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C. Veeramani

R. Venugopal

S. A. Edalatpanah

University of New Mexico

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C.Veeramani[1*], R.Venugopal[2] and S.A.Edalatpanah[3]

[1]Department of Applied Science(Mathematics), PSG College of Technology, Coimbatore- 641 004, India; veerasworld@yahoo.com

[2]Department of Applied Science(Mathematics), PSG College of Technology, Coimbatore - 641 004, India; venusm80@gmail.com

[3]Department of Mathematics, University of Guilan & Ayandegan Institute of Higher Education, Iran; saedalatpanah@gmail.com

[*]Correspondence: veerasworld@yahoo.com

**Abstract**. The relative performance analysis and ranking of the financial ratios are highly important for optimal portfolio selection in the stock market. However, the relative performance evaluation of the financial ratios is highly complex and nonlinear. Thus, the main goal of this study is to measure the relative importance of the financial ratios of two groups as Accounting based financial measures (AFM) and Economic value-based financial measures (EFM) through Decision Making Trial and Evaluation Laboratory (DEMATEL) method under the neutrosophic environment. In this regard, one-year data (June 2018-May 2019) has been collected from 8 industries in the IT sector. The AFM and EFM values have been evaluated for each firm through the balance sheet. The obtained values have been given to the two experts: an experienced investor in the NASDAQ exchange and a Professor in Finance. They have given their opinion in terms of linguistic terms. Then, the AFM and EFM have ranked based on the neutrosophic DEMATEL approach. Finally, the neutrosophic DEMATEL approach has compared with the fuzzy DEMATEL and classical DEMATEL approach. The empirical results assist the investor and traders in selecting among the selected stock.

**Keywords:** Neutrosophic number; Neutrosophic DEMATEL; Accounting based financial measures; Economic value-based financial measures

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## 1. **Introduction**

The performance assessment of the companies is usually carried out in the context of financial analysis. From a financial point of view, the notion of performance is defined as terms such as profit, profitability, production and economic growth, and so on. The use of financial ratios in the performance review process may be useful for all businesses and relevant industries. Financial ratios obtained from the data in the balance sheets and income statements are considered to be important metrics for assessing the output and financial assets of businesses. A large number of studies have been underway for many years (Chen and Shimerda [10], Halkos and Tzeremes [14], etc.) that prove that financial ratios are crucial indicators of the financial performance of firms. They allow users to review and analyze relevant data in order to provide useful information for decision-making. Singh and Schmidgall [24] have shown that the value of the financial ratios also illustrates the strengths and weaknesses sides of the company in terms of flexibility, productivity, and profitability. The financial ratios also measure the various funding aspects of the stock and influence the movement of the stock price [25]. As the financial performance measures demonstrate the productivity of the company and competitiveness, they should be carefully identified in the assessment process [10].

One of the widely accepted techniques in group decision making is the Multi-criteria decision-making (MCDM) technique. Traditional MCDM methods consist of a group of DMs providing a qualitative and quantitative assessment of the performance for every alternative with respect to the criteria and the relative significance of the criteria with regard to the entire judgments. Analytic Hierarchy Process (AHP), Simple Additive Weighting (SAW), Analytic Network Process (ANP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), etc., which are the existing MCDM methods in the literature. Decision-Making Trial and Evaluate on Laboratory (DEMATEL) is one of the popular MCDM approaches for the search for interaction effects between parameters and dimensions in decision-making problems. The DEMATEL method was initially developed to describe the causal relationship among the subcomponents via a causal diagram. It was shown to be a powerful tool for solving complex problems and has several benefits for describing the interrelated relationship between the criteria. Most of the existing research work has successfully applied to the financial stock market environment. Lee et al. [17] combined DEMATEL and ANP to analyze the interdependence between key factors of stock investment decision making. The DEMATEL method is used to analyze the causal relationship between the item groups instead of the ANP approach. Golcuk and Baykasoglu [12] have suggested for ranking the alternatives based on integrating the ANP and DEMATEL method. Recently, Venugopal et al. [30] developed a Fuzzy DEMATEL Approach for Financial Ratio Performance Evaluation of NASDAQ Exchange.

However, the decision-makers (DMs) provide linguistic evaluation for several alternatives and criteria. Fuzzy MCDM methods have been effectively handled these types of circumstances. Serkan and Turkay [29] have introduced a novel DEMATEL method to the Priority investment project by calculating their possibility of decreasing foreign trade deficit and creating new investment together. Mills et al. [19] proposed a hybrid MCDM approach by comprising an integrated ANP and DEMATEL for optimal portfolio selection. These results indicated that return, financial ratios, dividends, and risk are causal criteria group, which are the most influential determinants for obtaining high benefits of stock portfolio selection in the Shanghai Stock Exchange. Rezaeian and Akbari [22] developed a new approach, which combines ANP and DEMATEL for stock portfolio selection in the fuzzy environment. The fuzzy DEMATEL method is used for different applications and has been used to change the ANP by analyzing the causal relationship between the item classes. This approach is called DEMATEL-ANP, as suggested by Golcuk and Baykasoglu [12]. Wu et al. [31] used the fuzzy and gray Delphi approach to determine a set of reliable attributes. Varma and Kumar [29], Tabrizi et al. [28] have evaluated the different criteria that apply to companies and that can assist in the creation of portfolio construction and causal relations between the criteria defined. Perin [21], Aydn and Kahraman [7] has developed a fuzzy DEMATEL system for dealing with interactions between evaluation parameters and proposed a fuzzy ANP method to calculate the relative importance of each criterion, which was evaluating and the quality of service achievement of airlines in Turkey is ranked.

Recently, [ [13], [26], [32], [4], [15]] many authors have used the idea of neutrosophic set in MCDM methods. The concept of the neutrosophic set was introduced by Smarandache [23], which is distinguished by the role of truth-membership function, indeterminacy-membership function, and falsity-membership function. Therefore the neutrosophic set theory can be used to rationalize the confusion associated with ambiguity in an analogous way to human thought. This handles vague data as distributions of possibilities in terms of membership functions. Using the concept of triangular neutrosophic additive reciprocal preference relations Basset et.al, [6] developed a novel method for the group decision-making problem. Bhattacharya [8], [9], [16] discussed the concept of rule-based neutrosophic reasoning applied to the options Market. Basset et al. [6], [3] have presented a navel hybrid multiple criteria group decision-making framework for the project selection under the neutrosophic environment. Altuntas and Dereli [1] studied a novel approach based on a process called DEMATEL and patent quote analysis to prioritize investment project portfolios. The suggested strategy represents the viewpoint of the Government and takes into account foreign trade deficits and attract new investments for prioritization. The objective of this paper is to measure the relative importance of the financial ratios of two groups such as AFM and FM by using the DEMATEL approach under the neutrosophic environment.

### 1.1. *Motivation and Contributions*

Stock markets are unpredictable frameworks impacted by many interrelated financial, political, and internal factors and described by implicit non-linearities. Understanding whenever and how to invest in stock markets and to make the decisions are very difficult for investors. In this regard, investors need knowledge about the stocks and an intensive analysis associated with the markets along with an excellent experience. At present, there are numerous marketplaces, different variables, indicators, etc. that must be become analyzed before taking the financial decisions in the short interval of the time. The performance evaluation of companies is one of the most important measures that is considered by investors. Thus, the performance analysis is required in optimal stock selection to make use of mathematical and statistical tools to assist investors to decide at the optimum moment. However, there are many Accounting based financial measures(AFM) and Economic value-based financial measures (EFM) available in the stock market. Hence, the ranking of the AFM and EFM is important and essential in the stock market selection, which is motivated to research this field. The main purpose of the analysis is to evaluate which accounting earnings performance measures and value-based performance measures are best expressed in adjustments in the market value of the product. In general, most of the performance measures are not deterministic and can not be accurately predicted. Fuzzy set theory is vividly used to predict the performance values of securities in an uncertain environment. However, the fuzzy set focuses only on the degree of truth-membership and it does not take into account the non-membership and indeterminacy. Atanassov [5] developed intuitionist fuzzy set theory, which takes into account both degrees of truth and degree of falsity but does not find indeterminacy. So, it fails to deals with indeterminacy existing in the real world. To overcome these drawbacks of the fuzzy set, we are used the neutrosophic set in an uncertain environment. The neutrosophic set is an extent or generalization of the intuitionistic fuzzy set. It represents real-world problems effectively and efficiently by considering all aspects of decision situations (Abdel-Basset et al. [2]).

The neutrosophic DEMATEL model is used to deal with interdependencies between criteria and then to draw up a casual diagram between criteria for the assessment of financial performance ratios. This study intends to establish an investment decision model to provide investors with the MCDM model consisting of neutrosophic DEMATEL. The empirical results assist the investor and traders to select stock. To the best of our knowledge, there is no work studied yet for financial ratio performance selection by using the neutrosophic DEMATEL approach. The contributions of the paper as follows:

- The financial data of 8 companies, which are listed in the NASDAQ Exchange for a years time period between June 2018 - May 2019 have collected.

- AFM and EFM values are calculated from the balance sheet for each firm, which is given to the two experts.
- Opinion has been collected from two experts: an investor in the NASDAQ exchange, and a Professor in Finance.
- The relative performance ranking of the financial ratios is evaluated through the Neutrosophic DEMATEL framework.
- The Neutrosophic DEMATEL method is compared with the fuzzy DEMATEL and classical DEMATEL approach.

## 2. Neutrosophic sets

In this section, we discuss the definitions of neutrosophic sets, single-valued neutrosophic sets, triangular neutrosophic numbers, and operations on triangular neutrosophic numbers.

**Definition 2.1.** [23]

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 $0 \leq supT_X(\xi) + supI_X(\xi) + supF_X(\xi) \leq 3$.

**Definition 2.2.** [23]

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 membership degree, the indeterminacy-membership degree and the falsity membership degree of x to, respectively.

**Definition 2.3.** [23]

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-membership, indeterminacy-membership and falsity-membership functions are defined as:

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

$$I_l(\xi) = \begin{cases} \frac{(l^{(2)}-\xi+\theta_l(\xi-l^{(1)})}{l^{(2)}-l^{(1)}}, & l^{(1)} \le \xi \le l^{(2)} \\ \theta_l, & \xi = l^{(2)} \\ \frac{(\xi-l^{(2)}+\theta_l(l^{(3)}-\xi))}{l^{(3)}-l^{(2)}}, & l^{(2)} \le \xi \le l^{(3)} \\ 1, & \text{otherwise} \end{cases} \tag{2}$$

$$F_l(\xi) = \begin{cases} \frac{(l^{(2)}-\xi+\beta_l(\xi-l^{(1)}))}{l^{(2)}-l^{(1)}}, & l^{(1)} \le \xi \le l^{(2)} \\ \beta_l & \xi = l^{(2)} \\ \frac{(\xi-l^{(2)}+\beta_l(l^{(3)}-\xi)}{l^{(3)}-l^{(2)}}, & l^{(2)} \le \xi \le l^{(3)} \end{cases} \tag{3}$$

**Definition 2.4.** [23]

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:

(i) $l + m = \langle(l^{(1)} + m^{(1)}, l^{(2)} + m^{(2)}, l^{(3)} + m^{(3)}); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m\rangle$

(ii) $l - m = \langle(l^{(1)} - m^{(3)}, l^{(2)} - m^{(2)}, l^{(3)} - m^{(1)}); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_l, \beta_l \vee \beta_m\rangle$

(iii) $l^{-1} = \langle(\frac{1}{l^{(3)}}, \frac{1}{l^{(2)}}, \frac{1}{l^{(1)}}); \alpha_l, \theta_l, \beta_l\rangle, \quad \text{where } \ l \neq 0$

(iv) $\gamma l = \begin{cases} \langle(\gamma l^{(1)}, \gamma l^{(2)}, \gamma l^{(3)}); \alpha_l, \theta_l, \beta_l\rangle, & \text{if } (\gamma > 0) \\ \langle(\gamma l^{(3)}, \gamma l^{(2)}, \gamma l^{(1)}); \alpha_l, \theta_l, \beta_l\rangle, & \text{if } (\gamma < 0) \end{cases}$

(v) $\frac{l}{m} = \begin{cases} \langle(\frac{l^{(1)}}{m^{(3)}}, \frac{l^{(2)}}{m(2)}, \frac{l^{(3)}}{m^{(1)}}); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m\rangle, & \text{if } (l^{(3)} > 0, m^{(3)} > 0) \\ \langle(\frac{l^{(3)}}{m^{(3)}}, \frac{l^{(2)}}{m^{(2)}}, \frac{l^{(1)}}{m^{(1)}}); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m\rangle, & \text{if } (l^{(3)} < 0, m^{(3)} > 0) \\ \langle(\frac{l^{(3)}}{m^{(3)}}, \frac{l^{(2)}}{m^{(2)}}, \frac{l^{(1)}}{m^{(1)}}); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m\rangle, & \text{if } (l^{(3)} < 0, m^{(3)} < 0) \end{cases}$

(vi) $l/m =$

$$\begin{cases} \langle(l^{(1)}m^{(1)}, l^{(2)}m^{(2)}, l^{(3)}m^{(3)}); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m\rangle, & \text{if } (l^{(3)} > 0, m^{(3)} > 0) \\ \langle(l^{(1)}m^{(3)}, l^{(2)}m^{(2)}, l^{(3)}m^{(1)}); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m\rangle, & \text{if } (l^{(3)} < 0, m^{(3)} > 0) \\ \langle(l^{(3)}m^{(3)}, l^{(2)}m^{(2)}, l^{(1)}m^{(1)}); \alpha_l \wedge \alpha_m, \theta_l \vee \theta_m, \beta_l \vee \beta_m\rangle, & \text{if } (l^{(3)} < 0, m^{(3)} < 0) \end{cases}$$

## 3. Neutrosophic DEMATEL Approach

Smarandache [23] proposed the neutrosophic set theory. Neutrosophy handles vagueness and uncertainty, and attend the indeterminacy of values. Neutrosophy has some of the advantages:

(i) Neutrosophy provides the ability to present unknown information in our model using the indeterminacy degree, so the experts can present opinions about the unsure preferences.
(ii) Neutrosophy depicts the disagreement between decision-makers and experts.
(iii) Neutrosophy heeds all aspects of decision making situations by considering truthiness, indeterminacy, and falsity altogether.

Fontela and Gabus [11] have suggested that DEMATEL is used to be an important tool for defining the cause-and-effect chain components of a vast system. It deals with the evaluation of collaborative interaction between factors and the identification of critical relationships via a graphic conceptual framework. The neutrosophy DEMATEL model is used to deal with internal dependencies among criteria and then to construct a casual graph between the criteria for the financial performance ratio assessment. The neutrosophy DEMATEL method is briefly discussed as follows and the flow chart of the proposed framework is shown in Fig. 1.

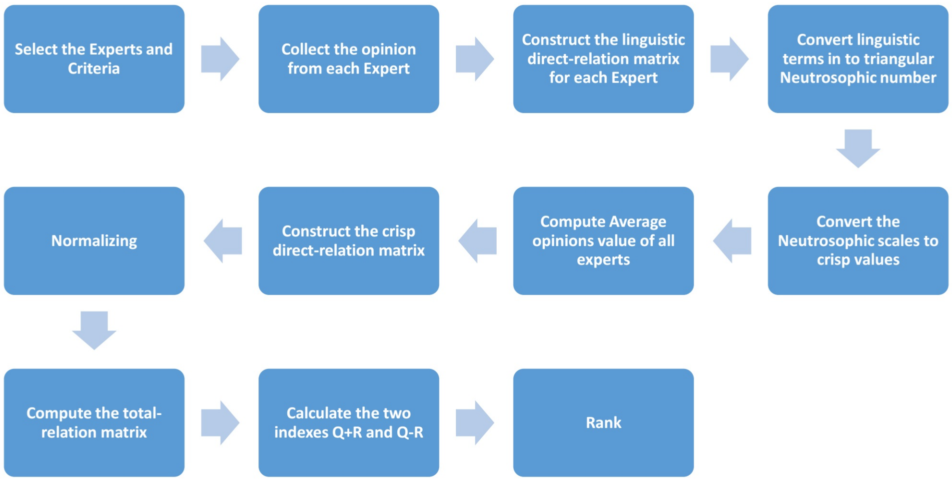


FIGURE 1. The framework of proposed neutrosophy DEMATEL method

Step 1 : Identify the experts who have well experience in the investment field.

Step 2 : Select the most important criteria which will influence the given problem.

Step 3 : Construct the linguistic direct-relation Matrix. This shows the degree of effect that each criterion has on other criteria. In this regard, collect the opinion from each expert and make the pairwise comparisons matrix for each expert, whose elements are linguistic terms such as Equally important, Slightly important, Strongly important, very strongly important, Absolutely important, etc., which is represented by the following matrix. This matrix is called linguistic the 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, absolutely important.

Step 4 : Convert the linguistic terms of direct-relation into the triangular neutrosophic scale, which is shown in table 2.

The triangular neutrosophic scale is in the form of $t_{ij} = \langle (t_{ij}^{(1)}, t_{ij}^{(2)}, t_{ij}^{(3)}; \alpha_{ij}, \theta_{ij}, \beta_{ij}) \rangle$ 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 following equations [27]:

| | $C_1$ | $C_2$ | $\cdots$ | $C_n$ |
|---|---|---|---|---|
| $C_1$ | $t_{11}$ | $t_{12}$ | $\cdots$ | $t_{1n}$ |
| $C_2$ | $t_{21}$ | $t_{22}$ | $\cdots$ | $t_{2n}$ |
| $\vdots$ | $\vdots$ | $\vdots$ | $\vdots$ | $\vdots$ |
| $C_n$ | $t_{n1}$ | $t_{n2}$ | $\cdots$ | $t_{nn}$ |

Table 1. Linguistic direct relation matrix

| | $C_1$ | $C_2$ | $\cdots$ | $C_n$ |
|---|---|---|---|---|
| $C_1$ | $\langle(t_{11}^{(1)}, t_{11}^{(2)}, t_{11}^{(3)}); \alpha_{11}, \theta_{11}, \beta_{11}\rangle$ | $\langle(t_{12}^{(1)}, t_{12}^{(2)}, t_{12}^{(3)}); \alpha_{12}, \theta_{12}, \beta_{12}\rangle$ | $\cdots$ | $\langle(t_{1n}^{(1)}, t_{1n}^{(2)}, t_{1n}^{(3)}); \alpha_{1n}, \theta_{1n}, \beta_{1n}\rangle$ |
| $C_2$ | $\langle(t_{21}^{(1)}, t_{21}^{(2)}, t_{21}^{(3)}); \alpha_{21}, \theta_{21}, \beta_{21}\rangle$ | $\langle(t_{22}^{(1)}, t_{22}^{(2)}, t_{22}^{(3)}); \alpha_{22}, \theta_{22}, \beta_{22}\rangle$ | $\cdots$ | $\langle(t_{2n}^{(1)}, t_{2n}^{(2)}, t_{2n}^{(3)}); \alpha_{2n}, \theta_{2n}, \beta_{2n}\rangle$ |
| $\vdots$ | $\vdots$ | $\vdots$ | $\ddots$ | $\vdots$ |
| $C_n$ | $\langle(t_{n1}^{(1)}, t_{n1}^{(2)}, t_{n1}^{(3)}); \alpha_{n1}, \theta_{n1}, \beta_{n1}\rangle$ | $\langle(t_{n2}^{(1)}, t_{n2}^{(2)}, t_{n2}^{(3)}); \alpha_{n2}, \theta_{n2}, \beta_{n2}\rangle$ | $\cdots$ | $\langle(t_{nn}^{(1)}, t_{nn}^{(2)}, t_{nn}^{(3)}); \alpha_{nn}, \theta_{nn}, \beta_{nn}\rangle$ |

Table 2. Neutrosophic Direct relation matrix

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

Step 6 : Combine the opinions of all experts in one integration matrix and measure the average opinions of the experts by dividing the opinion of all experts for each criterion by the number of experts (n) considered in the question. Each expert average value is determined by dividing each value by the number of experts (n) as shown in the equation (5), and then add all the expert's average values.

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

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 $k^{th}(k = 1, ..., m)$ 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.

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

Step 8 : Normalizing the direct relation matrix by using the following equations.

$$U = K \times S$$

$$K = Min(\frac{1}{Max \sum_{i=1}^{n} s_{ij}}, \frac{1}{Max \sum_{j=1}^{n} s_{ij}}), 1 \leq i \leq n, 1 \leq j \leq n \tag{6}$$

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

$$P = U \times (I - U)^{-1} \tag{7}$$

where I is the $n \times n$ identity matrix

Step 10 : Calculate the two indexes Q+R and Q-R for each criterion and draw the causal diagram. The first step to compute the sum of row (Q) and the sum of column (R) for each criterion separately. The (Q) and (R) are two vectors and the vector is calculated by using the following equations, where $P = [z_{ij}],\ i,\ j \in\ 1, 2, ..., n$

$$Q = \sum_{j=1}^{n} z_{ij}, \quad \forall i = 1, 2, ...n \tag{8}$$

$$R = \sum_{j=1}^{n} z_{ij}, \quad \forall i = 1, 2, ...n \tag{9}$$

## 4. **Case Study in NASDAQ Exchange**

In the present study, the neutrosophic DEMATEL approach is used for evaluation of relative importance of the financial ratio measure under the stock market environment. The proposed method is explained with a case study example as follows:

(1) Select the expects in the stock market field: We consider eight potential protable companies such as Apple, Micro-soft, Google, Intel Corporation, Adobe Inc, NVIDIA Corporation, and Micron Technology, Inc., Cognizant Technology Solutions Corp. The data for one-year performance (June 2018-May 2019) of 8 industries in the IT sector has been gained by distributing a questionnaire among two experts: (i) investors in the NASDAQ exchange (DM1), and (ii) a professor in Finance (DM2). The decision-maker collected opinion two different group financial measures: the Accounting based financial measures (AFM) and Economic value-based financial measures (EFM).

(2) Identify the most important criteria in financial ratio measure [33]: AFM based four criteria such Return On Assets (ROA), Return On Equity (ROE), Earnings per share (EPS), price for earnings ratio (P/E) Ratio which is shown in Fig. 2 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) whcih is shown in Fig.3.

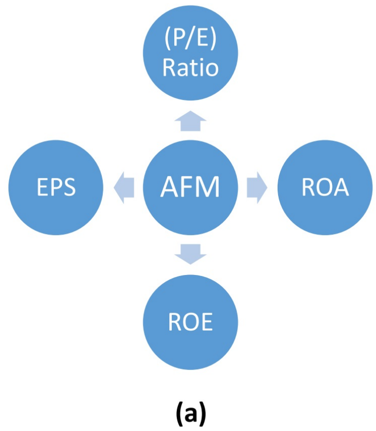


FIGURE 2. Accounting based financial measures

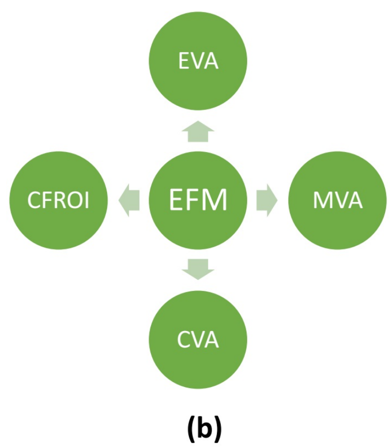


FIGURE 3. Economic value-based financial measures

(3) Construct the pairwise comparison matrix: In order to compare the interrelation between the four criteria such as ROA, ROE, EPS, 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 scale (see Table 3), which is given in Tables 4, 5, 6, and 7.

| Explanation | Scale | 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 3. The Neutrosophic Triangular scale value

| | $C_1$(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 4. The pairwise 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) | (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 5. The pairwise Neutrosophic comparison matrix of AFM's criteria given by expert 2

(4) Convert the neutrosophic AFM and EFM matrices into crisp matrix by using equation (4), which is shown in Table 8 and 9
(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 10.

| | $E_1$(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 6. The pairwise 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) | (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;0.9,0.1,0.1) | (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) |

Table 7. The pairwise Neutrosophic comparison matrix of EFM's criteria given by expert 2

| | 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 |
| $C_2$(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 8. The crisp values of pairwise comparison matrix for AFM

| | 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 |

Table 9. The crisp values of pairwise comparison matrix for EFM

(6) Normalizing the initial direct relation matrix by using equations (6) and (7). The normalized matrix is presented in Table 11.

| | 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 |

Table 10. Direct-relation matrix for AFM and EFM

| | AFM | | | | | EFM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $C_1$(ROA) | $C_2$(ROE) | $C_3$(EPS) | $C_1$(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 |

Table 11. Normalized decision matrix for AFM and EFM ratio

(7) Compute the total-relation matrix by using equation (8). The total-relation matrix, is given in Table 12.

| | AFM | | | | | EFM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $C_1$(ROA) | $C_2$(ROE) | $C_3$(EPS) | $C_1$(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 |
| $C_2$(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 |

Table 12. Total relation matrix

(8) By using equations (9) and (10), calculate the indexes Q+R and Q-R for each criterion and rank the criteria, which is shown in Table 13. Finally, draw the causal diagram for financial measures, which is shown in Fig. 3 and 4.

## 5. **Result and discussion**

In this section, we analyze the results of the proposed method. Table 14, presents the ranking of AFM and EFM, which has been used for financial performance evaluation. From the result, it is observed that ROE is the highest Q+R score value (-1.8418) secured the first rank, and P/E Ratio is indicated the Q+R value is -2.1230. Hence, it secured the second rank. The EPS has indicated the Q+R value is -3.4657. It has secured the least rank. Hence, ROE has secured the first rank, which shows that ROE is the most important criterion in AFM. The company management and investor are

| | 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 |

TABLE 13. The comparative neutrosophic DEMATEL technique $Q+R$ and $Q-R$ value

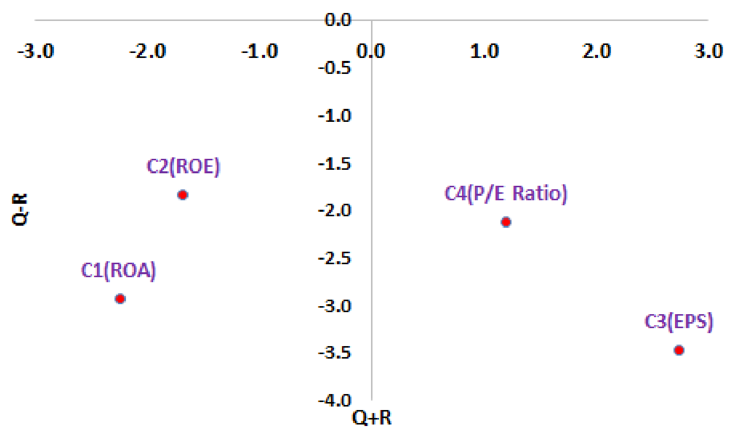


FIGURE 4. The causal diagram for Accounting based financial measures criteria

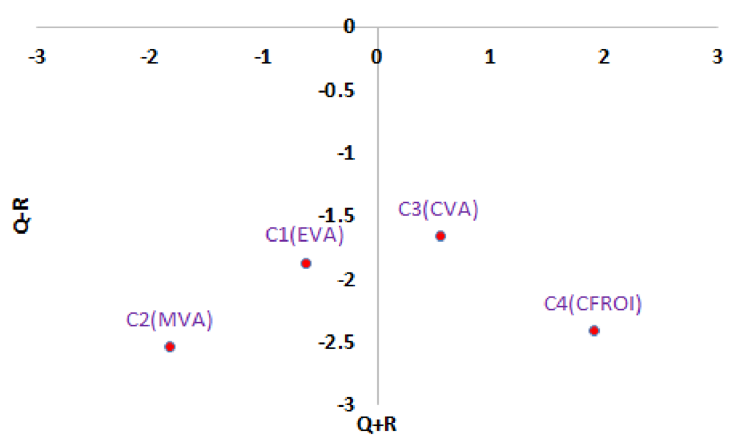


FIGURE 5. The causal diagram for Economic value-based financial measures criteria

recommended to pay more attention to ROE for achieving their best competitiveness in the organization. According to the degree of importance, Q+R the AFM criteria are ranked as follows: $C_3 > C_1 > C_4 > C_2$ .

In addition, table 14 presents a summary of financial measure EFM. From the result, we conclude that the criteria CVA is the most important of the criteria since it has the highest Q+R priority value (-1.6634). The Q+R value of EVA is -1.8711, which has secured the second rank. Similarly, MVA is the least performance of the criteria. The company management and investor are recommended to pay more attention to CVA for achieving their best competitiveness in the organization. According to the degree of importance,(S+R) the criteria EFM has ranked which are $E_2 > E_4 > E_1 > E_3$. However, the causal diagram constructed with the horizontal axis is Q+R and the vertical axis is Q-R. The causal diagram of AFM's and EFM's criteria are shown in Figures 3 and 4 respectively.

## 6. Conclusion

Financial ratios provide useful quantitative financial information about the performance of a company. The proposed approach (Neutrosophic-DEMATEL) is used to evaluate the relative importance of financial ratios compared to two groups: Accounting based financial measures (AFM) and Economic value-based financial measures (EFM). The empirical results are recommended the following results to the investor: ROE is the most important financial measure in AFM and CVA is the most influential measure in EFM. Hence, the proposed method suggests to the investors pay more attention to ROE in AFM and CVA in EFM. Moreover, the proposed neutrosophic- DEMATEL model gives a different result for both financial measures. Because neutrosophic DEMATEL has provided us with more degrees of freedom to represent uncertainty and indeterminacy in real-world information. The discussed results will help the companies, investors, and traders before making profound decisions.

In the future, we consider the other economic value measures such as shareholder value-added, equity economic value-added, and other performance measures by using different MCDM techniques like AHP, ELECTRE, and PROMETHEE under an interval valued neutrosophic environment.

## References

[1] Altuntas, S.; Dereli, T. A novel approach based on DEMATEL method and patent citation analysis for prioritizing a portfolio of investment projects. Expert systems with Applications, 2015, 42(3), pp.1003-1012.

[2] Abdel-Basset, M.; Manogaran, G.; Gamal, A.; Smarandache, F. A hybrid approach of neutrosophic sets and DEMATEL method for developing supplier selection criteria. Design Automation for Embedded Systems, 2018, 22(3), pp.257-278.

[3] Abdel-Basset, M.; Atef, A. and Smarandache, F.; A hybrid Neutrosophic multiple criteria group decision making approach for project selection. Cognitive Systems Research, 2019, 57, pp.216-227.

[4] Aslam, M.; Fahmi, A.; Almahdi, F.A.A.; Yaqoob, N.; Extension of TOPSIS method for group decision-making under triangular linguistic neutrosophic cubic sets. Soft Computing, 2021, 25(5), pp.3359-3376.

[5] Atanassov, K.T.; Intuitionistic fuzzy sets. Physica, Heidelberg, 1999, pp.1-137.

[6] Abdel-Basset, M.; Mohamed, M.; Hussien, A.N.; Sangaiah, A.K.; A novel group decision-making model based on triangular neutrosophic numbers. Soft Computing, 2018, 22(20), pp.6629-6643.

[7] Aydn, S.; Kahraman, C.; Evaluation of firms applying to Malcolm Baldrige National Quality Award: a modified fuzzy AHP method. Complex & Intelligent Systems, 2019, 5(1), pp.53-63.

[8] Bhattacharya, S.; Neutrosophic information fusion applied to the options market. Investment Management and Financial Innovations, 1, (2005) pp.139-145.

[9] Bhattacharya, S.; Utility, rationality and beyond-from behavioral finance to informational finance. American Research Press (2005).

[10] Chen, K.H.; Shimerda, T.A.; An empirical analysis of useful financial ratios. Financial management, 1981, pp.51-60.

[11] Fontela, E.; Gabus, A.; The DEMATEL observer, DEMATEL 1976 report. Battelle Geneva Research Center, 1976 Switzerland Geneva

[12] Golcuk, I; Baykasoglu, A.; An analysis of DEMATEL approaches for criteria interaction handling within ANP. Expert Systems with Applications, 2016, 46, pp.346-366.

[13] Hezam, I.M.; Nayeem, M.K.; Foul, A.; Alrasheedi, A.F.; COVID-19 Vaccine: A neutrosophic MCDM approach for determining the priority groups. Results in physics, 2021, 20, pp.103654.

[14] Halkos, G.E.; Tzeremes, N.G.; Industry performance evaluation with the use of financial ratios: An application of bootstrapped DEA. Expert Systems with Applications, 2012, 39(5), pp.5872-5880.

[15] Jana, C.; Pal, M.; Multi-criteria decision making process based on some single-valued neutrosophic Dombi power aggregation operators. Soft Computing, 2021, pp.1-18.

[16] Khoshnevisan, M.; Bhattacharya, S.; Neutrosophic information fusion applied to financial market. In Sixth International Conference of Information Fusion, 2003, 2, pp. 1252-1257.

[17] Lee, W.S.; Huang, A.Y.; Chang, Y.Y.; Cheng, C.M.; Analysis of decision making factors for equity investment by DEMATEL and Analytic Network Process. Expert Systems with Applications, 2011, 38(7), pp.8375-8383.

[18] Mahdi, I.M.; Riley, M.J.; Fereig, S.M.; Alex, A.P.; A multicriteria approach to contractor selection. Engineering Construction and Architectural Management, 2002, 9(1), pp.29-37.

[19] Mills, E.F.E.A.; Baafi, M.A.; Amowine, N.; Zeng, K.; A hybrid grey MCDM approach for asset allocation: evidence from Chinas Shanghai Stock Exchange. Journal of Business Economics and Management, 2020, 21(2), pp.446-472.

[20] Opricovic, S.; Tzeng, G.H.; Defuzzification within a multicriteria decision model. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 2003, 11(05), pp.635-652.

[21] Perin, S., Evaluating airline service quality using a combined fuzzy decision-making approach. Journal of Air Transport Management, 2017, 68, pp.48-60.

[22] Rezaeian, J.; Akbari, F.; Stock portfolio selection using a hybrid fuzzy approach: a case study in Tehran Stock Exchange. International Journal of Operational Research, 2015, 22(4), 423-453.

[23] Smarandache, F.; Neutrosophic seta generalization of the intuitionistic fuzzy set. Journal of Defense Resources Management, 2010, 1(1), pp.107-116.

[24] Singh, A.J.; Schmidgall, R.S.; Analysis of financial ratios commonly used by US lodging financial executives. Journal of Retail & Leisure Property, 2002, 2(3), pp.201-213.

[25] Sim, K.; Liu, G.; Gopalkrishnan, V.; Li, J.; A case study on financial ratios via cross-graph quasi-bicliques. Information Sciences, 2011, 181(1), pp.201-216.

[26] Slamaa, A.A.; El-Ghareeb, H.A.; Saleh, A.A.; A Road-map for Migration System-Architecture Decision by Neutrosophic-ANP and Benchmark for Enterprise Resource Planning Systems. IEEE Access, 2021, 9, pp.48583-48604.

[27] Nabeeh, N. A.; Smarandache, F.; Abdel-Basset, M.; El-Ghareeb, H. A.; Aboelfetouh, A.; An Integrated Neutrosophic-TOPSIS Approach and its Application to Personnel Selection: A New Trend in Brain Processing and Analysis. IEEE Access. 2019, doi: 10.1109/ACCESS.2019.2899841.

[28] Tabrizi, B.H.; Torabi, S.A; Ghaderi, S.F.; A novel project portfolio selection framework: An application of fuzzy DEMATEL and multi-choice goal programming. Scientia Iranica. Transaction E, Industrial Engineering, 2016, 23(6), pp.2945.

[29] Varma, K.; Kumar, K.S.; Criteria analysis aiding portfolio selection using DEMATEL. Procedia Engineering, 2012, 38, pp.3649-3661.

[30] Venugopal, R.; Veeramani, C.; Edalatpanah, S.A.; (2022). Analysis of Fuzzy DEMATEL Approach for Financial Ratio Performance Evaluation of NASDAQ Exchange. Proceedings of International Conference on Data Science and Applications. Lecture Notes in Networks and Systems, 2022, 287, pp.637648.

[31] Wu, K.J.; Liao, C.J.; Tseng, M.L.; Lim, M.K.; Hu, J.; Tan, K.; Toward sustainability: using big data to explore the decisive attributes of supply chain risks and uncertainties. Journal of Cleaner Production, 2017, 142, pp.663-676.

[32] Wu, J.; Khalil, A.M.; Hassan, N.; Smarandache, F.; Azzam, A.A.; Yang, H.; Similarity Measures and Multi-person TOPSIS Method Using m-polar Single-Valued Neutrosophic Sets. International Journal of Computational Intelligence Systems, 2021, 14(1), pp.869-885.

[33] Yalcin, N.; Bayrakdaroglu, A.; Kahraman, C., Application of fuzzy multi-criteria decision making methods for financial performance evaluation of Turkish manufacturing industries. Expert systems with applications, 2012, 39(1), pp.350-364.

[34] Zadeh.L.A.; Fuzzy sets. Information and Control, 1965, 8(3), 338353.

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