667	29.1667	4.6667	41.0667	61.6000
CTSH	9.0000	4.6667	72.0000	1.1000	0.1667	15.3333	61.6000	41.0667
GOOGL	61.6000	41.0667	72.0000	0.1667	61.6000	41.0667	72.0000	15.3333
INTC	0.1667	4.6667	41.0667	15.3333	29.1667	1.1000	29.1667	1.1000
MSFT	4.6667	15.3333	61.6000	61.6000	4.6667	72.0000	9.0000	9.0000
MU	41.0667	9.0000	4.6667	4.6667	15.3333	11.6667	4.6667	4.6667
NVDA	61.6000	4.6667	41.0667	72.0000	1.1000	9.0000	29.1667	72.0000

Step 3: In order to construct the decision matrix, measure the average opinions of the experts by using Equation (5). The decision matrix is shown in Table 21.

Table 21. The decision matrix

	DM1				DM2			
	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio	E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)
AAPL	0.1667	10.0000	22.2500	31.3500	30.8833	43.6667	25.0333	50.5833
ADBE	0.6333	20.6167	22.8667	35.1167	15.1333	16.9167	28.2000	51.3333
CTSH	12.1667	56.5333	20.6167	22.2500	4.5833	10.0000	66.8000	21.0833
GOOGL	28.2000	20.6167	25.0333	2.4167	61.6000	41.0667	72.0000	7.7500
INTC	41.0667	22.8667	36.5500	33.1333	14.6667	2.8833	35.1167	8.2167
MSFT	36.0833	7.7500	14.6667	14.6667	4.6667	43.6667	35.3000	35.3000
MU	56.5333	10.0000	21.0833	56.5333	28.2000	10.3333	4.6667	4.6667
NVDA	72.0000	36.0833	38.3333	66.8000	31.3500	6.8333	35.1167	72.0000

Step 4: Normalizing the decision matrix by using Equations (6) and (7). The normalized matrix is presented in Table 22.

Table 22. The normalized decision matrix

DM1					DM2			
	C_1 (ROA)	C_2 (ROE)	C_3 (EPS)	C_4 (P/E) Ratio	E_1 (EVA)	E_2(MVA)	E_3 (CVA)	E_4 (CFROI)
AAPL	0.0015	0.1277	0.2991	0.2900	0.3688	0.5615	0.2058	0.4576
ADBE	0.0057	0.2633	0.3074	0.3248	0.1807	0.2175	0.2318	0.4644
CTSH	0.1096	0.7220	0.2771	0.2058	0.0547	0.1286	0.5490	0.1907
GOOGL	0.2541	0.2633	0.3365	0.0224	0.7356	0.5281	0.5918	0.0701
INTC	0.3701	0.2920	0.4913	0.3065	0.1751	0.0371	0.2886	0.0743
MSFT	0.3252	0.0990	0.1971	0.1357	0.0557	0.5615	0.2901	0.3194
MU	0.5095	0.1277	0.2834	0.5229	0.3367	0.1329	0.0384	0.0422
NVDA	0.6489	0.4608	0.5153	0.6179	0.3743	0.0879	0.2886	0.6514

Step 5: Calculate the positive ideal solution (PIS) and negative ideal solution (NIS) by using (14) and (15), respectively. Then, the separation measures are calculated by using PIS and NIS values in Equations (16) and (17). The separation measures of positive and negative ideal solutions are given in Table 23.

Table 23. The separation measures from positive ideal and negative ideal solution

	AFM		EFM	
	D+	D-	y^{+}	y^{-}
AAPL	0.4376	0.5766	0.5423	0.3448
ADBE	0.4726	0.5620	0.5520	0.4859
CTSH	0.5283	0.5902	0.4813	0.5541
GOOGL	0.4838	0.5436	0.4370	0.3132
INTC	0.5347	0.4669	0.4264	0.5561
MSFT	0.4011	0.5039	0.5117	0.3585
MU	0.4329	0.3996	0.3953	0.4724
NVDA	0.6161	0.3601	0.6126	0.4663

Step 6: After that, the relative closeness is calculated by using the separation measures in Equation (21), which is given in Table 24.

Table 24. The relative closeness to the ideal solution for each alternative using the proposed combined method (π= 0.5)

	AFM		EFM	
	CC_i	Rank	mm_i	Rank
AAPL	0.4315	8	0.6113	1
ADBE	0.4568	6	0.5319	5
CTSH	0.4723	4	0.4649	6
GOOGL	0.4709	5	0.5825	3
INTC	0.5339	2	0.4340	8
MSFT	0.4432	7	0.5880	2
MU	0.5200	3	0.4556	7
NVDA	0.6311	1	0.5678	4

Step 7: Alternatives are ranked in the decreasing order of CC_i value, which is given in Table 24. The greater the value ofCC_i, the higher the alternative is preferred.

5. RESULT AND DISCUSSION

According to relative closeness values calculation, the AFM has ranked by using the neutrosophicTOPSIS and GRA method. This premise of the neutrosophic TOPSIS and GRA method is that the chosen alternative should have the 'shortest distance' from the ideal solution and the 'farthest distance' from the 'negative-ideal' solution. From Table 25, we observed that NVDA secured the first rank, and INTC is secured the second rank. Similarly, MU, CTSH, GOOGL, ADBE, and MSFT have very low-performance values and secured the ranks 3,4,5,6 and 7, respectively. Moreover, AAPL has gone down in ranking positions, indicating low performance. Similarly, we have ranked EFM by using the neutrosophic TOPSIS and GRA method, which as given in Table 26. From Table 26, we observed that the AAPL company secured the first rank, and MSFT has secured the second rank. Similarly, GOOGL, NVDA, ADBE, CTSH, and MU have low-performance values, which are secured the rank 3, 4,5,6, and 7, respectively. The INTC company got the last rank, which indicates that the INTC has low performance.

More intriguingly, the value of the resolving coefficient is employed for sensitivity analysis to determine whether or not the suggested method is logical and stable. As we proceed through the study, we notice that different resolving coefficient values have no bearing on the rankings of the organizations' financial efficiency ratings, which are displayed in Figure 6. The CC_i values with respect to various $\boldsymbol{\pi}$, values are shown in Table 25. According to Table 25, NVDA is the best firm to invest in based on the CC_i closeness coefficient. Regarding various $\boldsymbol{\pi}$ values, the order of the financial companies does not alter. From the output of CC_i , we found the ranking sequence of financial companies areas NVDA>INTC>MU>CTSH>GOOGL>ADBE>MSFT>AAPL. Similarly, we validate the proposed ranking method for EFM based on resolving coefficient values, which is shown in Figure 7. From Table 26, AAPL is the best company for investment with respect to the closeness coefficient of CC_i. The ranking order of financial companies does not change with respect to different £ values. From the results of CC_i, we obtain the priority sequence of financial companies areas AAPL > MSFT> GOOGL >NVDA >ADBE > CTSH > MU > INTC.

Table 25. CC_i values based on each resolving coefficient for different separation measures for AFM

Alternative	$\pi = 0.1$				$\pi = 0.2$				$\pi = 0.3$			
	D+	D-	CC_i	Rank	D+	D-	CC_i	Rank	D+	D-	CC_i	Rank
AAPL	0.22	0.26	0.46	8	0.27	0.34	0.45	8	0.33	0.42	0.44	8
ADBE	0.24	0.25	0.49	6	0.30	0.33	0.47	6	0.35	0.41	0.47	6
CTSH	0.26	0.26	0.50	4	0.33	0.34	0.49	4	0.40	0.43	0.48	4
GOOGL	0.24	0.24	0.50	5	0.30	0.32	0.49	5	0.36	0.39	0.48	5
INTC	0.27	0.21	0.56	2	0.33	0.27	0.55	2	0.40	0.34	0.54	2
MSFT	0.20	0.22	0.47	7	0.25	0.29	0.46	7	0.30	0.36	0.45	7
MU	0.22	0.18	0.55	3	0.27	0.23	0.54	3	0.32	0.29	0.53	3
NVDA	0.31	0.16	0.66	1	0.39	0.21	0.65	1	0.46	0.26	0.64	1
	$\pi = 0.4$				$\pi = 0.5$				$\pi = 0.6$			
	D+	D-	CC_i	Rank	D+	D-	CC_i	Rank	D+	D-	CC_i	Rank
AAPL	0.38	0.50	0.44	8	0.44	0.58	0.43	8	0.49	0.66	0.43	8
ADBE	0.41	0.48	0.46	6	0.47	0.56	0.46	6	0.53	0.64	0.45	6
CTSH	0.46	0.51	0.48	4	0.53	0.59	0.47	4	0.59	0.67	0.47	4
GOOGL	0.42	0.47	0.47	5	0.48	0.54	0.47	5	0.54	0.62	0.47	5
INTC	0.47	0.40	0.54	2	0.53	0.47	0.53	2	0.60	0.53	0.53	2
MSFT	0.35	0.43	0.45	7	0.40	0.50	0.44	7	0.45	0.57	0.44	7
MU	0.38	0.34	0.52	3	0.43	0.40	0.52	3	0.49	0.46	0.52	3
NVDA	0.54	0.31	0.63	1	0.62	0.36	0.63	1	0.69	0.41	0.63	1
	$\pi = 0.7$				$\pi = 0.8$				$\pi = 0.9$			
	D+	D-	CC_i	Rank	D+	D-	CC_i	Rank	D+	D-	CC_i	Rank
AAPL	0.55	0.74	0.43	8	0.60	0.82	0.42	8	0.66	0.90	0.42	8
ADBE	0.59	0.72	0.45	6	0.65	0.80	0.45	6	0.71	0.87	0.45	6
CTSH	0.66	0.75	0.47	4	0.73	0.84	0.46	4	0.79	0.92	0.46	4
GOOGL	0.60	0.69	0.47	5	0.66	0.77	0.46	5	0.72	0.85	0.46	5
INTC	0.67	0.60	0.53	2	0.73	0.66	0.53	2	0.80	0.73	0.52	2
MSFT	0.50	0.64	0.44	7	0.55	0.71	0.44	7	0.60	0.78	0.43	7
MU	0.54	0.51	0.51	3	0.59	0.57	0.51	3	0.65	0.62	0.51	3

Alternative	$\pi = 0.1$				$\pi = 0.2$				$\pi = 0.3$			
NVDA	0.77	0.46	0.63	1	0.85	0.51	0.62	1	0.92	0.56	0.62	1
	π=1											
	D+	D-	CC_i	Rank								
AAPL	0.71	0.98	0.42	8								
ADBE	0.77	0.95	0.45	6								
CTSH	0.86	1.00	0.46	4								
GOOGL	0.79	0.92	0.46	5								
INTC	0.87	0.79	0.52	2								
MSFT	0.65	0.85	0.43	7								
MU	0.70	0.68	0.51	3								
NVDA	1.00	0.61	0.62	1								

Table 26: CC_i values based on each resolving coefficient for different separation measures for EFM

Alternative	$£ = 0.1$				$£ = 0.2$				$£ = 0.3$			
	D+	D-	CC_i	Rank	D+	D-	CC_i	Rank	D+	D-	CC_i	Rank
AAPL	0.27	0.12	0.68	1	0.34	0.18	0.65	1	0.41	0.23	0.63	1
ADBE	0.27	0.18	0.61	5	0.34	0.25	0.58	5	0.41	0.33	0.55	5
CTSH	0.24	0.20	0.54	6	0.30	0.29	0.51	6	0.36	0.38	0.49	6
GOOGL	0.22	0.11	0.66	3	0.27	0.16	0.62	3	0.33	0.21	0.60	3
INTC	0.21	0.20	0.51	8	0.26	0.29	0.48	8	0.32	0.38	0.46	8
MSFT	0.25	0.13	0.66	2	0.32	0.19	0.63	2	0.38	0.24	0.61	2
MU	0.20	0.17	0.53	7	0.25	0.25	0.50	7	0.30	0.32	0.48	7
NVDA	0.30	0.17	0.64	4	0.38	0.24	0.61	4	0.46	0.32	0.59	4
	$£ = 0.4$				$£ = 0.5$				$£ = 0.6$			
	D+	D-	CC_i	Rank	D+	D-	CC_i	Rank	D+	D-	CC_i	Rank
AAPL	0.47	0.29	0.62	1	0.54	0.34	0.61	1	0.61	0.40	0.60	1
ADBE	0.48	0.41	0.54	5	0.55	0.49	0.53	5	0.62	0.56	0.52	5
CTSH	0.42	0.47	0.47	6	0.48	0.55	0.46	6	0.54	0.64	0.46	6
GOOGL	0.38	0.26	0.59	3	0.44	0.31	0.58	3	0.49	0.36	0.58	3
INTC	0.37	0.47	0.44	8	0.43	0.56	0.43	8	0.48	0.64	0.43	8
MSFT	0.45	0.30	0.60	2	0.51	0.36	0.59	2	0.58	0.42	0.58	2
MU	0.35	0.40	0.47	7	0.40	0.47	0.46	7	0.45	0.55	0.45	7
NVDA	0.54	0.39	0.58	4	0.61	0.47	0.57	4	0.69	0.54	0.56	4
	$£ = 0.7$				$£ = 0.8$				$£ = 0.9$			
	D+	D-	CC_i	Rank	D+	D-	CC_i	Rank	D+	D-	CC_i	Rank
AAPL	0.68	0.45	0.60	1	0.75	0.51	0.59	1	0.82	0.56	0.59	1
ADBE	0.69	0.64	0.52	5	0.76	0.72	0.51	5	0.83	0.80	0.51	5
CTSH	0.60	0.73	0.45	6	0.66	0.82	0.45	6	0.72	0.91	0.44	6
GOOGL	0.55	0.41	0.57	3	0.60	0.46	0.57	3	0.66	0.51	0.56	3
INTC	0.53	0.73	0.42	8	0.59	0.82	0.42	8	0.64	0.91	0.41	8
MSFT	0.64	0.47	0.58	2	0.71	0.53	0.57	2	0.77	0.59	0.57	2
MU	0.50	0.62	0.44	7	0.55	0.70	0.44	7	0.60	0.77	0.43	7
NVDA	0.77	0.62	0.56	4	0.85	0.69	0.55	4	0.92	0.76	0.55	4
	$£ = 1$											
	D+	D-	CC_i	Rank								
AAPL	0.89	0.62	0.59	1								
ADBE	0.90	0.87	0.51	5								
CTSH	0.79	1.00	0.44	6								
GOOGL	0.71	0.56	0.56	3								
INTC	0.70	1.00	0.41	8								
MSFT	0.84	0.64	0.56	2								
MU	0.65	0.85	0.43	7								
NVDA	1.00	0.84	0.54	4								

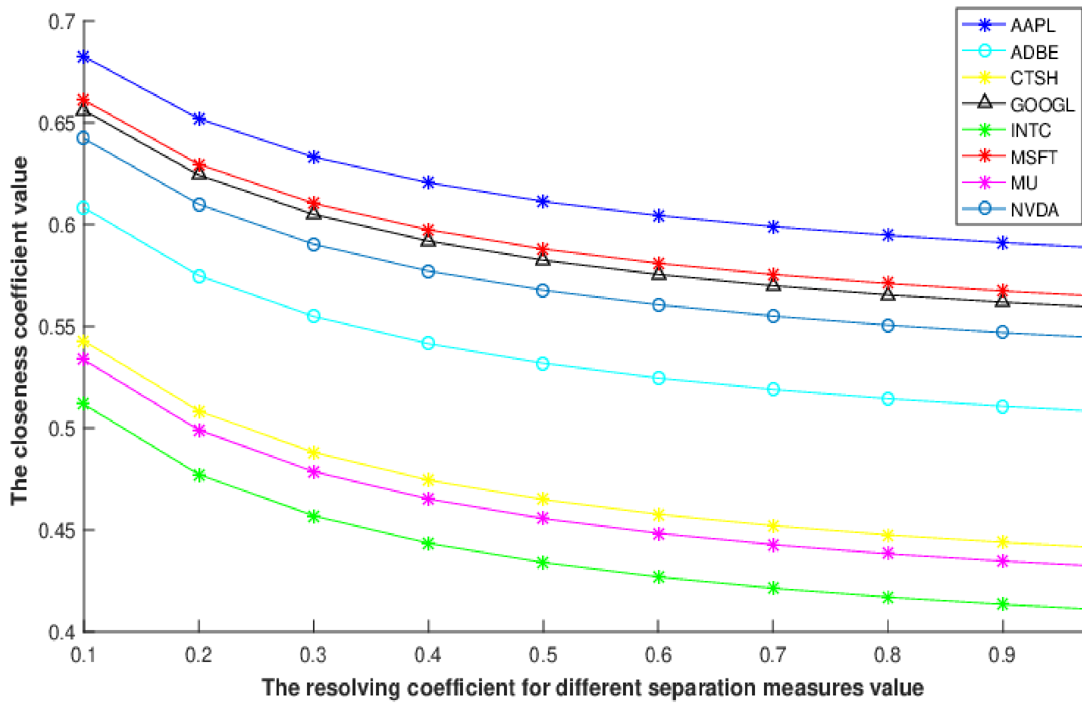

Figure 6.Accounting-based Financial Measures (AFM)

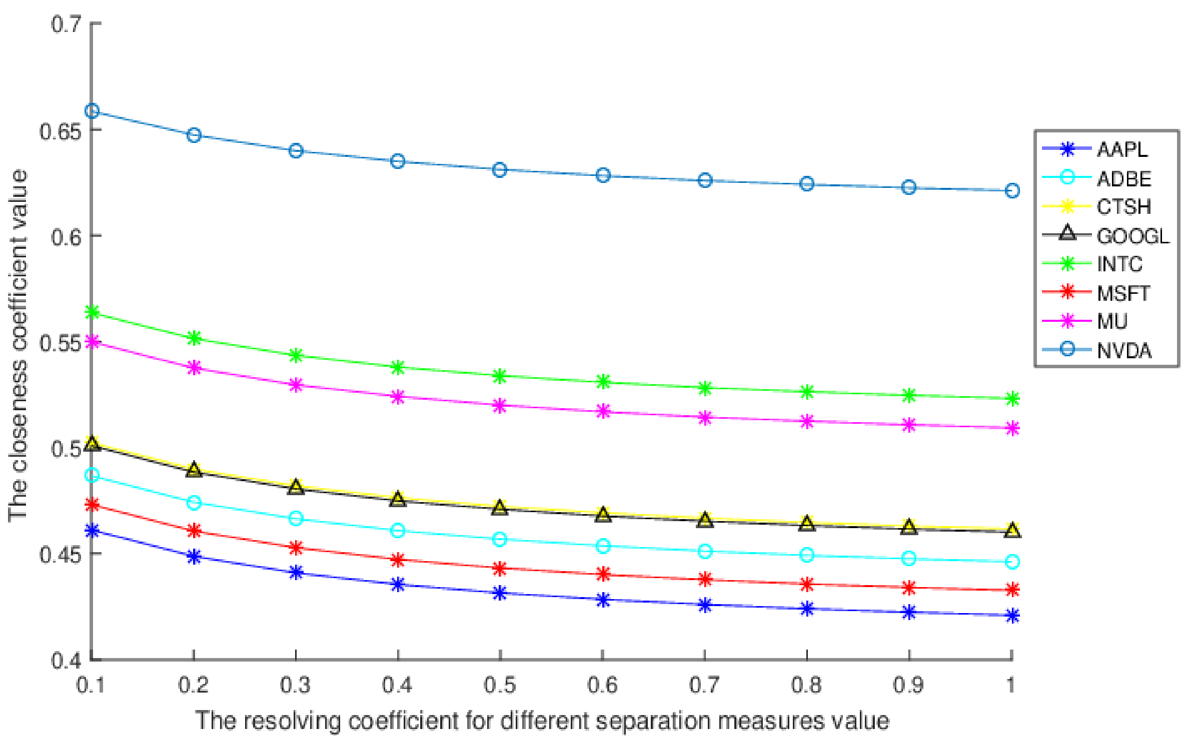

Figure 7. Economic value-based financial measures (EFM)

6. CONCLUSION AND FUTURE WORK

This study has discussed a novel approach for evaluating the financial performance of eight prominent companies in the Information Technology (IT) sector listed on the NASDAQ exchange. Employing a combination of traditional (AFM) and modern financial ratios (EFM), this research utilizes the neutrosophic TOPSIS and Grey Relational Analysis (GRA) model. The criteria weights essential for this assessment are determined through the neutrosophic DEMATEL approach. Subsequently, an aggregating function representing proximity to the reference point(s) is applied to rank the companies within the IT sector. Sensitivity analysis is performed using the closeness coefficient value to validate the proposed technique. Remarkably, the study finds that varying resolving coefficient values do not significantly impact the rank order of the financial performance assessment of the companies. The integration of the neutrosophic TOPSIS and GRA model, incorporating both conventional and contemporary financial ratios, provides a robust framework for evaluating the financial performance of IT sector companies. The results derived from this model offer valuable insights for both investors and analysts seeking to make informed decisions in the dynamic landscape of the financial market. According to the analysis based on AFM, NVDA emerges as the most promising investment opportunity, demonstrating exceptional performance in proximity to the reference point. Conversely, in the case of EFM, AAPL stands out as the top-performing company, exhibiting remarkable closeness to the reference point.

In the forthcoming research endeavors, we envision expanding the scope of economic value measures to encompass metrics such as shareholder value-added, equity economic value-added and other pertinent performance indicators. This will be achieved through the application of diverse MCDM techniques within a neutrosophic interval type-2 environment. By incorporating these additional measures, we aim to provide a comprehensive and nuanced assessment of the financial performance of companies, further enhancing the efficacy of decision-making processes in the realm of investment and financial analysis.

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