Sharia-compliant stock preference using similarity-based Fuzzy Grey Relational Analysis

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Abstract. The introduction of Sharia-compliant stocks at Bursa Malaysia can be considered as a type of socially responsible investing mechanism, especially for Muslim investors. An increase in the public interest in stock investment has led to the introduction of methods of categorizing and selecting preferred stocks effectively. Fuzzy decision-making methods have also become an important approach due to the nature of ambiguous and imprecise available data in the decision-making process. Nevertheless, some simplifications are inevitable to reduce the complexity of the problem, and consequently, loss of vital information may occur. In this paper, a similarity-based fuzzy grey relational analysis (FGRA) is proposed to rank selected Sharia-compliant stocks. An element of similarity measure is introduced in the original FGRA to reduce the loss of information in the computation when the distance between fuzzy numbers is utilized. The similarity measure can capture more information compared to distance measure since, in the computation, additional geometrical features of fuzzy numbers will be incorporated. An improvised procedure of FGRA is offered and implemented to rank selected Sharia-compliant stocks based on some fundamental analysis criteria. A comparison is then made on the preference obtained by the proposed procedure with the original FGRA.

1. Introduction

An investment can be considered as a necessity, especially for an individual or investor, who wants to ensure their present and future long-term financial security. Most investment platforms, such as stocks and bonds, offer good returns on investment over the long term. The growth of money is also important to fulfill basic needs in life and investing could help a person meet long-term life goals easily. Investment can be in many forms and stock investment is one of them. A stock, also known as ‘shares’ or ‘equity’ is a security type that signifies a corporation’s ownership and represents a claim on part of the assets and earnings in the corporation [1]. Stockholders will receive profit from the assets and earnings based on the number of shares they own. The process of determining the stocks with high returns and profits is a concern to investors. Adequate knowledge to analyze which stock to choose is necessary to make a wise and precise choice before investing.

The Sharia-compliant stock is an attractive choice to many investors. According to Chen [2], Sharia-compliant can be defined as the principles of the Muslim religion and investment funds governed by the requirements of Sharia’s law are considered to be a type of socially responsible investment. The product offered in Sharia-compliant must meet three aspects of Islamic law, such as related restrictions to Riba, which means an unjustified increment in borrowing or lending money that is paid above the amount of loan as a condition imposed by the lender, vague contract (Gharar) or gambling and other activities involving unethical products or services. According to Securities Commission Malaysia [3], there are 14 types of the stock market as of 26th November 2018 with a total number of 689 Sharia-compliant stocks and 213 non-Sharia compliant stocks.

Two main approaches to stock analysis are fundamental analysis and technical analysis. The fundamental analysis attempts to assess the stock’s intrinsic value by examining related economic, financial, and other qualitative and quantitative factors based on public data. On the other hand, technical analysis is analyzing the statistical trends gathered from trading activities such as price movement and volume to determine the performance of the stock. According to Scott et al. [4], fundamental analysis
ratios can be divided into six categories which are liquidity ratio, leverage ratio, asset management ratio, profitability ratio, market ratio, and company’s growth. Some of these financial ratios will be used in this paper as criteria to rank the stocks (alternatives) using the Multi-Criteria Decision Making (MCDM) approach.

Multi-Criteria Decision Making (MCDM) is a sub-discipline of operations research that explicitly evaluates multiple conflicting criteria in decision making aims to choose the best from the alternatives, actions, policies, or candidates by taking into consideration of multiple criteria, attributes, and goals [5]. Some well-known MCDM methods are Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Elimination Et Choix Traduisant La Realite (ELECTRE), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Grey Relational Analysis (GRA). Some of the MCDM methods have been applied to solve the stock selection problems. Danaei and Haghighi [6] used the TOPSIS method to compare the stock performance of various industries by considering six criteria which are operating profit, net profit, return on asset (ROA), earnings per share (EPS), total equity, and profit growth. Raei and Jahromi [7] applied the fuzzy Analytical Network Analysis (ANP) to find the appropriate weight of assets and a combination of multicriteria Optimization and Compromise Solution (VIKOR) and TOPSIS to rank the alternatives. Five categories of criteria have been considered, they are profitability, liquidity, leverage, performance, and market ratios. Hamzacebi & Pekkaya [8] combined the methods of GRA with the Analytical Hierarchical Process (AHP) for firm stock ordering. There were six selected financial ratios which were the price to earnings per share, market to book value ratio, return on total assets, the profit margin on sales, acid-test ratio, and total debt ratio, and eighteen alternatives from the finance sector were identified. Another study from Lajevardi and Razi [9] also used the method of GRA but with a combination of feature selection to rank fifty firms in Tehran Stock Exchange.

In this paper, we present the method of similarity-based Fuzzy GRA (FGRA) to rank some stocks of Sharia-compliant companies or securities in Bursa Malaysia based on fundamental analysis ratios. A few financial ratios are selected based on some dominant ratios discussed in the literature. Six common categories of financial ratios are the liquidity ratio, leverage ratio, asset management ratio, profitability ratio, market ratio, and the company’s growth. From these six categories, the six most popular ratios used in the literature are chosen which are the current ratio and quick ratio from liquidity ratio, net profit margin, return on assets and return on equity, and price to earnings ratio.

The element of similarity measure is introduced in the FGRA to reduce the loss of information in the computation when the distance between fuzzy numbers is utilized. Recently, several similarity measures and their applications have been proposed [10-12]. The similarity measure can capture more information compared to distance measure because additional geometrical features of fuzzy numbers will be incorporated. An improvised procedure of FGRA is offered and implemented to rank selected Sharia-compliant stocks based on some fundamental analysis criteria to help the investors decide which stocks are highly preferable to invest in.

2. Preliminaries

In this section, some definitions related to fuzzy numbers, mainly taken from [13], and the concept of similarity measure adapted from [14], is presented.

2.1 Basic Definitions

Definition 1. Consider a fuzzy set $A$ of the universe $U$. A fuzzy set $A$ [15] is defined by a set of ordered pairs, a binary relation,

$$A = \{ (x, \mu_A(x)) | x \in U \}$$
where \( \mu_A(x) \) is called a membership function. The value of \( \mu_A(x) \) specifies the grade or degree to which any element \( x \) in \( U \) belongs to the fuzzy set \( A \). A larger value of \( \mu_A(x) \) indicates a higher degree of membership.

**Definition 2.** A fuzzy set \( A \), where the universe \( U = R \), is convex if and only if the \( \alpha \)-level intervals

\[
A_\alpha = \{ x | x \in R, \mu_A(x) \geq \alpha \}
\]



are convex for all \( \alpha \) in the interval \([0, 1]\).

**Definition 3.** A fuzzy number is defined on the universe \( R \) as a convex and normalized fuzzy set.

**Definition 4.** A triangular fuzzy number \( A = (a_1, a_2, a_3) \) with membership function \( \mu_A(x) \) is defined on \( R \) by

\[
A \triangleq \mu_A(x) = \begin{cases} 
\frac{x - a_1}{a_2 - a_1} & \text{for } a_1 \leq x \leq a_2 \\
\frac{a_3 - x}{a_2 - a_3} & \text{for } a_2 \leq x \leq a_3 \\
0 & \text{otherwise}
\end{cases}
\]

**Definition 5.** A trapezoidal fuzzy number \( A = (a_1, a_2, a_3, a_4) \) with membership function \( \mu_A(x) \) is defined on a set of real numbers \( R \) by

\[
A \triangleq \mu_A(x) = \begin{cases} 
\frac{x - a_1}{a_2 - a_1} & \text{for } a_1 \leq x \leq a_2 \\
1 & \text{for } a_2 \leq x \leq a_3 \\
\frac{x - a_4}{a_3 - a_4} & \text{for } a_3 \leq x \leq a_4 \\
0 & \text{otherwise}
\end{cases}
\]

**Definition 6.** A normalized trapezoidal fuzzy numbers (NTFNs) \( \tilde{A} = (a_1, a_2, a_3, a_4; w_A) \) is a fuzzy set defined by a membership function \( \mu_{\tilde{A}}(x) : R \to [0,1] \) where

\[
\mu_{\tilde{A}}(x) = \begin{cases} 
\frac{x - a_1}{a_2 - a_1} & \text{for } a_1 \leq x \leq a_2 \\
1 & \text{for } a_2 \leq x \leq a_3 \\
\frac{x - a_4}{a_3 - a_4} & \text{for } a_3 \leq x \leq a_4 \\
0 & \text{otherwise}
\end{cases}
\]

such that \( a_1, a_2, a_3, a_4 \in R, a_1 \leq a_2 \leq a_3 \leq a_4 \) and \( w_A = 1 \).

**Definition 7.** Let \( \tilde{A} \) and \( \tilde{B} \) be two normalized trapezoidal fuzzy numbers such that \( \tilde{A} = (a_1, a_2, a_3, a_4) \) and \( \tilde{B} = (b_1, b_2, b_3, b_4) \). The arithmetic operations between \( \tilde{A} \) and \( \tilde{B} \) are given as follows:

**Addition:** \( \tilde{A} \oplus \tilde{B} = (a_1, a_2, a_3, a_4) \oplus (b_1, b_2, b_3, b_4) = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4) \).

**Subtraction:** \( \tilde{A} \ominus \tilde{B} = (a_1, a_2, a_3, a_4) \ominus (b_1, b_2, b_3, b_4) = (a_1 - b_1, a_2 - b_2, a_3 - b_3, a_4 - b_4) \).

**Multiplication:** \( \tilde{A} \otimes \tilde{B} = (a_1, a_2, a_3, a_4) \otimes (b_1, b_2, b_3, b_4) = (a_1b_1, a_2b_2, a_3b_3, a_4b_4) \).

**Division:** \( \tilde{A} \oslash \tilde{B} = (a_1, a_2, a_3, a_4) \oslash (b_1, b_2, b_3, b_4) = (a_1/b_1, a_2/b_2, a_3/b_3, a_4/b_4) \)

provided that \( b_i \neq 0, i = 1, 2, 3, 4 \).
2.2 Similarity Measure

Definition 8. Let $\tilde{A} = (a_1, a_2, a_3, a_4)$ and $\tilde{B} = (b_1, b_2, b_3, b_4)$ be two normalized trapezoidal fuzzy numbers. Then, the similarity measure based on a geometric distance between $\tilde{A}$ and $\tilde{B}$ is given as

$$S_1(\tilde{A}, \tilde{B}) = \left(1 - \frac{1}{4} \sum_{i=1}^{4} |a_i - b_i| \right)$$

Definition 9. Let $\tilde{A} = (a_1, a_2, a_3, a_4; 1)$ and $\tilde{B} = (b_1, b_2, b_3, b_4; 1)$ be two normalized trapezoidal fuzzy numbers (NTFNs). The similarity measure based on the center of gravity between $\tilde{A}$ and $\tilde{B}$ is given as

$$S_2(\tilde{A}, \tilde{B}) = (1 - |\hat{x}_A - \hat{x}_B|)^\beta(S_A, S_B)$$

where $\hat{x}_A$ and $\hat{y}_A$ are the horizontal center of gravity (COG) of $\tilde{A}$ and $\tilde{B}$ calculated as

$$\hat{x}_A = \frac{\gamma_A(a_2 + a_3) + (1 - \gamma_A)(a_1 + a_4)}{2} \quad ; \quad \hat{y}_A = \left\{ \begin{array}{ll} \frac{1}{6} \frac{a_3 - a_2 + 2}{a_2 - a_1} & \text{if } a_1 \neq a_4 \\ \frac{1}{2} & \text{if } a_1 = a_4 \end{array} \right.$$ and

$$B(S_A, S_B) = \begin{cases} 1 & \text{if } S_A + S_B > 0 \\ 0 & \text{if } S_A + S_B = 0 \end{cases}$$

such that $S_A = a_4 - a_1$ and $S_B = b_4 - b_1$.

Definition 10. Let $\tilde{A} = (a_1, a_2, a_3, a_4; 1)$ and $\tilde{B} = (b_1, b_2, b_3, b_4; 1)$ be two normalized trapezoidal fuzzy numbers (NTFNs). Then, the similarity measure based on Dice similarity index [16] between $\tilde{A}$ and $\tilde{B}$ is given as

$$S_3(\tilde{A}, \tilde{B}) = \left(1 - \frac{1}{4} \sum_{i=1}^{4} |a_i - b_i| \right) \times \left(1 - |\hat{x}_A - \hat{x}_B|\right)^\beta(S_A, S_B)$$

$$= \left(1 - \frac{1}{4} \sum_{i=1}^{4} |a_i - b_i| \right) \times \left(1 - \frac{2[(a_1 + a_2)(b_1 + b_2) + (a_3 + a_4)(b_3 + b_4)]}{((a_1 + a_2)^2 + (a_3 + a_4)^2) + ((b_1 + b_2)^2 + (b_3 + b_4)^2)} \right)$$

Based on the above definition, a new similarity measure is proposed in this study.

Definition 11. Given a continuous universe $U = [0,1]$ and a set of normalized fuzzy numbers $FS(U)$ over $U$. Let $\tilde{A} = (a_1, a_2, a_3, a_4; 1)$ and $(b_1, b_2, b_3, b_4; 1)$ be two normalized trapezoidal fuzzy numbers in $FS(U)$ and $S: FS(U) \times FS(U) \rightarrow [0,1]$. A similarity measure between $\tilde{A}$ and $\tilde{B}$ is defined as

$$S(\tilde{A}, \tilde{B}) = \left(1 - \frac{1}{4} \sum_{i=1}^{4} |a_i - b_i| \right) \times \left(1 - |\hat{x}_A - \hat{x}_B|\right)^\beta(S_A, S_B)$$

$$= \left(1 - \frac{1}{4} \sum_{i=1}^{4} |a_i - b_i| \right) \times \left(1 - \frac{2[(a_1 + a_2)(b_1 + b_2) + (a_3 + a_4)(b_3 + b_4)]}{((a_1 + a_2)^2 + (a_3 + a_4)^2) + ((b_1 + b_2)^2 + (b_3 + b_4)^2)} \right)$$

(1)

where $\hat{x}_A$ and $\hat{y}_A$ are the horizontal center of gravity (COG) of $\tilde{A}$ and $\tilde{B}$ calculated as

$$\hat{x}_A = \frac{\gamma_A(a_2 + a_3) + (1 - \gamma_A)(a_1 + a_4)}{2} \quad ; \quad \hat{y}_A = \left\{ \begin{array}{ll} \frac{1}{6} \frac{a_3 - a_2 + 2}{a_2 - a_1} & \text{if } a_1 \neq a_4 \\ \frac{1}{2} & \text{if } a_1 = a_4 \end{array} \right.$$ and

$$\hat{x}_B = \frac{\gamma_B(a_2 + a_3) + (1 - \gamma_B)(a_1 + a_4)}{2} \quad ; \quad \hat{y}_B = \left\{ \begin{array}{ll} \frac{1}{6} \frac{a_3 - a_2 + 2}{a_2 - a_1} & \text{if } a_1 \neq a_4 \\ \frac{1}{2} & \text{if } a_1 = a_4 \end{array} \right.$$
The decision matrix of the evaluation may be represented as given as below:

3. Proposed Methodology

This section will explain briefly the steps involved in Fuzzy Grey Relational Analysis (FGRA) method with similarity measure. The modification of the proposed method is in steps 6, 7, and 8 while the remaining steps are similar to the existing method of FGRA. The details of the proposed method are given as below:

Let \( A = \{A_1, A_2, \cdots, A_i, \cdots, A_m\} \) be a set of alternatives and \( C = \{C_1, C_2, \cdots, C_j, \cdots, C_n\} \) be a set of criteria under consideration. Suppose that the problem is evaluated by \( q \) number of decision-makers. The decision matrix of the evaluation may be represented as

Step 1: Identify the evaluation criteria and choose the appropriate linguistic variables to determine the criteria weight and the rating for alternatives.

Step 2: Obtain the decision matrix, \( X^t = [x^t_{ij}] \), where \( i = 1, 2, \cdots, m \), \( j = 1, 2, \cdots, n \), \( t = 1, 2, \cdots, q \), and \( q \) is the number of decision-makers.

Step 3: Determine the criteria weights, \( W = [w_j] \), \( j = 1, 2, \cdots, n \), and the aggregated decision matrix, \( X_{m \times n} \) where

\[
X_{m \times n} = \begin{bmatrix}
    a_{11} & a_{12} & \cdots & a_{1n} \\
    \vdots & \vdots & \ddots & \vdots \\
    a_{m1} & a_{m2} & \cdots & a_{mn}
\end{bmatrix}
\]

such that \( W_j = \frac{1}{q} (w^1_j + w^2_j + \cdots + w^q_j) \) and \( a_{ij} = (a_{ij}^1, a_{ij}^2, a_{ij}^3, a_{ij}^4) \) is in the form of trapezoidal fuzzy numbers.

Step 4: Construct the normalized decision matrix, \( \tilde{X}_{m \times n} \) represented in the form

\[
\tilde{X}_{m \times n} = [\tilde{a}_{ij}] = \begin{bmatrix}
    \tilde{a}_{11} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\
    \vdots & \vdots & \ddots & \vdots \\
    \tilde{a}_{m1} & \tilde{a}_{m2} & \cdots & \tilde{a}_{mn}
\end{bmatrix}
\]

where \( \tilde{a}_{ij} = (\tilde{a}_{ij}^1, \tilde{a}_{ij}^2, \tilde{a}_{ij}^3, \tilde{a}_{ij}^4), i = 1, 2, \cdots, m \), \( j = 1, 2, \cdots, n \). Note that the normalized process can be done as follows. For a function \( f(x) \) such that \( f(x) = mx + c \), when the attribute is a benefit criterion, \( f(\text{min}) = 0 \) and \( f(\text{max}) = 1 \) and when the attribute is a cost criterion, \( f(\text{max}) = 0 \) and \( f(\text{min}) = 1 \).

Step 5: Generate the reference series, \( R^* = [r_1^*, r_2^* \cdots r_j^* \cdots r_n^*] \) such that

\[
r_j^* = \begin{bmatrix}
    \max_i a_{ij}^1 & \max_i a_{ij}^2 & \max_i a_{ij}^3 & \max_i a_{ij}^4
\end{bmatrix} = (\tilde{a}_j^1, \tilde{a}_j^2, \tilde{a}_j^3, \tilde{a}_j^4)
\]

where \( j = 1, 2, \cdots, n \) represents the maximum standardized value of the \( j \)-th criterion.
Step 6: Calculate the similarity of $\Delta_{ij} = S(\bar{a}_{ij}, r^*_j)$ between each entry $\bar{a}_{ij}$ and the respective $r^*_j$ in the reference series, $R^*$ by using the similarity measure given in equation (1).

Step 7: Determine the similarity-based grey relational coefficient, $\gamma_{ij}$, for each entry where

$$\gamma_{ij} = 1 - \frac{\min_{\Delta_i} \Delta_i + \lambda \max_{\Delta_j} \Delta_j}{\max_{\Delta_i} \Delta_i + \lambda \min_{\Delta_j} \Delta_j}.$$ 

The distinguishing coefficient $\lambda$ with $0 \leq \lambda \leq 1$ represents the significance of $\max_{\Delta_i} \Delta_i$.

Step 8: Calculate the fuzzy grey relational grade, $\gamma_i$, that represents the fuzzy weighted sum of the grey relational coefficients of alternative $i$, where

$$\gamma_i = \frac{1}{4} \left[ \gamma_1^i + \gamma_2^i + \gamma_3^i + \gamma_4^i \right].$$

Step 9: Obtain the Best non-fuzzy Performance (BNP) values representing the crisp grey relational grades by defuzzifying the fuzzy relational grades using the defuzzification method where

$$BNP_i = \frac{1}{4} \left[ \gamma_1^i + \gamma_2^i + \gamma_3^i + \gamma_4^i \right].$$

The alternative with the highest grey relational grade can be considered as the best solution. The higher the value, the higher is the ranking position.

4. Implementation

As an illustration of the proposed method, a committee of four decision-makers or experts $D_1, D_2, D_3$ and $D_4$ has been assigned to evaluate the selected stocks with six benefit criteria under consideration. Four Sharia-compliant stocks from Bursa Malaysia $A_1, A_2, A_3$ and $A_4$ have been chosen as alternatives and the six criteria are current ratio ($C_1$), quick ratio ($C_2$), net profit margin ($C_3$), return of asset ($C_4$), return of equity ($C_5$), and price to earnings ratio ($C_6$). Information on the criteria of each stock is obtained from their respective annual reports. The data ended on 31st December and taken for five years from 2014 to 2018. Suitable linguistic variables are then determined for the criteria weight and the rating of alternatives. The linguistic variables adapted from Luukka [17] are used for the criteria weight determination and are shown in table 1. Based on experts’ opinions and the data values obtained from the financial report, the linguistic variables for the ratings of the stocks are given in table 2.

| Criteria Weight | Fuzzy Numbers |
|-----------------|--------------|
| Very Low (VL)   | (0.0, 0.0, 0.1, 0.2) |
| Low (L)         | (0.1, 0.2, 0.2, 0.3) |
| Medium Low (ML) | (0.2, 0.3, 0.4, 0.5) |
| Medium (M)      | (0.4, 0.5, 0.5, 0.6) |
| Medium High (MH)| (0.5, 0.6, 0.7, 0.8) |
| High (H)        | (0.7, 0.8, 0.8, 0.9) |
| Very High (VH)  | (0.8, 0.9, 1.0, 1.0) |
The evaluation is made by the decision-makers to determine the criteria weight and is given in Table 3.

### Table 2. Linguistic Variables for the Ratings of Stocks with respect to each criterion.

| Linguistic terms      | $C_1$          | $C_2$          | $C_3$          |
|-----------------------|----------------|----------------|----------------|
| Very Poor (VP)        | (0.17,0.17,0.68,1.19) | (0.17,0.17,0.55,0.93) | (-560.60,-560.60,-502.10,-443.50) |
| Poor (P)              | (0.68,1.19,1.19,1.17) | (0.55,0.93,0.93,1.31) | (-502.10,-443.50,-443.50,-384.90) |
| Marginally Poor (MP)  | (1.19,1.70,2.12,2.72) | (0.93,1.31,1.69,2.07) | (-443.50,-384.90,-326.40,-267.80) |
| Fair (F)              | (2.21,2.72,2.72,2.22) | (1.69,2.07,2.07,2.44) | (-326.40,-267.80,-267.80,-209.20) |
| Marginally Good (MG)  | (2.72,3.22,3.73,4.24) | (2.07,2.44,2.82,3.20) | (-267.80,-209.20,-150.70,-92.12) |
| Good (G)              | (3.73,4.24,4.44,4.75) | (2.82,3.20,3.20,3.58) | (-150.70,-92.12,-92.12,-33.56) |
| Very Good (VG)        | (4.24,4.75,5.26,5.26) | (3.20,3.58,3.96,3.96) | (-92.12,-33.56,25.0,0.25) |

The evaluation is made by the decision-makers to determine the criteria weight and is given in Table 3.

### Table 3. Evaluation of the Importance of Criteria Weight.

| Criteria / Decision Maker | $C_1$ | $C_2$ | $C_3$ | $C_4$ |
|---------------------------|-------|-------|-------|-------|
| Current Ratio             | MH    | VH    | VH    | MH    |
| Quick Ratio               | MH    | VH    | VH    | MH    |
| Net Profit Margin         | VH    | VH    | H     |       |
| Return on Asset           | VH    | VH    | VH    | MH    |
| Return on Equity          | VH    | VH    | VH    |       |
| Price to Earnings Ratio   | VH    | VH    | H     |       |

By considering the ratio values for each stock obtained from their annual financial report, each ratio of the stock alternatives will be assigned with the corresponding linguistic variables according to their values. For instance, suppose that the value obtained for the current ratio from the financial report is 2.0. Hence by referring to Table 2, the closest linguistic variables to represent this value is marginally poor (MP). Using this approach, the linguistic representations for each alternative for the given criteria for the year 2014-2018 are given in table 4. The linguistic evaluations in tables 3 and 4 are then presented in the form of trapezoidal fuzzy numbers to construct the fuzzy decision matrix and the fuzzy weight of each criterion. This is depicted in Table 5. As an illustration, only the calculation for the year 2014 is shown in detail in Table 5.
Table 4. The Ratings of the Four (4) Stocks for Five Years.

| Criteria                  | Criteria | Year  | Year  | Year  | Year  | Year  |
|---------------------------|----------|-------|-------|-------|-------|-------|
|                           |          | 2014  | 2015  | 2016  | 2017  | 2018  |
| Current ratio C₁          | A₁       | MP    | VP    | P     | VP    | VP    |
|                           | A₂       | VG    | MP    | MP    | F     | F     |
|                           | A₃       | MP    | MP    | MP    | P     | MP    |
|                           | A₄       | P     | VP    | VP    | MP    | MG    |
| Quick Ratio C₂            | A₁       | F     | VP    | P     | VP    | VP    |
|                           | A₂       | VG    | MP    | MP    | F     | MP    |
|                           | A₃       | MP    | MP    | MP    | MP    | MP    |
|                           | A₄       | P     | VP    | VP    | MP    | MG    |
| Net Profit Margin C₃      | A₁       | VG    | VG    | VG    | VG    | VG    |
|                           | A₂       | VG    | G     | VP    | VG    | VG    |
|                           | A₃       | VG    | VG    | VG    | G     | MG    |
|                           | A₄       | VG    | VG    | MP    | MG    | VG    |
| Return On Asset C₄        | A₁       | VG    | G     | G     | MG    | G     |
|                           | A₂       | G     | P     | VP    | VG    | VG    |
|                           | A₃       | G     | G     | MG    | MG    | MP    |
|                           | A₄       | G     | MG    | MG    | F     | G     |
| Return On Equity C₅       | A₁       | VG    | VG    | VG    | VG    | VG    |
|                           | A₂       | VG    | VG    | G     | VG    | VG    |
|                           | A₃       | VG    | VG    | VG    | G     | MG    |
|                           | A₄       | VG    | VG    | VG    | VG    | VG    |
| Price to Earnings ratio C₆| A₁       | MG    | MG    | MG    | F     | MG    |
|                           | A₂       | VG    | F     | F     | MG    | MG    |
|                           | A₃       | MG    | F     | F     | F     | F     |
|                           | A₄       | MG    | F     | F     | F     | VP    |

Table 5. The Fuzzy Decision Matrix and Fuzzy Weights of Four Alternatives for 2014.

| Ai | C₁     | C₂     | C₃     |
|----|--------|--------|--------|
|    | (1.19, 1.70, 2.21, 2.72) | (1.69, 2.07, 2.07, 2.44) | (−92.12, −33.56, 25.00, 25.00) |
| A₁ |        |        |        |
| A₂ | (4.24, 4.75, 5.26, 5.26) | (3.20, 3.58, 3.96, 3.96) | (−92.12, −33.56, 25.00, 25.00) |
| A₃ | (1.19, 1.70, 2.21, 2.72) | (0.93, 1.31, 1.69, 2.07) | (−92.12, −33.56, 25.00, 25.00) |
| A₄ | (0.68, 1.19, 1.19, 1.70) | (0.55, 0.93, 0.93, 1.31) | (−92.12, −33.56, 25.00, 25.00) |
| Weight | (0.65, 0.75, 0.85, 0.90) | (0.65, 0.75, 0.85, 0.90) | (0.78, 0.88, 0.95, 0.98) |

| Ai | C₁     | C₅     | C₆     |
|----|--------|--------|--------|
|    |        |        |        |
| A₁ | (1.72, 9.84, 1.79, 1.79) | (−108.70, −43.27, 22.16, 22.16) | (−6.60, 7.10, 20.75, 34.44) |
| A₂ | (−6.40, 1.72, 1.72, 9.84) | (−108.70, −43.27, 22.16, 22.16) | (34.44, 48.12, 61.80, 61.80) |
| A₃ | (−6.40, 1.72, 1.72, 9.84) | (−108.70, −43.27, 22.16, 22.16) | (−6.60, 7.10, 20.75, 34.44) |
| A₄ | (−6.40, 1.72, 1.72, 9.84) | (−108.70, −43.27, 22.16, 22.16) | (−6.60, 7.10, 20.75, 34.44) |
| Weight | (0.73, 0.83, 0.93, 0.95) | (0.80, 0.90, 1.00, 1.00) | (0.78, 0.88, 0.95, 0.98) |
Using step 4, the fuzzy normalized decision matrix as in table 6 is obtained which will be used to calculate the reference series, \( R^* \).

**Table 6. The Fuzzy Normalized Decision Matrix for 2014.**

| \( A_i \) | \( C_1 \) | \( C_2 \) | \( C_3 \) | \( C_4 \) | \( C_5 \) | \( C_6 \) |
|-----------|----------|----------|----------|----------|----------|----------|
| \( A_1 \) | (0.11, 0.22, 0.33, 0.45) | (0.33, 0.45, 0.45, 0.55) | (0.00, 0.50, 1.00, 1.00) |         |         |         |
| \( A_2 \) | (0.78, 0.89, 1.00, 1.00) | (0.78, 0.89, 1.00, 1.00) | (0.00, 0.50, 1.00, 1.00) |         |         |         |
| \( A_3 \) | (0.11, 0.22, 0.33, 0.45) | (0.11, 0.22, 0.33, 0.45) | (0.00, 0.50, 1.00, 1.00) |         |         |         |
| \( A_4 \) | (0.00, 0.11, 0.11, 0.22) | (0.00, 0.11, 0.11, 0.22) | (0.00, 0.50, 1.00, 1.00) |         |         |         |

Using the values in table 6, the reference series, \( R^* \) is obtained as
\[
R^* = [(0.78, 0.89, 1.00, 1.00), (0.78, 0.89, 1.00, 1.00), (0.00, 0.50, 1.00, 1.00),
(0.33, 0.67, 1.00, 1.00), (0.00, 0.50, 1.00, 1.00), (0.60, 0.80, 1.00, 1.00)].
\]

Hence, using tabulation (1), the similarity values between the alternatives with respect to each criterion from the reference series are given in table 7.

**Table 7. Similarity value of FGRA.**

| \( A_i \) | \( C_1 \) | \( C_2 \) | \( C_3 \) | \( C_4 \) | \( C_5 \) | \( C_6 \) | \( \text{Min} \) | \( \text{Max} \) |
|-----------|----------|----------|----------|----------|----------|----------|----------|----------|
| \( A_1 \) | 0.0749   | 0.2218   | 1.0000   | 1.0000   | 1.0000   | 0.1344   | 0.0749   | 1.0000   |
| \( A_2 \) | 1.0000   | 1.0000   | 1.0000   | 0.2661   | 1.0000   | 1.0000   | 0.2661   | 1.0000   |
| \( A_3 \) | 0.0749   | 0.0750   | 1.0000   | 0.2661   | 1.0000   | 0.1344   | 0.0749   | 1.0000   |
| \( A_4 \) | 0.0096   | 0.0096   | 1.0000   | 0.2661   | 1.0000   | 0.1344   | 0.0096   | 1.0000   |

| Min       | 0.0096   | 0.0096   | 1.0000   | 0.2661   | 1.0000   | 0.1344   | 0.0096   | 1.0000   |
| Max       | 1.0000   | 1.0000   | 1.0000   | 1.0000   | 1.0000   | 1.0000   | 0.2661   | 1.0000   |

The maximum and the minimum of the rows and columns are determined from table 7. Using these values, the grey relational coefficient, \( \gamma_{ij} \) for all entries are calculated and are shown in table 8.

**Table 8. Grey Relational Coefficient, \( \gamma_{ij} \).**

| \( A_i \) | \( C_1 \) | \( C_2 \) | \( C_3 \) | \( C_4 \) | \( C_5 \) | \( C_6 \) |
|-----------|----------|----------|----------|----------|----------|----------|
| \( A_1 \) | 0.1135   | 0.2939   | 0.6603   | 0.6603   | 0.6603   | 0.1967   |
| \( A_2 \) | 0.6603   | 0.6603   | 0.6603   | 0.3348   | 0.6603   | 0.6603   |
| \( A_3 \) | 0.1135   | 0.1138   | 0.6603   | 0.3348   | 0.6603   | 0.1967   |
| \( A_4 \) | 0.0000   | 0.0000   | 0.6603   | 0.3348   | 0.6603   | 0.1967   |

As in Step 8, the fuzzy grey relational grade, \( \chi_i \) for each stock can be obtained and shown in table 9.
Table 9. Fuzzy Relational Grade, $\gamma_i$.

| $A_i$ | Fuzzy Relational Grade |
|-------|------------------------|
| $A_1$ | (0.3226, 0.3657, 0.4052, 0.4150) |
| $A_2$ | (0.4421, 0.5027, 0.5578, 0.5757) |
| $A_3$ | (0.2638, 0.2985, 0.3295, 0.3364) |
| $A_4$ | (0.2392, 0.2700, 0.2973, 0.3023) |

Finally, the BNP values of each stock for the year 2014 are obtained as in Table 10.

Table 10. BNP Values and Ranking of Alternatives.

| Alternative | BNP Values |
|-------------|------------|
| $A_1$       | 0.3771     |
| $A_2$       | 0.5196     |
| $A_3$       | 0.3070     |
| $A_4$       | 0.2772     |

The ranking order of the four stocks is $A_2, A_1, A_3, A_4$.

For comparison purposes, Table 11 shows the summary of the result for the ranking of stocks with BNP values from the year 2014 until 2018.

Table 11. BNP Values with Ranking of Alternatives for 2014-2018.

| Year / Ranking | First Rank | Second Rank | Third Rank | Fourth Rank |
|----------------|------------|-------------|------------|-------------|
| 2014           | $A_2$      | $A_1$       | $A_3$      | $A_4$       |
| BNP Value      | 0.5196     | 0.3771      | 0.3070     | 0.2772      |
| 2015           | $A_3$      | $A_1$       | $A_2$      | $A_4$       |
| BNP Value      | 0.5613     | 0.4241      | 0.3968     | 0.3605      |
| 2016           | $A_1$      | $A_3$       | $A_4$      | $A_2$       |
| BNP Value      | 0.5136     | 0.5094      | 0.3052     | 0.2802      |
| 2017           | $A_2$      | $A_3$       | $A_4$      | $A_1$       |
| BNP Value      | 0.5561     | 0.3535      | 0.3025     | 0.2846      |
| 2018           | $A_2$      | $A_4$       | $A_1$      | $A_3$       |
| BNP Value      | 0.5195     | 0.4659      | 0.3941     | 0.3459      |

Based on the BNP values, as mentioned before, the ranking order of the stocks for the year 2014 is $A_2, A_1, A_3, A_4$. Meanwhile, the ranking order of the stocks for the year 2015 is $A_3, A_1, A_2, A_4$ and for the year 2016 is $A_1, A_3, A_4, A_2$. The ranking changed again for the years 2017 and 2018 as in Table 11 above because the financial report depends on the performances of the stocks and this will affect the ranking of the stocks. Since every year their performances are not the same for each financial report, the ranking of the stocks will be expected to be different for each year. Stock $A_2$ shows a strong performance during the five years interval as it ranks first for three years meanwhile $A_4$ does not show a good ending most of the years (except 2018) as it ranks lower compared to others.

5. Conclusion

In this paper, a stock selection problem has been solved by using a similarity-based fuzzy grey relational method. A new similarity measure is proposed and incorporated in the method of FGRA. In many instances, the similarity measure is preferred to the distance approach to minimize the loss of information. Hence, a new procedure of decision-making is proposed. Four alternatives of stock from
Bursa Malaysia were chosen and six major ratios from the fundamental analysis were used in the evaluation process. Suitable linguistic variables were defined to represent the performance. The criteria weight of importance of the ratios were determined by the decision makers meanwhile the performance rating of the four stocks concerning each ratio was based on the annual financial report of the stocks. The performance of each stock was studied for the range of years from 2014 to 2018. It is concluded that the proposed method has been able to rank the stocks effectively based on some major ratios from the fundamental analysis. This work may be extended in two ways. Firstly, new variants of similarity measures may be introduced and applied in the similarity-based FGRA for further investigation. Secondly, the scope of the investigation may be widened to more stocks, either under Sharia-compliant or non-Sharia-compliant and also by including other ratios in the fundamental analysis.

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