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Performance Evaluation of Healthcare Companies with Hybrid Multi-Criteria Decision-Making (MCDM) Methods During the COVID-19 Pandemic

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Abstract: The COVID-19 pandemic significantly challenged business resilience, particularly in the healthcare sector, where pharmaceutical and biotechnology companies experienced growth and service-oriented entities faced operational stress. In this study, the advanced Multi-Criteria Decision-Making (MCDM) techniques were employed to investigate the financial performance of healthcare firms listed on the Standard and Poor's 500 index from year 2018 to 2023. The research evaluated ten firms based on 16 criteria, encompassing both financial and non-financial dimensions. The financial criteria included Leverage Ratio, Tobin's Q Ratio, Revenue Growth, Operating Profit Growth, Equity Growth, Firm Size, Net Income, Total Liabilities, Revenue, Operating Profit, and Market Capitalization. In parallel, the non-financial indicators such as Human Resource Management, Supply Chain Management, Risk and Crisis Management, Business Ethics, and Environmental Policy were integrated to reflect managerial quality and sustainability practices. Out of the 16 criteria, two costs and nine benefits were quantitative whereas the remaining five benefits were qualitative. Expert assessments were modeled on the Spherical Cubic Fuzzy (SCF) sets and aggregated with the Aczel–Alsina operator. Alternatives were ranked using methods like the Ranking of Alternatives through Nested Cumulative Operator Method (RANCOM) and the Alternative Ranking Order Method with Adjustment Normalization (AROMAN), hence producing a multidimensional evaluation matrix enriched by both numerical and verbal judgments from ten experts. This research contributed to the literature in three key ways: (1) It provided a holistic assessment of financial performance in a highly dynamic and uncertain environment; (2) It broadened the performance evaluation framework to include non-financial and sustainability-driven criteria; and (3) It demonstrated the utility of novel MCDM tools like the SCF sets, the Aczel–Alsina aggregation, the RANCOM, and the AROMAN in complicated decision environments. The study offers a robust and innovative analytical model for academics and practitioners seeking to understand firm resilience and performance amid crises.

Keywords: Performance evaluation; Financial performance; Healthcare companies; COVID-19; Hybrid Multi-Criteria Decision-Making; RANCOM; AROMAN; Spherical Cubic Fuzzy

1 Introduction

Financial performance is a multidimensional area of evaluation that measures the efficiency of an enterprise in respect of resource utilization, profitability, and capacity to generate sustainable value. Traditionally, this assessment relied on financial ratios such as profit margins, leverage ratios, and asset efficiency indicators. However, in recent years, non-financial factors such as environmental sensitivity, corporate governance structure, human resource practices, and crisis management capabilities have been increasingly recognized as critical determinants of firm performance. This shift necessitates a more holistic approach to performance analysis.

Financial performance, as a multidimensional concept, enables the quantitative evaluation of economic activities carried out by a firm to reveal the extent of its resource utilization in terms of effectiveness, efficiency, and profitability, while helping to determine the economic values generated for stakeholders. In this regard, financial performance plays a critical role not only in controlling internal managerial decision-making processes but also in shaping investors' behavior and building trust among external stakeholders.

The theoretical background of financial performance is grounded in various financial and managerial theories. On the one hand, the Stakeholder Theory posits that the success of a firm is directly linked not only to the interests of shareholders, but also to its ability to meet the expectations of all stakeholders, including employees, customers, society, and suppliers [1]. On the other hand, the Profit Maximization Theory and the Firm Value Theory define the primary objective of a firm as value maximization although this value is shaped by sustainable financial performance [2].

In the complicated and multidimensional decision-making environments nowadays, decisions are often based on numerous, sometimes conflicting criteria. Real-world problems are rarely singular in nature; rather, they are inherently multi-criteria. Therefore, the Multi-Criteria Decision-Making (MCDM) methods provide rational and systematic decision support in environments characterized by high levels of uncertainty and complexity. The MCDM methods require the evaluation and ranking of multiple alternatives based on a variety of criteria. However, information gaps, uncertainty, and subjective judgments are inevitable in such contexts. In this light, uncertainty-focused approaches such as the fuzzy set theory offer decision-makers more flexible analytical capabilities.

Various methods have been proposed in the literature to address such complex decision structures. However, the choice of methods largely depends on the nature of the problem, the structure of the criteria, and the perspective of the decision-maker. Accordingly, evaluating a large number of diverse criteria simultaneously has significantly raised interest in the MCDM approaches.

The COVID-19 pandemic, emerged in year 2019 and continued to exert global influence until year 2023, imposed tests on the financial structures and resilience levels of businesses. The healthcare sector was affected in a dual manner during this period. While pharmaceutical and biotechnology companies were experiencing substantial growth, hospital operators, health insurance providers, and service-oriented firms were facing increasing costs and operational pressures. Understanding these trends necessitated investigation of responses from firms within the sector during the crisis through various strategies and organizational structures.

The objective of this study is to analyze, with the MCDM methods, the financial performance of healthcare firms listed in the Standard & Poor's (S&P) 500 index from year 2018 to year 2023, when the COVID-19 pandemic was significantly influential. Within the scope of the study, 10 alternative firms were evaluated based on 16 criteria. These criteria were not only structured around traditionally financial indicators but also incorporated non-financial sustainability and managerial quality dimensions. Among the criteria considered were financial indicators such as Leverage Ratio, Tobin's Q Ratio, Revenue Growth, Operating Profit Growth, Equity Growth, Firm Size, Net Income/Loss Reporting, Total Liabilities, Revenue, Operating Profit, and Market Capitalization. In addition, qualitative and sustainability-oriented indicators such as Human Resource Management, Supply Chain Management, Risk and Crisis Management, Business Ethics, and Environmental Policy and Management were included. Out of the 16 criteria, 11 were quantitative, with two classified as costs and nine as benefits, while the remaining five were qualitative and categorized as benefits.

The criterion weights, derived on the basis of expert judgments, were modeled using Spherical Cubic Fuzzy (SCF) sets and aggregated through the Aczel–Alsina aggregation operator. The ranking of alternatives was performed using the Ranking of Alternatives through Nested Cumulative Operator Method (RANCOM) and the Alternative Ranking Order Method with Adjustment Normalization (AROMAN). The decision matrix utilized in the study was evaluated by a panel of ten experts. This structure allowed an advanced and multidimensional analysis to be done by integrating both quantitative and qualitative data sources.

This research offers three key contributions. First, it enables a comprehensive analysis of changes in the financial performance of firms operating in the healthcare sector, which was significantly affected during the COVID-19 period. Second, the study adopts an extended performance evaluation framework by incorporating not only traditionally financial ratios but also non-financial criteria such as managerial capabilities, sustainability policies, and ethical governance practices. Finally, through the use of advanced methodologies including Spherical Cubic Fuzzy (SCF) sets, the Aczel–Alsina aggregation operator, the RANCOM and the AROMAN ranking techniques, this study introduces next-generation approaches that support decision-making under uncertainty and contribute to methodological diversity in the literature. Thus, the research stands out as a robust and multidimensional analytical tool for both academic researchers and practitioners.

2 Methodology

2.1 Phase 2: Performance Analysis of Promotional Videos Using the MCDM and Fuzzy Logic

The propose.

2.1.1 Preliminaries of Spherical Cubic Fuzzy (SCF) sets

Definition 1.

The SCF sets based on the combined use of cubic fuzzy (CF) sets and spherical fuzzy (SF) sets, where $\left([\mu_S^-(x), \mu_S^+(x)], \mu_S(x)\right)$ denotes positive membership, $\left([\vartheta_S^-(x), \vartheta_S^+(x)], \vartheta_S(x)\right)$ denotes neutral membership and $\left([\pi_S^-(x), \pi_S^+(x)], \pi_S(x)\right)$ denotes negative membership. In addition, the SCF set must satisfy the following conditions: a SCF set, denoted as:

$$\tilde{S} = \left\{ \left\langle x, \left([\mu_{\tilde{S}}^-(x), \mu_{\tilde{S}}^+(x)], \mu_{\tilde{S}}(x)\right), \left([\vartheta_{\tilde{S}}^-(x), \vartheta_{\tilde{S}}^+(x)], \vartheta_{\tilde{S}}(x)\right), \left([\pi_{\tilde{S}}^-(x), \pi_{\tilde{S}}^+(x)], \pi_{\tilde{S}}(x)\right) \mid x \in X \right\rangle \right\}$$

utilizes functions defined over a universe X and comprising x elements. In addition, the SCF set must be satisfied as follows [3]:

$$0 \le \left(\sup\left([\mu_{\tilde{S}}^-(x), \mu_{\tilde{S}}^+(x)]\right)\right)^2 + \left(\sup\left([\vartheta_{\tilde{S}}^-(x), \vartheta_{\tilde{S}}^+(x)]\right)\right)^2 + \left(\sup\left([\pi_{\tilde{S}}^-(x), \pi_{\tilde{S}}^+(x)]\right)\right)^2 \le 1 \text{ and}$$

$$0 \le (\mu_{\tilde{S}}(x))^2 + (\vartheta_{\tilde{S}}(x))^2 + (\pi_{\tilde{S}}(x))^2 \le 1.$$

Definition 2. To illustrate operations between SCF sets, consider two SCF sets:

$$\tilde{S}_1 = \left\{ \left\langle x, \left([\mu_{\tilde{S}_1}^-(x), \mu_{\tilde{S}_1}^+(x)], \mu_{\tilde{S}_1}(x)\right), \left([\vartheta_{\tilde{S}_1}^-(x), \vartheta_{\tilde{S}_1}^+(x)], \vartheta_{\tilde{S}_1}(x)\right), \left([\pi_{\tilde{S}_1}^-(x), \pi_{\tilde{S}_1}^+(x)], \pi_{\tilde{S}_1}(x)\right) \mid x \in X \right\rangle \right\} \text{ and}$$

$$\tilde{S}_2 = \left\{ \left\langle x, \left([\mu_{\tilde{S}_2}^-(x), \mu_{\tilde{S}_2}^+(x)], \mu_{\tilde{S}_2}(x)\right), \left([\vartheta_{\tilde{S}_2}^-(x), \vartheta_{\tilde{S}_2}^+(x)], \vartheta_{\tilde{S}_2}(x)\right), \left([\pi_{\tilde{S}_2}^-(x), \pi_{\tilde{S}_2}^+(x)], \pi_{\tilde{S}_2}(x)\right) \mid x \in X \right\rangle \right\}.$$

The operations can be shown as follows [3]:

(i) $\tilde{S}_1 \oplus \tilde{S}_2 =$

$$\Bigg\{ \Bigg\langle \Bigg(\Bigg[\sqrt{(\mu_{\tilde{S}_1}^-(x))^2 + (\mu_{\tilde{S}_2}^-(x))^2 - (\mu_{\tilde{S}_1}^-(x))^2(\mu_{\tilde{S}_2}^-(x))^2}, \sqrt{(\mu_{\tilde{S}_1}^+(x))^2 + (\mu_{\tilde{S}_2}^+(x))^2 - (\mu_{\tilde{S}_1}^+(x))^2(\mu_{\tilde{S}_2}^+(x))^2} \Bigg], \sqrt{(\mu_{\tilde{S}_1}(x))^2 + (\mu_{\tilde{S}_2}(x))^2 - (\mu_{\tilde{S}_1}(x))^2(\mu_{\tilde{S}_2}(x))^2} \Bigg), \Bigg(\Big[\vartheta_{\tilde{S}_1}^-(x)\vartheta_{\tilde{S}_2}^-(x), \vartheta_{\tilde{S}_1}^+(x)\vartheta_{\tilde{S}_2}^+(x) \Big], \vartheta_{\tilde{S}_1}(x)\vartheta_{\tilde{S}_2}(x) \Bigg), \Bigg(\Big[\pi_{\tilde{S}_1}^-(x)\pi_{\tilde{S}_2}^-(x), \pi_{\tilde{S}_1}^+(x)\pi_{\tilde{S}_2}^+(x) \Big], \pi_{\tilde{S}_1}(x)\pi_{\tilde{S}_2}(x) \Bigg) \Bigg\rangle \mid x \in X \Bigg\},$$

(ii) $\tilde{S}_1 \oplus \tilde{S}_2 =$

$$\Bigg\{ \Bigg\langle \Bigg(\Big[\mu_{\tilde{S}_1}^-(x)\mu_{\tilde{S}_2}^-(x), \mu_{\tilde{S}_1}^+(x)\mu_{\tilde{S}_2}^+(x) \Big], \mu_{\tilde{S}_1}(x)\mu_{\tilde{S}_2}(x) \Bigg), \Bigg(\Big[\vartheta_{\tilde{S}_1}^-(x)\vartheta_{\tilde{S}_2}^-(x), \vartheta_{\tilde{S}_1}^+(x)\vartheta_{\tilde{S}_2}^+(x) \Big], \vartheta_{\tilde{S}_1}(x)\vartheta_{\tilde{S}_2}(x) \Bigg), \Bigg(\Bigg[\sqrt{(\pi_{\tilde{S}_1}^-(x))^2 + (\pi_{\tilde{S}_2}^-(x))^2 - (\pi_{\tilde{S}_1}^-(x))^2(\pi_{\tilde{S}_2}^-(x))^2}, \sqrt{(\pi_{\tilde{S}_1}^+(x))^2 + (\pi_{\tilde{S}_2}^+(x))^2 - (\pi_{\tilde{S}_1}^+(x))^2(\pi_{\tilde{S}_2}^+(x))^2} \Bigg], \sqrt{(\pi_{\tilde{S}_1}(x))^2 + (\pi_{\tilde{S}_2}(x))^2 - (\pi_{\tilde{S}_1}(x))^2(\pi_{\tilde{S}_2}(x))^2} \Bigg) \Bigg\rangle \mid x \in X \Bigg\},$$

(iii) $\lambda\tilde{S}_1 =$

$$\Bigg\{ \Bigg\langle \Bigg(\Bigg[\sqrt{1-(1-(\mu_{\tilde{S}_1}^-(x))^2)^\lambda}, \sqrt{1-(1-(\mu_{\tilde{S}_1}^+(x))^2)^\lambda} \Bigg], \sqrt{1-(1-(\mu_{\tilde{S}_1}(x))^2)^\lambda} \Bigg), \Bigg(\Big[(\vartheta_{\tilde{S}_1}^-(x))^\lambda, (\vartheta_{\tilde{S}_1}^+(x))^\lambda \Big], (\vartheta_{\tilde{S}_1}(x))^\lambda \Bigg), \Bigg(\Big[(\pi_{\tilde{S}_1}^-(x))^\lambda, (\pi_{\tilde{S}_1}^+(x))^\lambda \Big], (\pi_{\tilde{S}_1}(x))^\lambda \Bigg) \Bigg\rangle \mid x \in X \Bigg\} \quad \text{for} \quad \lambda > 0,$$

(iv) $\tilde{S}_1{}^\lambda =$

$$\Bigg\{ \Bigg\langle \Bigg(\Big[(\mu_{\tilde{S}_1}^-(x))^\lambda, (\mu_{\tilde{S}_1}^+(x))^\lambda \Big], (\mu_{\tilde{S}_1}(x))^\lambda \Bigg), \Bigg(\Big[(\vartheta_{\tilde{S}_1}^-(x))^\lambda, (\vartheta_{\tilde{S}_1}^+(x))^\lambda \Big], (\vartheta_{\tilde{S}_1}(x))^\lambda \Bigg), \Bigg(\Bigg[\sqrt{1-(1-(\pi_{\tilde{S}_1}^-(x))^2)^\lambda}, \sqrt{1-(1-(\pi_{\tilde{S}_1}^+(x))^2)^\lambda} \Bigg], \sqrt{1-(1-(\pi_{\tilde{S}_1}(x))^2)^\lambda} \Bigg) \Bigg\rangle \mid x \in X \Bigg\} \quad \text{for} \quad \lambda > 0.$$

Definition 3. Consider two SCF sets as:

$$\tilde{S}_f = \left\{ \left\langle x, \left(\Big[\mu_{\tilde{S}_f}^-(x), \mu_{\tilde{S}_f}^+(x) \Big], \mu_{\tilde{S}_f}(x) \right), \left(\Big[\vartheta_{\tilde{S}_f}^-(x), \vartheta_{\tilde{S}_f}^+(x) \Big], \vartheta_{\tilde{S}_f}(x) \right), \left(\Big[\pi_{\tilde{S}_f}^-(x), \pi_{\tilde{S}_f}^+(x) \Big], \pi_{\tilde{S}_f}(x) \right) \mid x \in X \right\rangle \right\}; f(=1,2).$$

To obtain numerical representations from the SCF sets, a score function $(Sc(\tilde{S}_f))$ shown in Eq. (1) is applied. If multiple sets result in equal scores, an accuracy function $(Ac(\tilde{S}_f))$—defined in Eq. (2)—serves as a tie-breaking mechanism. Eq. (1) is used to compute the score function [3]:

$$Sc\left(\tilde{S}_f\right) = \frac{1}{2}\left(1+\frac{1}{9}\left(\left(\mu^-_{\tilde{S}_f}(x)+\mu^+_{\tilde{S}_f}(x)+\mu_{\tilde{S}_f}(x)\right)^2+\left(\vartheta^-_{\tilde{S}_f}(x)+\vartheta^+_{\tilde{S}_f}(x)+\vartheta_{\tilde{S}_f}(x)\right)^2 + \left(\pi^-_{\tilde{S}_f}(x)+\pi^+_{\tilde{S}_f}(x)+\pi_{\tilde{S}_f}(x)\right)^2\right)\right). \tag{1}$$

$$Ac\left(\tilde{S}_f\right) = \frac{1}{9}\left(\left(\mu^-_{\tilde{S}_f}(x)+\mu^+_{\tilde{S}_f}(x)+\mu_{\tilde{S}_f}(x)\right)^2+\left(\vartheta^-_{\tilde{S}_f}(x)+\vartheta^+_{\tilde{S}_f}(x)+\vartheta_{\tilde{S}_f}(x)\right)^2 + \left(\pi^-_{\tilde{S}_f}(x)+\pi^+_{\tilde{S}_f}(x)+\pi_{\tilde{S}_f}(x)\right)^2\right). \tag{2}$$

2.1.2 Aczel-Alsina *t-norm* and *t-conorm* based aggregation operator for the SCF

Definition 4. The Aczel-Alsina *t-norm* (TN^η_{AA}) and *t-conorm* (TC^η_{AA}) are calculated using Eq. (3) and Eq. (4), respectively [4]:

$$TN^\eta_{AA}(a,b) = \exp\left\{-\left((-\ln a)^\eta + (-\ln b)^\eta\right)^{\frac{1}{\eta}}\right\}. \tag{3}$$

$$TC^\eta_{AA}(a,b) = 1-\exp\left\{-\left((-\ln(1-a))^\eta + (-\ln(1-b))^\eta\right)^{\frac{1}{\eta}}\right\}. \tag{4}$$

herein, $a,b \in [0,1]$ and $\eta > 0$.

Definition 5. Consider a family of the SCF sets defined as:

$$\tilde{S}_f = \left\{\left\langle x, \left(\left[\mu_{\tilde{S}_f}(x), \mu^+_{\tilde{S}_f}(x)\right], \mu_{\tilde{S}_f}(x)\right), \left(\left[\vartheta^-_{\tilde{S}_f}(x), \vartheta^+_{\tilde{S}_f}(x)\right], \vartheta_{\tilde{S}_f}(x)\right), \left(\left[\pi^-_{\tilde{S}_f}(x), \pi^+_{\tilde{S}_f}(x)\right], \pi_{\tilde{S}_f}(x)\right) \mid x \in X\right\rangle\right\}; f(=1,2,...,F).$$

The SCFAAWA aggregation operator is calculated by employing Eq. (5) [3]:

$$\begin{aligned}
&SCFAAWA(\tilde{S}_1,\tilde{S}_2,\ldots,\tilde{S}_f,\ldots,\tilde{S}_F) = \oplus_{f=1}^F \lambda_f \tilde{S}_f = \\
&\left\{\left\langle\left(\left[\sqrt{1-\exp\left\{-\left(\sum_{f=1}^F \lambda_f\left(-\ln\left(1-(\mu^-_{\tilde{S}_f}(x))^2\right)\right)^\eta\right)^{1/\eta}\right\}},\right.\right.\right.\right. \\
&\left.\sqrt{1-\exp\left\{-\left(\sum_{f=1}^F \lambda_f\left(-\ln\left(1-(\mu^+_{\tilde{S}_f}(x))^2\right)\right)^\eta\right)^{1/\eta}\right\}}\right], \\
&\left.\sqrt{1-\exp\left\{-\left(\sum_{f=1}^F \lambda_f\left(-\ln\left(1-(\mu_{\tilde{S}_f}(x))^2\right)\right)^\eta\right)^{1/\eta}\right\}}\right), \\
&\left(\left[\sqrt{\exp\left\{-\left(\sum_{f=1}^F \lambda_f\left(-\ln\left((\vartheta^-_{\tilde{S}_f}(x))^2\right)\right)^\eta\right)^{1/\eta}\right\}}, \sqrt{\exp\left\{-\left(\sum_{f=1}^F \lambda_f\left(-\ln\left((\vartheta^+_{\tilde{S}_f}(x))^2\right)\right)^\eta\right)^{1/\eta}\right\}}\right],\right. \\
&\left.\sqrt{\exp\left\{-\left(\sum_{f=1}^F \lambda_f\left(-\ln\left((\vartheta_{\tilde{S}_f}(x))^2\right)\right)^\eta\right)^{1/\eta}\right\}}\right), \left(\left[\sqrt{\exp\left\{-\left(\sum_{f=1}^F \lambda_f\left(-\ln\left((\pi^-_{\tilde{S}_f}(x))^2\right)\right)^\eta\right)^{1/\eta}\right\}},\right.\right. \\
&\left.\left.\left.\sqrt{\exp\left\{-\left(\sum_{f=1}^F \lambda_f\left(-\ln\left((\pi^+_{\tilde{S}_f}(x))^2\right)\right)^\eta\right)^{1/\eta}\right\}}\right], \sqrt{\exp\left\{-\left(\sum_{f=1}^F \lambda_f\left(-\ln\left((\pi_{\tilde{S}_f}(x))^2\right)\right)^\eta\right)^{1/\eta}\right\}}\right)\right\rangle \\
&\left.\mid x \in X\right\}.
\end{aligned} \tag{5}$$

The weight vector $\lambda_f = (\lambda_1, \lambda_2, \ldots, \lambda_f, \ldots, \lambda_F)$ has relation with $\tilde{S}_f (f = 1, 2, \ldots, F)$. Also, $\lambda_f > 0$ and $\sum_{f=1}^F \lambda_f = 1$ and $\eta > 0$ [4].

2.1.3 The novel SFC–Aczel–Alsina–RANCOM–AROMAN hybrid method

A hybrid method, SCF–Aczel–Alsina–RANCOM–AROMAN, was proposed in this study to assess the performance levels of alternatives. The method comprised two phases: In the first stage, experts evaluated the criteria and their significance levels were determined via the SCF–RANCOM method. In the second stage, alternative performances were evaluated using the AROMAN method based on the obtained weights. The decision-making process was carried out with expert involvement in both stages of the hybrid framework. The decision model of the proposed SFC–Aczel–Alsina–RANCOM–AROMAN hybrid method included experts ($\mathrm{E} = \{e_1, e_2, \ldots, e_k, \ldots, e_K\}$ $(k = 1, 2, \ldots, K)$), qualitative criteria $\left(\mathrm{C}^{\mathbb{L}} = \left\{c_1^{\mathbb{L}}, c_2^{\mathbb{L}}, \ldots, c_l^{\mathbb{L}}, \ldots, c_L^{\mathbb{L}}\right\}\right.$ $(l = 1, 2, \ldots, L)$), quantitative criteria $\left(\mathrm{C}^{\mathbb{N}} = \left\{c_1^{\mathbb{N}}, c_2^{\mathbb{N}}, \ldots, c_n^{\mathbb{N}}, \ldots, c_N^{\mathbb{N}}\right\}\right.$ $(n = 1, 2, \ldots, N)$), total criteria $\left(\mathrm{C}^{\mathbb{T}} = \left\{c_1^{\mathbb{T}}, c_2^{\mathbb{T}}, \ldots, c_t^{\mathbb{T}}, \ldots, c_T^{\mathbb{T}}\right\}\right.$ $(t = 1, 2, \ldots, T)$) and alternatives ($\mathrm{A} = \{A_1, A_2, \ldots, A_i, \ldots, A_m\}$ $(i = 1, 2, \ldots, m)$). The steps of implementing the SFC–Aczel–Alsina–RANCOM–AROMAN hybrid method were as follows:

• **Stage 1** – Criteria weighting based on the SCF–RANCOM method [5]:

Step 1-1: Expertise levels were first evaluated by domain experts (e_k) utilizing the linguistic scale outlined in Table 1. The linguistic terms were subsequently transformed into their respective SCF values, upon which the SCF-based expert evaluation matrix $\left(\tilde{\mathbb{E}} = \left[\tilde{\mathbb{E}}_k\right]_K\right)$ was formulated.

Table 1. Expertise/criteria/alternative evaluation levels [3, 6]

Expertise/Criteria/Alternative Evaluation Levels	SCF Numbers $\{([\mu^-(x), \mu^+(x)], \mu(x)), ([\vartheta^-(x), \vartheta^+(x)], \vartheta(x)), ([\pi^-(x), \pi^+(x)], \pi(x))\}$
Extremely high importance (EHI)	$\{([0.80, 0.90], 0.85), ([0.00, 0.10], 0.05), ([0.00, 0.10], 0.05)\}$
Very high importance (VHI)	$\{([0.70, 0.80], 0.75), ([0.10, 0.20], 0.15), ([0.10, 0.20], 0.15)\}$
High importance (HI)	$\{([0.60, 0.70], 0.65), ([0.20, 0.30], 0.25), ([0.20, 0.30], 0.25)\}$
Slightly high importance (SHI)	$\{([0.50, 0.60], 0.55), ([0.30, 0.40], 0.35), ([0.30, 0.40], 0.35)\}$
Medium importance (MI)	$\{([0.40, 0.50], 0.45), ([0.40, 0.50], 0.45), ([0.40, 0.50], 0.45)\}$
Slightly low importance (SLI)	$\{([0.30, 0.40], 0.35), ([0.30, 0.40], 0.35), ([0.50, 0.60], 0.55)\}$
Low importance (LI)	$\{([0.20, 0.30], 0.25), ([0.20, 0.30], 0.25), ([0.20, 0.70], 0.65)\}$
Very low importance (VLI)	$\{([0.10, 0.20], 0.15), ([0.10, 0.20], 0.15), ([0.10, 0.80], 0.75)\}$
Extremely low importance (ELI)	$\{([0.00, 0.10], 0.05), ([0.00, 0.10], 0.05), ([0.00, 0.90], 0.85)\}$

Step 1-2: Eq. (6) was used to calculate the score function values of the experts $\left(Sc\left(\tilde{\mathbb{E}}_k\right)\right)$.

$$Sc\left(\tilde{\mathbb{E}}_k\right) = \frac{1}{2}\left(1 + \frac{1}{9}\left(\left(\mu_{\tilde{\mathrm{I}}_k}^-(x) + \mu_{\tilde{\mathrm{I}}_k}^+(x) + \mu_{\tilde{\mathrm{I}}_k}(x)\right)^2 + \left(\vartheta_{\tilde{\mathrm{I}}_k}^-(x) + \vartheta_{\tilde{\mathrm{I}}_k}^+(x) + \vartheta_{\tilde{\mathrm{I}}_k}(x)\right)^2 + \left(\pi_{\tilde{\mathrm{I}}_k}^-(x) + \pi_{\tilde{\mathrm{I}}_k}^+(x) + \pi_{\tilde{\mathrm{I}}_k}(x)\right)^2\right)\right). \tag{6}$$

Step 1-3: The score function values of the experts were normalized by Eq. (7) and the weights of the experts $(\varepsilon = [\varepsilon]_K)$ were calculated:

$$\varepsilon_k = \frac{Sc\left(\tilde{\mathbb{E}}_k\right)}{\sum_{k=1}^{K} Sc\left(\tilde{\mathbb{E}}_k\right)}; (k = 1, \ldots, K), \varepsilon_k \in [0, 1] \tag{7}$$

Step 1-4: Experts (e_k) evaluated the overall criteria $\left(c_t^{\mathbb{T}}\right)$ of the alternatives using the linguistic scale presented in Table 1. These linguistic assessments were then converted into SCF values, forming the SCF-based evaluation matrix for the overall criteria of the alternatives $\left(\tilde{D} = [\tilde{D}_{kt}]_{KT}\right)$.

Step 1-5: To obtain an aggregated criteria evaluation matrix $\left(\tilde{D} = [\tilde{D}_t]_T\right)$, the expert evaluations for each criterion were aggregated using the SCFAAWA aggregation operator as in Eq. (8), which employs the Aczél–Alsina *t-norm* and *t-conorm* within the SCF framework.

$$
\begin{aligned}
\tilde{D}_t =& SCFAAWA\left(\tilde{D}^{(e_1)}, \tilde{D}^{(e_2)}, \ldots, \tilde{D}^{(e_k)}, \ldots, \tilde{D}^{(e_K)}\right) = \oplus_{t=1}^{T} \varepsilon_k \tilde{D}^{e_k} = \\
&\Bigg\{\Bigg(\Bigg[\sqrt{1-\exp\Bigg\{-\Big(\sum_{k=1}^{K}\varepsilon_k\big(-\ln\big(1-(\mu^{-}_{\tilde{D}^{(e_k)}}(x))^2\big)\big)^{\eta}\Big)^{1/\eta}\Bigg\}}, \\
&\sqrt{1-\exp\Bigg\{-\Big(\sum_{k=1}^{K}\varepsilon_k\big(-\ln\big(1-(\mu^{+}_{\tilde{D}^{(e_k)}}(x))^2\big)\big)^{\eta}\Big)^{1/\eta}\Bigg\}}\Bigg], \\
&\sqrt{1-\exp\Bigg\{-\Big(\sum_{k=1}^{K}\varepsilon_k\big(-\ln\big(1-(\mu_{\tilde{D}^{(e_k)}}(x))^2\big)\big)^{\eta}\Big)^{1/\eta}\Bigg\}}\Bigg), \\
&\Bigg(\Bigg[\sqrt{\exp\Bigg\{-\Big(\sum_{k=1}^{K}\varepsilon_k\big(-\ln\big((\vartheta^{-}_{\tilde{D}^{(k)}}(x))^2\big)\big)^{\eta}\Big)^{1/\eta}\Bigg\}}, \\
&\sqrt{\exp\Bigg\{-\Big(\sum_{k=1}^{K}\varepsilon_k\big(-\ln\big((\vartheta^{+}_{\tilde{D}^{(e_k)}}(x))^2\big)\big)^{\eta}\Big)^{1/\eta}\Bigg\}}\Bigg], \\
&\sqrt{\exp\Bigg\{-\Big(\sum_{k=1}^{K}\varepsilon_k\big(-\ln\big((\vartheta_{\tilde{D}^{(e_k)}}(x))^2\big)\big)^{\eta}\Big)^{1/\eta}\Bigg\}}\Bigg), \\
&\Bigg(\Bigg[\sqrt{\exp\Bigg\{-\Big(\sum_{k=1}^{K}\varepsilon_k\big(-\ln\big((\pi^{-}_{\tilde{D}^{(e_k)}}(x))^2\big)\big)^{\eta}\Big)^{1/\eta}\Bigg\}}, \\
&\sqrt{\exp\Bigg\{-\Big(\sum_{k=1}^{K}\varepsilon_k\big(-\ln\big((\pi^{+}_{\tilde{D}^{(e_k)}}(x))^2\big)\big)^{\eta}\Big)^{1/\eta}\Bigg\}}\Bigg], \\
&\sqrt{\exp\Bigg\{-\Big(\sum_{k=1}^{K}\varepsilon_k\big(-\ln\big((\pi_{\tilde{D}^{(e_k)}}(x))^2\big)\big)^{\eta}\Big)^{1/\eta}\Bigg\}}\Bigg)\Bigg) \mid x \in X\Bigg\}.
\end{aligned} \tag{8}
$$

Step 1-6: The aggregated decision matrix values were converted into score function values by Eq. (9):

$$
\begin{aligned}
D_t = Sc\left(\tilde{D}_t\right) = \frac{1}{2}\left(1\frac{1}{9}\left(\left(\mu^{-}_{\tilde{D}_t}(x)+\mu^{+}_{\tilde{D}_t}(x)+\mu_{\tilde{D}_t}(x)\right)^2+\left(\vartheta^{-}_{\tilde{D}_t}(x)+\vartheta^{+}_{\tilde{D}_t}(x)+\vartheta_{\tilde{D}_t}(x)\right)^2\right.\right. \\
\left.\left.+\left(\pi^{-}_{\tilde{D}_t}(x)+\pi^{+}_{\tilde{D}_t}(x)+\pi_{\tilde{D}_t}(x)\right)^2\right)\right).
\end{aligned} \tag{9}
$$

Step 1-7: Based on the aggregated evaluations of the criteria, the relative criteria comparison matrix ($\mathbb{R} = [\mathbb{R}_{tt'}]_{TT}$) was subsequently formulated to represent the comparative significance of each criterion as in Eq. (10):

$$
\mathbb{R}_{tt'} = \begin{cases} \textit{If } D_t > D_{t'} \textit{ then } 1 \\ \textit{If } D_t = D_{t'} \textit{ then } 0.5; \ (t, t' = 1, 2, \ldots, T) \\ \textit{If } D_t < D_{t'} \textit{ then } 0 \end{cases} \tag{10}
$$

Step 1-8: The total values of the relative criteria comparison matrix ($\mathbb{O} = [\mathbb{O}_t]_T$) were calculated with Eq. (11):

$$
\mathbb{O}_t = \sum_{t=1}^{T} \mathbb{R}_{tt'}; \ (t, t' = 1, 2, \ldots, T) \tag{11}
$$

Step 1-9: As the last step of the RANCOM method, the importance levels of the criteria ($\omega = [\omega_t]_T$) were calculated with Eq. (12):

$$
\omega_t = \frac{\mathbb{O}_t}{\sum_{t=1}^{T} \mathbb{O}_n}; \ (t = 1, 2, \ldots, T) \tag{12}
$$

• **Stage 2** – Ranking of alternatives using the AROMAN method [7].

Step 2-1: Each alternative was evaluated by the experts according to the qualitative criteria $\left(c_l^{\mathbb{L}}\right)$ using the linguistic expressions in Table 1. Thus, a decision matrix was created for the qualitative criteria $\left(\tilde{\mathbb{U}} = [\tilde{\mathbb{U}}_{kl}]_{K\mathbb{L}}\right)$.

Step 2-2: The SCFAAWA aggregation operator in Step 1-5 was used to aggregate the expert opinions. This created an aggregated decision matrix for the qualitative criteria $\left(\tilde{\mathbb{F}} = [\tilde{\mathbb{F}}_l]_{\mathbb{L}}\right)$.

Step 2-3: The score function values $\left(Sc\left(\tilde{\mathbb{F}}_l\right)\right)$ were calculated as in Step 1-6.

Step 2-4: By combining the score function values obtained in Step 2-3 with the quantitative data, the initial decision matrix ($\mathrm{A} = [\mathrm{A}_{it}]_{mT}$) to be used in the AROMAN method was obtained.

Step 2-5: The initial decision matrix was normalized with Eq. (13) as the first normalization step:

$$\mathcal{N}_{it}^1 = \begin{cases} \dfrac{\mathrm{A}_{it} - \min\limits_{1\le a\le \mathcal{A}}(\mathrm{A}_{it})}{\max(\mathrm{A}_{it}) - \min(\mathrm{A}_{it})}, & \textit{for benefit criteria} \\ \dfrac{\max\limits_{1\le a\le \mathcal{A}}(\mathrm{A}_{it}) - \mathrm{A}_{it}}{\max(\mathrm{A}_{it}) - \min(\mathrm{A}_{it})}, & \textit{for cost criteria} \end{cases} ;\ (i = 1, 2, \ldots, m; t = 1, 2, \ldots, T). \tag{13}$$

Step 2-6: The initial decision matrix was normalized with Eq. (14) as the second normalization step:

$$\mathcal{N}_{it}^2 = \begin{cases} \dfrac{\mathrm{A}_{it}}{\sqrt{\sum\limits_{i=1}^{m} (\mathrm{A}_{it})^2}}, & \textit{for benefit criteria} \\ 1 - \dfrac{\mathfrak{G}_{ac}}{\sqrt{\sum\limits_{i=1}^{m} (\mathrm{A}_{it})^2}}, & \textit{for cost criteria} \end{cases}. \tag{14}$$

Step 2-7: The decision matrices normalized by two different methods were aggregated by Eq. (15):

$$\mathcal{N}_{it}^* = \frac{\tau\mathcal{N}_{it}^1 + (1-\tau)\mathcal{N}_{it}^2}{2};\ (\tau \in [0, 1]). \tag{15}$$

Step 2-8: The aggregated decision matrix was weighted by Eq. (16) with criteria importance levels:

$$\mathrm{G}_{it} = \omega_t\, \mathcal{N}_{it}^*. \tag{16}$$

Step 2-9: The weighted decision matrix values were summed separately for the benefit and cost criteria using Eq. (17) and Eq. (18):

$$\mathcal{C}_i^- = \sum_{t=1}^{T} \mathrm{G}_{it};\ \textit{for cost criteria}. \tag{17}$$

$$\mathcal{C}_i^+ = \sum_{t=1}^{T} \mathrm{G}_{it};\ \textit{for benefit criteria}. \tag{18}$$

Step 2-10: Eq. (19) was used to obtain the ranking values of the alternatives:

$$\Delta_i = \left(\mathcal{C}_i^-\right)^{\phi} + \left(\mathcal{C}_i^+\right)^{(1-\phi)}. \tag{19}$$

The parameter ϕ represents the relative significance level of the cost-based criteria and is computed as the ratio of the number of cost-based criteria to the number of benefit-based criteria and $\phi \in [0, 1]$.

Step 2-11: Eq. (20) was used to obtain the final ranking values of the alternatives:

$$\nabla_i = \frac{\Delta_i}{\sum\limits_{i=1}^{m} \Delta_i}. \tag{20}$$

3 Application

In this study, the hybrid method of SCF–Aczel–Alsina–RANCOM–AROMAN was proposed to assess the performance of ten healthcare companies listed in the S&P 500 index during year 2018 to year 2023, a period marked by the global impact of the COVID-19 pandemic. A comprehensive MCDM framework was developed by integrating both financial metrics, e.g., Tobin's Q ratio and revenue growth, and non-financial dimensions such as sustainability, ethical management, and crisis resilience. The decision model derived from expert evaluations modeled via Spherical Cubic Fuzzy (SCF) sets and aggregated with the Aczel–Alsina operator. The rankings of firms were generated by the RANCOM and AROMAN methods, and supported by the expertise of ten professionals. This structure enables a robust analysis that addresses both quantitative and qualitative uncertainties.

3.1 Evaluation Criteria and Healthcare Company Alternatives for the Analyzing Financial Performance

During the phase of implementation, 16 evaluation criteria comprising both financial and non-financial indicators were utilized to assess the financial performance of ten healthcare companies listed in the S&P 500 index. These criteria reflected a comprehensive framework that incorporated traditionally financial ratios such as Tobin's Q, Revenue Growth, Operating Profit, and Leverage, alongside qualitative sustainability and governance indicators including Human Resource Management, Environmental Policy, and Business Ethics. Together, these metrics offered an integrated perspective of profitability, operational efficiency, financial structure related resilience. The criteria, which formed the basis of the MCDM methods, are detailed as follows:

Financial Ratios:

Leverage Ratio (C1): This is a fundamental financial indicator of a company expressed through the proportion of total debts to total assets. The ratio reveals the extent to which assets are financed through debts and plays a critical role in assessing the capital structure of a business. A high leverage ratio indicates an excessive reliance on debt financing, which may increase the risks associated with long-term debt repayment capacity. Conversely, a low leverage ratio suggests a more conservative borrowing policy and potentially stable financial structure. This ratio is frequently employed by investors and financial analysts to evaluate a firm's exposure to debt-related risks, its resilience during financial crises, and its overall financial sustainability. Moreover, leverage ratio serves as an essential guide in shaping the future investment decisions, debt management strategies, and growth potential of a company [8].

Tobin's Q Ratio (C2): This ratio represents the proportion of the market value to the book value of the total assets. Developed by Nobel Prize-winning economist James Tobin, this metric aids in analyzing how the market perceives the company and the extent to which its assets are valued in financial markets. The ratio is calculated by comparing the stock market value with the book or accounting value of its assets, as reported in the balance sheet. This comparison reveals the gap between the actual market valuation and the accounting-based valuation of a company. A Tobin's Q ratio greater than 1 indicates that the market value exceeds the book value of assets, hence suggesting that the market holds a positive outlook on the future growth potential of a firm. This reflects high investor confidence and a perception that the value-creation capacity of a company exceeds expectations. Conversely, a Q ratio below 1 implies market skepticism about the performance or future prospects of a company and this indicates that the expected returns on its assets are considered to be low [9]. When a Tobin's Q ratio is equal to 1, it indicates a state of equilibrium between the market value and the book value of assets. In such case, the market perceives the intrinsic value of a company to be accurately reflected in its financial statements. Tobin's Q is widely recognized as a critical financial analysis tool, particularly in strategic assessments such as investment decisions, mergers, and acquisitions. It enables a comprehensive evaluation of corporate valuation by incorporating both internal factors, e.g., financial structure, and external elements, e.g., market perception, thus offering a holistic perspective on the potential and positioning of a firm [10].

Revenue Growth Rate (C3): The revenue growth rate is one of the key financial performance indicators that measures the degree of increase or decrease in sales revenue over a specific period, when compared to the previous ones. This metric provides direct insight into the capacity of a firm to generate income, expand its market, and operate efficiently. It also plays a crucial role in evaluating the effectiveness of growth strategies for a company. Positive and high growth rates indicate that a company is experiencing sustained revenue increase, securing a strong market position, and facing robust customers' demands [11]. Conversely, low or negative growth rates may signal weakening sales performance, contracting markets, and declining competitive strength. Therefore, the revenue growth rate is closely monitored by investors, analysts, and managers as an important metric for assessing the financial health, growth potential, and future strategic direction of a firm. Beyond assessing historical performance, the revenue growth rate serves as a forward-looking metric that informs sales forecasts, investment decisions, and budgeting processes.

Operating Profit Growth Rate (C4): This rate is a key financial performance indicator that measures the increase or decrease in earnings generated from the core business activities over time. This metric is particularly useful for assessing the operational success within the primary line of businesses, efficiency levels, and cost management capabilities. By excluding non-operating income and expenses, the ratio reflects the true profitability trend derived solely from core operations. A high operating profit growth rate not only indicates increased sales but also suggests that the company is effectively managing its costs and improving operational efficiency [12]. In contrast, low and negative growth rates may indicate operational inefficiencies, rising costs, or a decline in market demand. Since this metric excludes non-operating incomes and expenses such as interest incomes, foreign exchange gains and returns from financial investments, it is considered a more reliable indicator for assessing the sustainability and performance of the core business model. For investors and corporate managers, the operating profit growth rate holds critical importance, particularly in competitive markets, as it reveals the extent a company can generate value from its core operations.

Equity Growth Rate (C5): This rate is a fundamental financial performance indicator to reflect the extent a company increases the equity of its shareholders over a specific period. This ratio reveals the value generated from internal resources, the profitability level, and the extent of earnings reinvested into equity. It is calculated by subtracting the equity of the previous period from that of the current period; then the result is divided by the equity of the previous period. A high equity growth rate indicates that the company is following a sustainable growth trajectory [13] and has successfully transformed its earnings into equity. The company could inspire long-term confidence among investors and has reduced its reliance on external financing within its capital structure. Conversely, a low and negative equity growth rate may signal the erosion or stagnation of shareholders' equity, thus raising concerns about the internal financing capacity of a firm. This ratio is particularly valuable for investors and analysts aiming to evaluate the financial resilience, profitability trends, and future growth potential of a company. It plays a critical role in shaping decisions related to dividend policies, reinvestment strategies, and borrowing needs.

Firm Size (C6): Firm size, measured by the total assets, refers to the aggregate monetary value of all assets owned by a business at a specific point in time. This indicator corresponds to the total on the asset side of the balance sheet and provides direct insight into the scale of operation, investment capacity, business volume, and overall financial position of the enterprise. Firms with a high level of total assets generally operate across broader markets, possess greater investment opportunities, and access more substantial financial resources [14]. This condition indicates the size and relative significance of a firm in the industry. Conversely, a lower total asset base may reflect an entity with a smaller scale of operation or limited resources. This criterion holds critical importance in both internal financial assessments and cross-industry benchmarking.

Net Profit (C7): This financial metric represents the final financial gain a company achieves at the end of a specific period after deducting all expenses including the cost of sales, operating expenses, interest expenses, taxes, and depreciation from the total revenue. Net profit directly reflects the efficiency and profitability of a company during the operational period. A positive net profit indicates that the revenues of a company exceed its expenses, thus signaling value creation over the period. Conversely, a negative net profit denotes a loss and implies that the operations of a company are insufficient to cover the associated costs [15]. This indicator serves as a fundamental metric for evaluating the overall financial performance, strategic effectiveness, and long-term sustainability from the perspectives of investors, managers, and stakeholders. Moreover, net profit functions as a critical input for advanced financial analyses including earnings per share, dividend distribution, reinvestment decisions, and costs of capital assessments.

Total Liabilities (C8): This financial indicator represents the aggregate amount of all debts and financial obligations a company holds as of a specific date. This indicator reveals the extent a firm relies on external financing to support its assets and serves as a fundamental financial metric for analyzing the leverage position. A high level of total liabilities indicates significant use of financial leverage, which may also imply elevated financial risks. Conversely, a low level of liabilities suggests that the company is less dependent on debts and has maintained a more conservative and stable financial structure [14].

Revenue (C9): This financial indicator represents the total economic benefits earned by a business in exchange for goods and services provided during a specific period. From the financial reporting perspective, revenue reflects the gross earnings derived from the core operation of a company and thus serves as a direct indicator of its commercial success and cash-generating capacity [16]. The level of revenue reflects the effectiveness of a company in the market, its ability to meet customers' demands, and its value-creation potential of products or services. Increasing revenue typically signals business expansion, competitive strength, and growing market presence whereas declining revenue may indicate demand contraction, loss of competitiveness, and operational inefficiencies. In financial analysis, revenue is not only essential for evaluating performance but also fundamental in assessing profitability ratios, growth metrics, and cash flow analyses. Therefore, revenue is regarded as one of the most basic and prioritized financial indicators by investors, managers, and analysts in assessing the overall financial health of a company.

Operating Profit (C10): This financial indicator refers to the income a business earns from its core operating activities. This indicator represents the amount remained after deducting direct and indirect costs, namely the cost for goods sold, marketing expenses, general and administrative costs, from the revenue generated through selling products or services. Since it excludes non-operating income and expenses, it provides insights solely into the efficiency and profitability of the fundamental business model. A high operating profit suggests strong operational performance, effective cost management, and sustainable earnings derived from core activities. Conversely, a low and declining operating profit may indicate operational inefficiencies, increased cost pressures, or sales volume decrease.

Market Value (C11): This financial indicator is a fundamental financial indicator that reflects the total valuation of a company in the capital market. It is commonly applied to publicly traded companies and is calculated by multiplying the current stock price by the total number of outstanding shares. This computation reveals the worth that a company is perceived in financial markets. Market value provides investors and financial analysts with direct insights into the financial magnitude, market reputation, and future outlook of a firm. A high market value typically signals stable financial performance, strong profitability, and considerable growth potential. In contrast, a low market value may indicate limited growth expectations or declining investor confidence. This indicator plays a critical role in evaluating market positioning, conducting benchmarking with peer firms, and guiding investment decisions. Furthermore, it is one of the primary metrics used in strategic financial processes, such as mergers and acquisitions, risk assessments, and portfolio management.

Human Resource Management (HRM) Maturity Level (C12): This indicator refers to the degree of strategic integration and maturity of human resource management in an organization. Conceptually, it encompasses the alignment of core HRM functions including recruitment and selection, training and development, performance management, compensation, and employee engagement with the primary objective and strategic direction of an organization. The strategic HRM literature emphasizes the importance of effectively managing human capital, which is regarded as a critical resource for achieving sustained competitive advantages. A high level of HRM maturity in implementation is manifested through the use of competency-based selection methods, continuous employee training initiatives, talent management programs, and performance-based reward systems. From the managerial perspective, contemporary research demonstrates that advanced HRM practices enhance employee productivity and motivation, reduce turnover rates, and impact the overall organizational performance positively [17]. High performance HRM practices have been empirically supported by academic research to enhance the financial performance of a firm, hence increasing both its productivity and profitability [18].

Supply Chain Management Maturity Level (C13): This indicator refers to the extent a company has integrated and matured its supply chain process. Conceptually, this level encompasses the degree of integration in the management of materials, information, and financial flows across the entire supply chain from suppliers to end customers. In the literature, supply chain maturity models are utilized to define the developmental stages of firms across various dimensions of supply chain management. As companies progress to the advanced level of maturity, their supply chains become more integrated, agile, and capable [19]. In practice, a high level of supply chain management maturity involves achieving both internal and external integration, establishing close collaboration with suppliers and customers, utilizing advanced analytics and digital technologies in inventory and production planning, and adopting lean and agile operational techniques. From the managerial perspective, a mature supply chain management level enhances operational efficiency, reduces costs, and improves adaptability to demand fluctuations, thereby providing firms with a significant competitive advantage. Academic research highlights that increasing the maturity and integration level of supply chain processes contributes to improved firm performance and greater process capacity. Consequently, alongside the maturity of supply chain management, companies become more resilient to market uncertainties, more responsive to customers' demands, and on the whole, more successful in strategic and operational outcomes.

Risk and Crisis Management Maturity Level (C14): This indicator refers to the extent an organization has developed systematic risk management practices and its capacity to prepare for unexpected crises. Conceptually, this level encompasses the institutional maturity of processes such as risk identification and assessment, and the formulation of appropriate response strategies within the framework of enterprise risk management. It also includes a holistic crisis management approach that involves proactive preparedness, emergency planning, crisis communication, and recovery or business continuity measures. In practice, a high level of risk and crisis management maturity is characterized by the establishment of a pervasive risk culture throughout the organization: (1) Managers can detect and report uncertainties early; (2) Comprehensive risk inventories and scenario analyses are regularly conducted; (3) Emergency and crisis response plans are developed and tested through simulations; and (4) An effective stakeholder communication strategy is implemented during crises. From the managerial perspective, to minimize operational disruptions and recover rapidly, firms that are well-prepared for crises and can manage risks effectively tend to be more resilient in the face of unexpected shocks. For instance, the concept of organizational resilience, defined as the ability to anticipate risks, manage unexpected events, and adapt to changing conditions quickly, is more pronounced in organizations with high levels of risk management maturity. Additionally, it has been reported that companies with enhanced risk management maturity are able to improve operational performance by improving quality and reducing costs [20]. Therefore, organizations with a high level of risk and crisis management maturity tend to demonstrate more stable performance both financially and managerially, and are better positioned to maintain their competitive advantages in environments characterized by uncertainty.

Level of Business Ethics (C15): This indicator refers to the extent a company integrates ethical principles and values into its managerial processes and adheres to moral standards in all stakeholder interactions. Conceptually, business ethics encompass the execution of business activities and decision-making processes in accordance with core ethical principles such as honesty, fairness, responsibility, transparency, and respect for the law. This ethical framework guides organizational conduct across a wide range of domains, including employees' behavior, supplier and customer relations, corporate governance practices, and initiatives related to social and environmental responsibilities. In practice, organizations with a high level of business ethics implement formal codes of ethics and conduct guidelines, provide regular ethics training to employees, establish whistleblowing and feedback mechanisms to prevent ethical violations, and foster a culture rooted in moral values. Ethical leadership at the top management level is especially critical for embedding ethical standards throughout an organization. From the managerial perspective, numerous studies showed that companies with strong ethical commitments experience enhanced corporate reputation, increased customers' trust and loyalty, and heightened employee engagement and motivation [21]. Organizations that prioritize ethical conduct and social responsibility tend to achieve greater financial success and sustainability in the long term.

Ethical practices reduce the risk of legal sanctions, preserve brand value, and strengthen stakeholders' trust in the company. In contrast, organizations with a weak ethical culture often face significant managerial challenges such as reputational damage, decreased customers' confidence, and higher employee turnover rates. Consequently, it is widely recognized in the literature that firms with high levels of business ethics demonstrate enduring corporate sustainability and performance in managerial decisions and strategic planning.

Environmental Policy and Management Level (C16): This indicator refers to the extent an enterprise integrates environmental sustainability principles into its organizational policies and processes, as well as the maturity of environmental management practices. Conceptually, this level encompasses the set of principles, standards, and strategies adopted by a company to systematically control and mitigate the environmental impacts of its operations. Many organizations aim to enhance their environmental performance and ensure regulatory compliance by implementing international environmental management standards [22]. At the implementation level, a high degree of environmental management maturity is reflected through tangible initiatives such as reduction of carbon emissions and waste, improvements in energy and water efficiency, adoption of renewable energy sources, design of green products, sourcing of environmentally friendly raw materials, and application of green supply chain practices. Internally, this level includes institutionalizing the awareness of environmental responsibility and monitoring sustainability performance indicators such as carbon footprints and recycling rates by senior management actively. From the managerial perspective, companies that implement robust environmental policies and effective environmental management systems tend to achieve greater operational efficiency, lower waste and energy costs, hence proactively mitigating environmental risks, avoiding legal penalties, and enhancing their corporate reputation [23]. More and more recent studies have demonstrated the positive impact of environmental management practices on company performance. For instance, empirical findings support that companies adopting sustainability-oriented strategies with internalized environmental management practices experience improvements in both market value and profitability [24]. Accordingly, firms with a high level of environmental management maturity tend to comply more effectively with regulatory requirements and cultivate a responsible environmental image in the eyes of stakeholders, thereby gaining a sustainable competitive advantage in the long term.

Market Equities as Alternatives:

Eli Lilly and Company (A1): Founded in 1876 by Colonel Eli Lilly in Indianapolis of the United States, Eli Lilly and Company is one of the world's leading pharmaceutical firms. The company specializes in developing therapeutic solutions in fields such as diabetes, oncology, immunology, and neuroscience, and operates globally in the discovery, manufacturing, and marketing of products targeting these areas. Today, the company employs more than 46,000 people worldwide, with approximately 10,000 dedicated exclusively to research and development (R&D) activities. Eli Lilly conducts clinical trials in over 55 countries and maintains manufacturing facilities in nine countries as well as R&D centers in seven different countries. Its products are marketed in more than 105 countries. With expensive global infrastructure, the company is able to accelerate the development of innovative pharmaceuticals and reach diverse international markets effectively. The substantial investments in R&D constitute the cornerstone of its sustainable growth strategy [25].

United Health Group, Inc. (A2): As one of the largest healthcare and health technology companies based in the United States, this company was founded by Richard T. Burke in 1977 and headquartered in Eden Prairie of Minneapolis. The operation of this company encompasses services in healthcare, software solutions, and data consulting; it offers services in four main segments, i.e., UnitedHealthcare, OptumHealth, OptumInsight, and OptumRx. The UnitedHealthcare segment focuses on coordinating patient care, improving access to medical services, analyzing cost trends, and managing pharmacy services. It leverages technological and operational capabilities of Optum to enhance collaboration with healthcare providers and to deliver a more streamlined experience for users. The OptumHealth segment delivers health and wellness services to a diverse client base that includes insurers, employers, government agencies, life sciences firms, and individual consumers. OptumInsight provides core stakeholders in the healthcare sector with data analytics, technological solutions, and insight-driven consultancy services. Finally, the OptumRx segment offers comprehensive pharmaceutical care through drug prescription management and pharmacy services [26].

Johnson & Johnson (A3): Founded in 1886 by Robert Wood Johnson I, James Wood Johnson, and Edward Mead Johnson Sr., Johnson & Johnson is a global healthcare holding company headquartered in New Brunswick, New Jersey, the USA. The company operates in research and development, manufacturing, and marketing of products in the healthcare sector. Structured under three main segments, i.e., Consumer Health, Pharmaceuticals, and Medical Devices, Johnson & Johnson offers a broad portfolio addressing diverse health needs. The Consumer Health segment includes products related to baby care, oral care, beauty, over-the-counter medications, women health, and wound care. This segment primarily targets individual consumers by addressing their daily health and wellness needs. The Pharmaceuticals segment focuses on therapeutic areas such as immunology, infectious diseases, neuroscience, oncology, pulmonary hypertension, and cardiovascular and metabolic disorders. Known for substantial investments in the development of innovative therapies, this segment of Johnson & Johnson represents a significant portion of research and development capabilities. The Medical Devices segment provides advanced technological devices and equipment for orthopedics, surgery, cardiovascular and neurovascular systems, and vision care; its primary goal is to enhance the effectiveness of both clinical practices and patient care [27].

AbbVie Incorporated (A4): This is a research-based biopharmaceutical company founded on October 19, 2011 and headquartered in North Chicago, Illinois, the USA. The company is primarily focused on the development and global commercialization of pharmaceutical products aimed at treatment of complex and chronic diseases. The research and therapeutic strategy of AbbVie targets a broad spectrum of serious health conditions, including rheumatology, gastroenterology, dermatology, oncology (particularly hematologic malignancies), virology (hepatitis C virus and human immunodeficiency virus), neurological disorders such as Parkinson's disease, thyroid diseases, complications related to cystic fibrosis, and endometriosis-associated pain. One of the most significant products of AbbVie is Humira, a biologic medication administered via injection. As of year 2023, Humira accounted for approximately 27% of the company's total revenue and generated around $14 billion. The drug was approved for the treatment of various autoimmune disorders, including rheumatoid arthritis, Crohn's disease, plaque psoriasis, and ulcerative colitis. The business model of AbbVie is oriented toward the development of advanced biotechnology-based therapies, delivering innovative solutions targeted at the underlying biological mechanisms of the diseases. Through this approach in business, the company aims to achieve sustainable improvements in global healthcare outcomes [28].

Merck & Co., Inc. (A5): Founded in 1891, Merck & Co., Inc. is a global healthcare company headquartered in Rahway, New Jersey, the USA. Beyond the United States and Canada, the company operates under the name of Merck Sharp & Dohme (MSD). Merck provides diversified healthcare solutions through prescription medicines, vaccines, biologic therapies, animal health products, and consumer care offerings. Its operations are structured under three primary business segments, i.e., Pharmaceuticals, Animal Health, and Other. The Pharmaceuticals segment, which represents the largest source of revenue for the company, encompasses human health-related therapeutic drugs and vaccines. The Animal Health segment focuses on the development, production, and marketing of pharmaceuticals and vaccines aimed at preventing, treating, and managing diseases in both livestock and companion animals. The Other segment includes sales from health-related services and non-reportable business operations. The product portfolio of Merck features six blockbuster drugs and vaccines, each generating over $1 billion in the annual revenue, including Keytruda (cancer immunotherapy), Januvia (type 2 diabetes treatment), Gardasil (human papillomavirus), Varivax (varicella vaccine), Bridion (neuromuscular blockade reversal agent), and Pneumovax (pneumococcal polysaccharide vaccine). Apart from these, Merck's innovative and comprehensive portfolio is further strengthened by key products such as Isentress (HIV/AIDS therapy), Simponi (immunosuppressant), RotaTeq (rotavirus vaccine), and Lynparza (maintenance therapy for advanced ovarian cancer) [29].

Abbott Laboratories (A6): Founded in 1888 by Wallace Calvin Abbott and headquartered in Abbott Park of Illinois, Abbott Laboratories is a long-established company engaged in the discovery, development, manufacturing, and global marketing of health-related products. The company operates via four main business segments: Established Pharmaceutical Products, Diagnostic Products, Nutritional Products, and Medical Devices. The Established Pharmaceutical Products segment primarily consists of branded generic pharmaceuticals marketed outside the United States, especially in emerging markets. This segment plays a vital role in global health by offering accessible and effective treatment options. The Diagnostic Products segment provides diagnostic systems and testing solutions to a wide range of healthcare providers, including blood banks, hospitals, commercial laboratories, clinics, physicians' offices, governmental agencies, and alternative care sites. Abbott's diagnostic innovations are crucial for early detection of diseases and monitoring of treatment progress. The Nutritional Products segment includes the global sales of pediatric and adult nutrition products. This segment occupies a significant position in the global nutrition market by delivering innovative formulas that support health and well-being at every stage of life. The Medical Devices segment encompasses technologies used in the treatment of cardiovascular diseases such as rhythm management, electrophysiology, heart failure therapies, and structural heart interventions, as well as devices for diabetes care like continuous glucose monitoring and neuromodulation. This segment offers technologically advanced solutions for managing chronic conditions [30].

Thermo Fisher Scientific, Inc. (A7): Established on October 11, 1960 and headquartered in Waltham, Massachusetts, the USA, Thermo Fisher Scientific is a global science and technology company operating in the fields of research, analysis, discovery, and diagnostics. The company supports scientific discovery processes through the provision of analytical instruments, laboratory equipment, reagents, consumables, software, and scientific services. It operates in four primary business segments: Life Sciences Solutions, Analytical Instruments, Specialty Diagnostics, and Laboratory Products and Biopharma Services. The Life Sciences Solutions segment encompasses a broad portfolio of reagents, instruments, and consumables used in the development of new drugs and vaccines or in biological and medical research. This segment is particularly vital to the biotechnology and pharmaceutical sectors. The Analytical Instruments segment offers measurement and analysis tools, integrated software, support services, and consumables for various applications including environmental analysis, materials science, chemical production, and food safety testing. The Specialty Diagnostics segment provides a comprehensive range of diagnostic products for healthcare, clinical, pharmaceutical, industrial, and food safety laboratories. This includes diagnostic test kits, reagents, culture media, instruments, and related systems. Lastly, the Laboratory Products and Biopharma Services segment encompasses nearly all products and services required by laboratories, while delivering outsourced solutions for biopharmaceutical production and clinical research activities [31].

Intuitive Surgical, Inc. (A8): Founded in 1995 by Frederic H. Moll, John Gordon Freund, and Robert G. Younge, and headquartered in Sunnyvale, California, the USA, Intuitive Surgical, Inc. is a global pioneer in robotic-assisted surgical technologies. The company develops and delivers advanced technological systems aimed at enhancing surgical precision, reducing invasiveness, and improving procedural efficiency.

The most renowned innovation of Intuitive Surgical is the da Vinci Surgical System, which enables surgeons to perform minimally invasive procedures with greater precision, dexterity, and control. In addition, the company has developed the Ion Endoluminal System, designed primarily for minimally invasive lung biopsy procedures. These systems are engineered to improve patient outcomes and reduce the durations of hospital stay. The company offers a comprehensive suite of instruments and a robust support infrastructure integrated with its surgical systems. Services include installation, repair, maintenance, 24/7 technical support, and proactive system of health monitoring. Furthermore, Intuitive Surgical provides hospitals with integrated digital solutions aimed at enhancing clinical performance through real-time monitoring and data analytics. Product sales are conducted through a direct sales organization, with specialized sales teams focusing on capital equipment and clinical applications. These teams are instrumental in delivering tailored solutions to healthcare providers, thus ensuring optimal system use and clinical value [32].

Amgen Inc. (A9): Founded on April 8, 1980 by William K. Bowes, Jr., Franklin Pitcher Johnson, Jr., George B. Rathmann, and Joseph Rubinfeld, Amgen Inc. is a leading biotechnology company headquartered in Thousand Oaks, California, the USA. The name of the company originates from the abbreviation of its original title, Applied Molecular Genetics (AMGen). Following its initial public offering in year 1983, the organization officially adopted the name Amgen Inc. Amgen is dedicated to the research, development, production, and global commercialization of human therapeutics, particularly in the field of biologics. It is widely recognized as a pioneer in the use of living cells for the manufacturing of biologic medicines. Through its innovative R&D approach, Amgen has developed a range of therapeutic solutions targeting complex and chronic diseases. The primary therapeutic focus areas of the company include oncology, hematology, inflammation, bone health, cardiovascular diseases, and nephrology. Its biologic therapies in these domains aim to provide high clinical efficacy and patient-centered treatment options. Amgen's strategic emphasis on advanced biotechnology and scientific innovation has positioned itself as a key player in the global healthcare sector, particularly noted for its leadership in cell-based drug production platforms [33].

Danaher Corporation (A10): Founded in 1984 by Steven M. Rales and Mitchell P. Rales, Danaher Corporation is a multinational technology company headquartered in Washington, D.C., the USA. The company is engaged in the design, manufacturing, and marketing of professional, medical, industrial, and commercial products and services. The operations of Danaher are structured into three primary segments: Biotechnology, Life Sciences, and Diagnostics. The Biotechnology segment encompasses bioprocess technologies, discovery solutions, and systems for medical applications. This segment delivers advanced tools, consumables, and services that support drug development processes. The Life Sciences segment provides instrumentation and consumables for the analysis of deoxyribonucleic acid (DNA), ribonucleic acid (RNA), and other core biomolecules. These products are widely utilized in both academic and industrial research laboratories to investigate fundamental biological building blocks. The Diagnostics segment includes analytical instruments, reagents, software solutions, and support services used in clinical diagnostic procedures. These offerings play a critical role in disease diagnosis and in accurate therapeutic decision-making. The research and development (R&D), manufacturing, sales, distribution, service, and administrative operations of Danaher span more than 50 countries, hence reflecting its extensive global presence and operational capabilities [34].

3.2 For Year 2023

• **Stage 1** – Criteria weighting based on the SCF-RANCOM method

Step 1-1: Information about the experts is given below $\left(\tilde{\mathbb{E}} = [\tilde{\mathbb{E}}_k]_K\right)$:

In this study, evaluation of the financial performance of healthcare companies listed in the S&P 500 index from year 2018 to year 2023 was carried out with the support of expert opinions provided by ten professionals with extensive experience in their respective fields. The experts were selected based on their professional backgrounds in financial analysis, decision support systems, accounting, and managerial practices.

Expert one is a finance executive with 18-year experience, specializing in company performance assessments, particularly during crises. Expert two has nearly 25-year experience in large-scale corporations and actively involves in financial strategy development and performance monitoring. Expert three is an academic with over 20 years of research experience in financial analysis and decision-making methodologies. Expert four is a financial affairs manager with 23 years of experience in the healthcare industry and possesses practical expertise in performance auditing. Expert five has 21 years of field and consultancy experience, focusing on accounting and reporting systems.

Expert six is a professor with a 16-year academic background in finance and accounting; he has conducted research on the MCDM approaches. Expert seven is a scholar with ten-year experience in financial decision support systems. Expert eight, with 30 years of industry experience, provides consultancy services on performance measurement and financial analysis for large-scale firms. Expert nine has 15 years of experience in the private sector, with a focus on the relationship between non-financial performance indicators and corporate strategies. Lastly, expert ten who specializes in financial reporting, crisis management, and managerial evaluation systems, has 17 years of combined experience in both the public and private sectors. The information about the experts is presented in Table 2.

Table 2. Information on the experts

Experts	Linguistic Values	SCF Values
e_1	VHI	$\{([0.70, 0.80], 0.75), ([0.10, 0.20], 0.15), ([0.10, 0.20], 0.15)\}$
e_2	EHI	$\{([0.80, 0.90], 0.85), ([0.00, 0.10], 0.05), ([0.00, 0.10], 0.05)\}$
e_3	VHI	$\{([0.70, 0.80], 0.75), ([0.10, 0.20], 0.15), ([0.10, 0.20], 0.15)\}$
e_4	SHI	$\{([0.50, 0.60], 0.55), ([0.30, 0.40], 0.35), ([0.30, 0.40], 0.35)\}$
e_5	HI	$\{([0.60, 0.70], 0.65), ([0.20, 0.30], 0.25), ([0.20, 0.30], 0.25)\}$
e_6	HI	$\{([0.60, 0.70], 0.65), ([0.20, 0.30], 0.25), ([0.20, 0.30], 0.25)\}$
e_7	VHI	$\{([0.70, 0.80], 0.75), ([0.10, 0.20], 0.15), ([0.10, 0.20], 0.15)\}$
e_8	EHI	$\{([0.80, 0.90], 0.85), ([0.00, 0.10], 0.05), ([0.00, 0.10], 0.05)\}$
e_9	MI	$\{([0.40, 0.50], 0.45), ([0.40, 0.50], 0.45), ([0.40, 0.50], 0.45)\}$
e_{10}	MI	$\{([0.40, 0.50], 0.45), ([0.40, 0.50], 0.45), ([0.40, 0.50], 0.45)\}$

Steps 1-2 and 1-3: Score function values and weights of the experts were calculated as in Table 3.

Table 3. Experts' score functions $\left(Sc(\tilde{\mathbb{E}}_k)\right)$ and weights ($\varepsilon = [\varepsilon]_K$)

Experts	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}
$Sc(\tilde{\mathbb{E}}_k)$	0.7813	0.8613	0.7813	0.6513	0.7113	0.7113	0.7813	0.8613	0.6013	0.6013
ε	0.1064	0.1173	0.1064	0.0887	0.0969	0.0969	0.1064	0.1173	0.0819	0.0819

Step 1-4: All criteria were evaluated by the experts as in Table 4.

Table 4. Criteria assessment $\left(\tilde{D} = [\tilde{D}_{kt}]_{KT}\right)$

Experts	$c_1^{\mathbb{T}}$	$c_2^{\mathbb{T}}$	$c_3^{\mathbb{T}}$	$c_4^{\mathbb{T}}$	$c_5^{\mathbb{T}}$	$c_6^{\mathbb{T}}$	$c_7^{\mathbb{T}}$	$c_8^{\mathbb{T}}$	$c_9^{\mathbb{T}}$	$c_{10}^{\mathbb{T}}$	$c_{11}^{\mathbb{T}}$	$c_{12}^{\mathbb{T}}$	$c_{13}^{\mathbb{T}}$	$c_{14}^{\mathbb{T}}$	$c_{15}^{\mathbb{T}}$	$c_{16}^{\mathbb{T}}$
e_1	MI	MI	MI	MI	MI	MI	MI	MI	MI	SHI	SHI	SHI	SHI	SHI	SHI	SHI
e_2	SHI	SHI	SHI	SHI	SHI	SHI	SHI	SHI	SHI	HI	HI	HI	HI	HI	HI	HI
e_3	HI	HI	HI	HI	HI	HI	HI	HI	HI	VHI	VHI	VHI	VHI	VHI	VHI	VHI
e_4	MI	MI	MI	MI	MI	MI	MI	MI	MI	HI	HI	HI	HI	HI	HI	HI
e_5	MI	MI	MI	MI	MI	MI	MI	MI	MI	MI	MI	MI	MI	MI	MI	MI
e_6	HI	HI	HI	HI	HI	HI	HI	HI	HI	HI	HI	HI	HI	HI	HI	HI
e_7	MI	MI	MI	MI	MI	MI	MI	MI	MI	SHI	SHI	SHI	SHI	SHI	SHI	SHI
e_8	SHI	SHI	SHI	SHI	SHI	SHI	SHI	SHI	SHI	HI	HI	HI	HI	HI	HI	HI
e_9	MI	MI	MI	MI	MI	MI	MI	MI	MI	HI	HI	HI	HI	HI	HI	HI
e_{10}	MI	MI	MI	MI	MI	MI	MI	MI	MI	SHI	SHI	SHI	SHI	SHI	SHI	SHI

Step 1-5: The decision matrix combined with the SCFAAWA aggregation operator is shown in Table 5.

Table 5. The aggregated decision matrix $\left(\tilde{D} = [\tilde{D}_t]_T\right)$

$\tilde{\boldsymbol{D}}$									
					$\boldsymbol{c}_1^{\mathbb{T}}$				
	0.4922	0.5915	0.5416	0.9518	0.9120	0.9334	0.9518	0.9120	0.9334
					$\boldsymbol{c}_2^{\mathbb{T}}$				
	0.5851	0.6863	0.6354	0.9785	0.9505	0.9659	0.9785	0.9505	0.9659
					$\boldsymbol{c}_3^{\mathbb{T}}$				
	0.6545	0.7561	0.7050	0.9911	0.9717	0.9828	0.9911	0.9717	0.9828
					$\boldsymbol{c}_4^{\mathbb{T}}$				
	0.3145	0.4102	0.3620	0.9646	0.9307	0.9491	0.9456	0.8087	0.8432
					$\boldsymbol{c}_5^{\mathbb{T}}$				
	0.3608	0.4593	0.4099	0.9434	0.9016	0.9241	0.9016	0.8457	0.8756
					$\boldsymbol{c}_6^{\mathbb{T}}$				
	0.2547	0.3501	0.3020	0.9794	0.9521	0.9671	0.9729	0.7589	0.7994
					$\boldsymbol{c}_7^{\mathbb{T}}$				
	0.3438	0.4404	0.3918	0.9568	0.9194	0.9396	0.9374	0.8306	0.8623
					$\boldsymbol{c}_8^{\mathbb{T}}$				
	0.4280	0.5269	0.4773	0.9359	0.8913	0.9153	0.9288	0.8817	0.9070
					$\boldsymbol{c}_9^{\mathbb{T}}$				
	0.4185	0.5167	0.4674	0.9434	0.9016	0.9241	0.9227	0.8734	0.8998
					$\boldsymbol{c}_{10}^{\mathbb{T}}$				
	0.6302	0.7327	0.6810	0.9871	0.9633	0.9766	0.9871	0.9633	0.9766
					$\boldsymbol{c}_{11}^{\mathbb{T}}$				
	0.3008	0.3936	0.3466	0.9728	0.9428	0.9592	0.9685	0.7898	0.8265
					$\boldsymbol{c}_{12}^{\mathbb{T}}$				
	0.5433	0.6431	0.5930	0.9675	0.9344	0.9524	0.9675	0.9344	0.9524
					$\boldsymbol{c}_{13}^{\mathbb{T}}$				
	0.5046	0.6041	0.5541	0.9568	0.9194	0.9396	0.9568	0.9194	0.9396
					$\boldsymbol{c}_{14}^{\mathbb{T}}$				
	0.6849	0.7856	0.7352	0.9944	0.9788	0.9879	0.9944	0.9788	0.9879
					$\boldsymbol{c}_{15}^{\mathbb{T}}$				
	0.6708	0.7719	0.7212	0.9927	0.9751	0.9852	0.9927	0.9751	0.9852
					$\boldsymbol{c}_{16}^{\mathbb{T}}$				
	0.6221	0.7242	0.6728	0.9864	0.9628	0.9759	0.9864	0.9628	0.9759

Step 1-6: Score function values of the combined decision matrix were calculated as in Table 6.

Table 6. Score function values of the aggregated decision matrix

	$\boldsymbol{c}_1^{\mathbb{T}}$	$\boldsymbol{c}_2^{\mathbb{T}}$	$\boldsymbol{c}_3^{\mathbb{T}}$	$\boldsymbol{c}_4^{\mathbb{T}}$	$\boldsymbol{c}_5^{\mathbb{T}}$	$\boldsymbol{c}_6^{\mathbb{T}}$	$\boldsymbol{c}_7^{\mathbb{T}}$	$\boldsymbol{c}_8^{\mathbb{T}}$
$Sc(\tilde{\mathbb{E}}_k)$	0.6468	0.7020	0.7487	0.6403	0.6278	0.6565	0.6329	0.6216
	$\boldsymbol{c}_9^{\mathbb{T}}$	$\boldsymbol{c}_{10}^{\mathbb{T}}$	$\boldsymbol{c}_{11}^{\mathbb{T}}$	$\boldsymbol{c}_{12}^{\boldsymbol{T}}$	$\boldsymbol{c}_{13}^{\mathbb{T}}$	$\boldsymbol{c}_{14}^{\mathbb{T}}$	$\boldsymbol{c}_{15}^{\mathbb{T}}$	$\boldsymbol{c}_{16}^{\mathbb{T}}$
$Sc(\tilde{\mathbb{E}}_k)$	0.6315	0.7321	0.6482	0.6759	0.6536	0.7703	0.7601	0.7265

Step 1-7: The relative criteria comparison matrix is shown in Table 7.

Table 7. The relative criteria comparison matrix ($\mathbb{R} = [\mathbb{R}_{tt'}]_{TT}$)

	$\boldsymbol{c}_1^{\mathbb{T}}$	$\boldsymbol{c}_2^{\mathbb{T}}$	$\boldsymbol{c}_3^{\mathbb{T}}$	$\boldsymbol{c}_4^{\mathbb{T}}$	$\boldsymbol{c}_5^{\mathbb{T}}$	$\boldsymbol{c}_6^{\mathbb{T}}$	$\boldsymbol{c}_7^{\mathbb{T}}$	$\boldsymbol{c}_8^{\mathbb{T}}$	$\boldsymbol{c}_9^{\mathbb{T}}$	$\boldsymbol{c}_{10}^{\mathbb{T}}$	$\boldsymbol{c}_{11}^{\mathbb{T}}$	$\boldsymbol{c}_{12}^{\mathbb{T}}$	$\boldsymbol{c}_{13}^{\mathbb{T}}$	$\boldsymbol{c}_{14}^{\mathbb{T}}$	$\boldsymbol{c}_{15}^{\mathbb{T}}$	$\boldsymbol{c}_{16}^{\mathbb{T}}$
$c_1^{\mathbb{T}}$	0.5	0	0	1	1	0	1	1	1	0	0	0	0	0	0	0
$c_2^{\mathbb{T}}$	1	0.5	0	1	1	1	1	1	1	0	1	1	1	0	0	0
$c_3^{\mathbb{T}}$	1	1	0.5	1	1	1	1	1	1	1	1	1	1	0	0	1
$c_4^{\mathbb{T}}$	0	0	0	0.5	1	0	1	1	1	0	0	0	0	0	0	0
$c_5^{\mathbb{T}}$	0	0	0	0	0.5	0	0	1	0	0	0	0	0	0	0	0
$c_6^{\mathbb{T}}$	1	0	0	1	1	0.5	1	1	1	0	1	0	1	0	0	0
$c_7^{\mathbb{T}}$	0	0	0	0	1	0	0.5	1	1	0	0	0	0	0	0	0
$c_8^{\mathbb{T}}$	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0
$c_9^{\mathbb{T}}$	0	0	0	0	1	0	0	1	0.5	0	0	0	0	0	0	0
$c_{10}^{\mathbb{T}}$	1	1	0	1	1	1	1	1	1	0.5	1	1	1	0	0	1
$c_{11}^{\mathbb{T}}$	1	0	0	1	1	0	1	1	1	0	0.5	0	0	0	0	0
$c_{12}^{\mathbb{T}}$	1	0	0	1	1	1	1	1	1	0	1	0.5	1	0	0	0
$c_{13}^{\mathbb{T}}$	1	0	0	1	1	0	1	1	1	0	1	0	0.5	0	0	0
$c_{14}^{\mathbb{T}}$	1	1	1	1	1	1	1	1	1	1	1	1	1	0.5	1	1
$c_{15}^{\mathbb{T}}$	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0.5	1
$c_{16}^{\mathbb{T}}$	1	1	0	1	1	1	1	1	1	0	1	1	1	0	0	0.5

Step 1-8: The total values of the calculated relative criteria comparison matrix are shown in Table 8.

Table 8. The total values ($\mathbb{O} = [\mathbb{O}_t]_T$)

	$\boldsymbol{c}_1^{\mathbb{T}}$	$\boldsymbol{c}_2^{\mathbb{T}}$	$\boldsymbol{c}_3^{\mathbb{T}}$	$\boldsymbol{c}_4^{\mathbb{T}}$	$\boldsymbol{c}_5^{\mathbb{T}}$	$\boldsymbol{c}_6^{\mathbb{T}}$	$\boldsymbol{c}_7^{\mathbb{T}}$	$\boldsymbol{c}_8^{\mathbb{T}}$	$\boldsymbol{c}_9^{\mathbb{T}}$	$\boldsymbol{c}_{10}^{\mathbb{T}}$	$\boldsymbol{c}_{11}^{\mathbb{T}}$	$\boldsymbol{c}_{12}^{\mathbb{T}}$	$\boldsymbol{c}_{13}^{\mathbb{T}}$	$\boldsymbol{c}_{14}^{\mathbb{T}}$	$\boldsymbol{c}_{15}^{\mathbb{T}}$	$\boldsymbol{c}_{16}^{\mathbb{T}}$
$\mathbb{O}_t$	5.5	10.5	13.5	4.5	1.5	8.5	3.5	0.5	2.5	12.5	6.5	9.5	7.5	15.5	14.5	11.5

Step 1-9: The calculated criteria importance levels and rankings are shown in Table 9.

Table 9. The criteria importance levels and rankings ($\omega = [\omega_t]_T$)

	$\boldsymbol{c}_1^{\mathbb{T}}$	$\boldsymbol{c}_2^{\mathbb{T}}$	$\boldsymbol{c}_3^{\mathbb{T}}$	$\boldsymbol{c}_4^{\mathbb{T}}$	$\boldsymbol{c}_5^{\mathbb{T}}$	$\boldsymbol{c}_6^{\mathbb{T}}$	$\boldsymbol{c}_7^{\mathbb{T}}$	$\boldsymbol{c}_8^{\mathbb{T}}$
ω_t	0.0430	0.0820	0.1055	0.0352	0.0117	0.0664	0.0273	0.0039
Ranking	11	6	3	12	15	8	13	16
	$\boldsymbol{c}_9^{\mathbb{T}}$	$\boldsymbol{c}_{10}^{\mathbb{T}}$	$\boldsymbol{c}_{11}^{\mathbb{T}}$	$\boldsymbol{c}_{12}^{\mathbb{T}}$	$\boldsymbol{c}_{13}^{\mathbb{T}}$	$\boldsymbol{c}_{14}^{\mathbb{T}}$	$\boldsymbol{c}_{15}^{\mathbb{T}}$	$\boldsymbol{c}_{16}^{\mathbb{T}}$
ω_t	0.0195	0.0977	0.0508	0.0742	0.0586	0.1211	0.1133	0.0898
Ranking	14	4	10	7	9	1	2	5

• **Stage 2** – Rankings of alternatives using the AROMAN method [7]
Step 2-1: The evaluation of the qualitative criteria by the experts is shown in Table 10.

Table 10. The evaluation of the qualitative criteria $\left(\tilde{\mathbb{U}} = [\tilde{\mathbb{U}}_{kl}]_{KL}\right)$

Alt.	**Expert**	$c_1^{\mathbb{L}}$	$c_2^{\mathbb{L}}$	$c_3^{\mathbb{L}}$	$c_4^{\mathbb{L}}$	$c_5^{\mathbb{L}}$	**Expert**	$c_1^{\mathbb{L}}$	$c_2^{\mathbb{L}}$	$c_3^{\mathbb{L}}$	$c_4^{\mathbb{L}}$	$c_5^{\mathbb{L}}$	**Expert**	$c_1^{\mathbb{L}}$	$c_2^{\mathbb{L}}$	$c_3^{\mathbb{L}}$	$c_4^{\mathbb{L}}$	$c_5^{\mathbb{L}}$
A_1		VHI	VHI	VHI	VHI	VHI		VHI	VHI	VHI	VHI	VHI		VHI	VHI	VHI	VHI	VHI
A_2		HI	HI	HI	HI	HI		VHI	VHI	HI	HI	HI		VHI	HI	HI	HI	HI
A_3		SHI	SHI	SHI	SHI	SHI		SHI	SHI	SHI	SHI	SHI		SHI	SHI	SHI	SHI	SHI
A_4		VLI	VLI	VLI	VLI	VLI		LI	LI	VLI	LI	LI		LI	LI	VLI	LI	LI
A_5		MI	MI	MI	MI	MI		SLI	SLI	MI	SLI	SLI		SLI	SLI	MI	SLI	SLI
A_6	e_1	SHI	SHI	SHI	SHI	SHI	e_2	HI	HI	SHI	HI	HI	e_3	HI	HI	SHI	HI	HI
A_7		SLI	SLI	SLI	SLI	SLI		MI	MI	SLI	MI	MI		MI	MI	SLI	MI	MI
A_8		VLI	VLI	VLI	VLI	VLI		LI	LI	VLI	LI	LI		LI	LI	VLI	LI	LI
A_9		LI	LI	LI	LI	LI		VLI	VLI	LI	VLI	VLI		VLI	VLI	LI	VLI	VLI
A_{10}		SLI	SLI	SLI	SLI	SLI		LI	LI	SLI	LI	SLI		LI	LI	SLI	LI	LI
Alt.	**Expert**	$c_1^{\mathbb{L}}$	$c_2^{\mathbb{L}}$	$c_3^{\mathbb{L}}$	$c_4^{\mathbb{L}}$	$c_5^{\mathbb{L}}$	**Expert**	$c_1^{\mathbb{L}}$	$c_2^{\mathbb{L}}$	$c_3^{\mathbb{L}}$	$c_4^{\mathbb{L}}$	$c_5^{\mathbb{L}}$	**Expert**	$c_1^{\mathbb{L}}$	$c_2^{\mathbb{L}}$	$c_3^{\mathbb{L}}$	$c_4^{\mathbb{L}}$	$c_5^{\mathbb{L}}$
A_1		VHI	VHI	VHI	VHI	VHI		VHI	VHI	VHI	VHI	VHI		VHI	VHI	VHI	VHI	VHI
A_2		HI	HI	VHI	VHI	HI		HI	HI	VHI	HI	HI		VHI	VHI	VHI	HI	HI
A_3		SHI	SHI	SHI	SHI	SHI		SHI	SHI	SHI	SHI	SHI		SHI	SHI	SHI	SHI	SHI
A_4		LI	LI	LI	LI	VLI		VLI	VLI	LI	VLI	LI		LI	LI	LI	VLI	VLI
A_5		SLI	SLI	SLI	SLI	MI		MI	MI	SLI	MI	SLI		SLI	SLI	SLI	MI	MI
A_6	e_4	HI	HI	HI	HI	SHI	e_5	SHI	SHI	HI	SHI	HI	e_6	HI	HI	HI	SHI	SHI
A_7		MI	MI	MI	MI	SLI		SLI	SLI	MI	SLI	MI		MI	MI	MI	SLI	SLI
A_8		LI	LI	LI	LI	VLI		LI	VLI	LI	VLI	LI		LI	LI	LI	VLI	LI
A_9		VLI	VLI	VLI	VLI	LI		VLI	LI	VLI	LI	VLI		VLI	VLI	VLI	LI	VLI
A_{10}		LI	SLI	LI	LI	SLI		LI	SLI	SLI	SLI	SLI		LI	SLI	LI	SLI	LI
Alt.	**Expert**	$c_1^{\mathbb{L}}$	$c_2^{\mathbb{L}}$	$c_3^{\mathbb{L}}$	$c_4^{\mathbb{L}}$	$c_5^{\mathbb{L}}$	**Expert**	$c_1^{\mathbb{L}}$	$c_2^{\mathbb{L}}$	$c_3^{\mathbb{L}}$	$c_4^{\mathbb{L}}$	$c_5^{\mathbb{L}}$	**Expert**	$c_1^{\mathbb{L}}$	$c_2^{\mathbb{L}}$	$c_3^{\mathbb{L}}$	$c_4^{\mathbb{L}}$	$c_5^{\mathbb{L}}$
A_1		VHI	VHI	VHI	VHI	VHI		VHI	VHI	VHI	VHI	VHI		VHI	VHI	VHI	VHI	VHI
A_2		HI	VHI	HI	VHI	HI		VHI	HI	HI	HI	SHI		HI	VHI	VHI	HI	HI
A_3		SHI	SHI	SHI	SHI	SHI		SHI	SHI	SHI	SHI	SHI		SHI	SHI	SHI	SHI	SHI
A_4		LI	LI	VLI	LI	VLI		LI	VLI	VLI	LI	LI		VLI	LI	LI	VLI	LI
A_5		SLI	SLI	MI	SLI	MI		SLI	MI	MI	SLI	SLI		MI	SLI	SLI	MI	SLI
A_6	e_7	HI	HI	SHI	HI	SHI	e_8	HI	SHI	SHI	HI	HI	e_9	SHI	HI	HI	SHI	HI
A_7		MI	MI	SLI	MI	SLI		MI	SLI	SLI	MI	MI		SLI	MI	MI	SLI	MI
A_8		LI	LI	LI	LI	LI		LI	LI	VLI	LI	LI		VLI	LI	LI	LI	LI
A_9		VLI	VLI	VLI	VLI	VLI		VLI	VLI	LI	VLI	VLI		LI	VLI	VLI	VLI	VLI
A_{10}		SLI	LI	LI	LI	LI		LI	LI	SLI	LI	VLI		SLI	SLI	LI	LI	LI
Alt.	**Expert**	$c_1^{\mathbb{L}}$	$c_2^{\mathbb{L}}$	$c_3^{\mathbb{L}}$	$c_4^{\mathbb{L}}$	$c_5^{\mathbb{L}}$	**Expert**	$c_1^{\mathbb{L}}$	$c_2^{\mathbb{L}}$	$c_3^{\mathbb{L}}$	$c_4^{\mathbb{L}}$	$c_5^{\mathbb{L}}$	**Expert**	$c_1^{\mathbb{L}}$	$c_2^{\mathbb{L}}$	$c_3^{\mathbb{L}}$	$c_4^{\mathbb{L}}$	$c_5^{\mathbb{L}}$
A_1		VHI	VHI	VHI	VHI	VHI												
A_2		HI	HI	VHI	HI	HI												
A_3		SHI	SHI	SHI	SHI	SHI												
A_4		VLI	VLI	LI	VLI	LI												
A_5		MI	MI	SLI	MI	SLI												
A_6	e_{10}	SHI	SHI	HI	SHI	HI												
A_7		SLI	SLI	MI	SLI	MI												
A_8		LI	LI	LI	LI	LI												
A_9		VLI	VLI	VLI	VLI	VLI												
A_{10}		LI	LI	LI	LI	SLI												

Step 2-2: Qualitative criteria assessed by the experts were combined as in Table 11.

Table 11. The aggregated decision matrix $\left(\tilde{\mathbb{F}} = [\tilde{\mathbb{F}}_l]_{\mathbb{L}}\right)$

Alt.	$c_1^{\mathbb{L}}$									$c_2^{\mathbb{L}}$								
	0.70	0.80	0.75	0.99	0.98	0.99	0.99	0.98	0.99	0.70	0.80	0.75	0.99	0.98	0.99	0.99	0.98	0.99
	$c_3^{\mathbb{L}}$									$c_4^{\mathbb{L}}$								
A_1	0.70	0.80	0.75	0.99	0.98	0.99	0.99	0.98	0.99	0.70	0.80	0.75	0.99	0.98	0.99	0.99	0.98	0.99
	$c_5^{\mathbb{L}}$																	
	0.70	0.80	0.75	0.99	0.98	0.99	0.99	0.98	0.99									
Alt.	$c_1^{\mathbb{L}}$									$c_2^{\mathbb{L}}$								
	0.65	0.75	0.70	0.99	0.97	0.98	0.99	0.97	0.98	0.66	0.76	0.71	0.99	0.97	0.98	0.99	0.97	0.98
	$c_3^{\mathbb{L}}$									$c_4^{\mathbb{L}}$								
A_2	0.66	0.77	0.71	0.99	0.97	0.98	0.99	0.97	0.98	0.63	0.73	0.68	0.99	0.96	0.97	0.99	0.96	0.97
	$c_5^{\mathbb{L}}$																	
	0.59	0.69	0.64	0.98	0.95	0.97	0.98	0.95	0.97									
Alt.	$c_1^{\mathbb{L}}$									$c_2^{\mathbb{L}}$								
	0.50	0.60	0.55	0.95	0.92	0.94	0.95	0.92	0.94	0.50	0.60	0.55	0.95	0.92	0.94	0.95	0.92	0.94
	$c_3^{\mathbb{L}}$									$c_4^{\mathbb{L}}$								
A_3	0.50	0.60	0.55	0.95	0.92	0.94	0.95	0.92	0.94	0.50	0.60	0.55	0.95	0.92	0.94	0.95	0.92	0.94
	$c_5^{\mathbb{L}}$																	
	0.50	0.60	0.55	0.95	0.92	0.94	0.95	0.92	0.94									
Alt.	$c_1^{\mathbb{L}}$									$c_2^{\mathbb{L}}$								
	0.18	0.27	0.23	0.99	0.97	0.98	0.99	0.68	0.73	0.18	0.28	0.23	0.99	0.96	0.98	0.99	0.69	0.74
	$c_3^{\mathbb{L}}$									$c_4^{\mathbb{L}}$								
A_4	0.17	0.27	0.22	0.99	0.97	0.98	0.99	0.67	0.72	0.17	0.27	0.22	0.99	0.97	0.98	0.99	0.67	0.72
	$c_5^{\mathbb{L}}$																	
	0.18	0.28	0.23	0.99	0.96	0.98	0.99	0.69	0.74									
Alt.	$c_1^{\mathbb{L}}$									$c_2^{\mathbb{L}}$								
	0.35	0.45	0.40	0.94	0.90	0.92	0.89	0.83	0.86	0.34	0.44	0.39	0.95	0.90	0.93	0.88	0.82	0.86
	$c_3^{\mathbb{L}}$									$c_4^{\mathbb{L}}$								
A_5	0.36	0.45	0.40	0.94	0.90	0.92	0.89	0.83	0.87	0.36	0.46	0.41	0.94	0.90	0.92	0.89	0.84	0.87
	$c_5^{\mathbb{L}}$																	
	0.34	0.44	0.39	0.95	0.90	0.93	0.88	0.82	0.86									
Alt.	$c_1^{\mathbb{L}}$									$c_2^{\mathbb{L}}$								
	0.57	0.67	0.62	0.97	0.94	0.96	0.97	0.94	0.96	0.58	0.68	0.63	0.97	0.95	0.96	0.97	0.95	0.96
	$c_3^{\mathbb{L}}$									$c_4^{\mathbb{L}}$								
A_6	0.56	0.66	0.61	0.97	0.94	0.96	0.97	0.94	0.96	0.56	0.66	0.61	0.97	0.94	0.96	0.97	0.94	0.96
	$c_5^{\mathbb{L}}$																	
	0.58	0.68	0.63	0.97	0.95	0.96	0.97	0.95	0.96									

continued

Alt.	$\boldsymbol{c_1^{\mathbb{L}}}$									$\boldsymbol{c_2^{\mathbb{L}}}$								
	0.37	0.47	0.42	0.93	0.89	0.91	0.90	0.85	0.88	0.38	0.48	0.43	0.93	0.88	0.91	0.90	0.85	0.88
	$\boldsymbol{c_3^{\mathbb{L}}}$									$\boldsymbol{c_4^{\mathbb{L}}}$								
A_7	0.37	0.46	0.42	0.94	0.89	0.92	0.90	0.84	0.87	0.36	0.46	0.41	0.94	0.89	0.92	0.90	0.84	0.87
	$\boldsymbol{c_5^{\mathbb{L}}}$																	
	0.38	0.48	0.43	0.93	0.88	0.91	0.90	0.85	0.88									
Alt.	$\boldsymbol{c_1^{\mathbb{L}}}$									$\boldsymbol{c_2^{\mathbb{L}}}$								
	0.19	0.29	0.24	0.98	0.96	0.97	0.98	0.70	0.75	0.19	0.29	0.24	0.98	0.96	0.97	0.98	0.71	0.75
	$\boldsymbol{c_3^{\mathbb{L}}}$									$\boldsymbol{c_4^{\mathbb{L}}}$								
A_8	0.18	0.28	0.23	0.99	0.97	0.98	0.99	0.68	0.73	0.19	0.29	0.24	0.99	0.96	0.97	0.99	0.70	0.74
	$\boldsymbol{c_5^{\mathbb{L}}}$																	
	0.20	0.29	0.24	0.98	0.96	0.97	0.98	0.71	0.75									
Alt.	$\boldsymbol{c_1^{\mathbb{L}}}$									$\boldsymbol{c_2^{\mathbb{L}}}$								
	0.14	0.23	0.18	0.99	0.98	0.99	0.99	0.63	0.69	0.13	0.22	0.17	0.99	0.98	0.99	0.99	0.62	0.68
	$\boldsymbol{c_3^{\mathbb{L}}}$									$\boldsymbol{c_4^{\mathbb{L}}}$								
A_9	0.16	0.25	0.20	0.99	0.97	0.98	0.99	0.65	0.70	0.14	0.23	0.19	0.99	0.98	0.99	0.99	0.63	0.69
	$\boldsymbol{c_5^{\mathbb{L}}}$																	
	0.12	0.22	0.17	0.99	0.98	0.99	0.99	0.62	0.67									
Alt.	$\boldsymbol{c_1^{\mathbb{L}}}$									$\boldsymbol{c_2^{\mathbb{L}}}$								
	0.24	0.34	0.29	0.97	0.95	0.96	0.97	0.75	0.79	0.26	0.36	0.31	0.97	0.94	0.96	0.96	0.76	0.80
	$\boldsymbol{c_3^{\mathbb{L}}}$									$\boldsymbol{c_4^{\mathbb{L}}}$								
A_{10}	0.26	0.36	0.31	0.97	0.94	0.96	0.96	0.76	0.80	0.23	0.33	0.28	0.98	0.95	0.96	0.97	0.74	0.78
	$\boldsymbol{c_5^{\mathbb{L}}}$																	
	0.25	0.35	0.30	0.98	0.95	0.97	0.97	0.75	0.79									

Step 2-3: The score function values are calculated as in Table 12.

Table 12. Score function values of the aggregated decision matrix $\left(Sc(\tilde{\mathbb{F}}_l)\right)$

	$\boldsymbol{c_1^{\mathbb{L}}}$	$\boldsymbol{c_2^{\mathbb{L}}}$	$\boldsymbol{c_3^{\mathbb{L}}}$	$\boldsymbol{c_4^{\mathbb{L}}}$	$\boldsymbol{c_5^{\mathbb{L}}}$
A_1	0.7803	0.7803	0.7803	0.7803	0.7803
A_2	0.7466	0.7515	0.7552	0.7285	0.7049
A_3	0.6506	0.6506	0.6506	0.6506	0.6506
A_4	0.6838	0.6802	0.6873	0.6887	0.6800
A_5	0.6350	0.6383	0.6317	0.6303	0.6385
A_6	0.6922	0.6960	0.6883	0.6868	0.6962
A_7	0.6223	0.6184	0.6259	0.6273	0.6182
A_8	0.6747	0.6700	0.6819	0.6750	0.6695
A_9	0.7061	0.7111	0.6980	0.7058	0.7115
A_{10}	0.6559	0.6513	0.6521	0.6588	0.6593

Step 2-4: The initial decision matrix is created as in Table 13.

Table 13. The initial decision matrix $(\mathrm{A} = [\mathrm{A}_{it}]_{mT})$

	$c_1^{\mathbb{T}}$	$c_2^{\mathbb{T}}$	$c_3^{\mathbb{T}}$	$c_4^{\mathbb{T}}$	$c_5^{\mathbb{T}}$	$c_6^{\mathbb{T}}$	$c_7^{\mathbb{T}}$	$c_8^{\mathbb{T}}$	$c_9^{\mathbb{T}}$	$c_{10}^{\mathbb{T}}$	$c_{11}^{\mathbb{T}}$	$c_{12}^{\mathbb{T}}$	$c_{13}^{\mathbb{T}}$	$c_{14}^{\mathbb{T}}$	$c_{15}^{\mathbb{T}}$	$c_{16}^{\mathbb{T}}$
A_1	0.8300	9.0100	0.1956	0.2470	0.0082	64.0100	5.2400	53.1400	34.1200	10.3300	524.2000	0.7803	0.7803	0.7803	0.7803	0.7803
A_2	0.6400	2.3900	0.1346	0.0038	0.1456	278.4200	22.3800	179.5000	367.8100	28.5500	486.9000	0.7466	0.7515	0.7552	0.7285	0.7049
A_3	0.5800	2.8400	0.0636	0.0450	-0.1046	167.5600	14.1700	98.7800	85.1500	22.1600	377.3000	0.6506	0.6506	0.6506	0.6506	0.6506
A_4	0.9200	2.9500	-0.0644	-0.2000	-0.3986	134.7100	4.8200	124.3100	54.3200	18.0800	273.6000	0.6838	0.6802	0.6873	0.6887	0.6800
A_5	0.6400	3.1000	0.0239	-0.8471	-0.1829	106.6700	0.3650	69.0400	59.8700	2.9800	276.3000	0.6350	0.6383	0.6317	0.6303	0.6385
A_6	0.4600	3.0700	-0.0812	-0.2304	0.0521	73.2100	5.7000	34.3900	40.1100	6.4300	191.1000	0.6922	0.6960	0.6883	0.6868	0.6962
A_7	0.5200	2.6000	-0.0458	-0.1266	0.0610	98.7300	6.0000	51.8800	42.8600	7.4500	205.1000	0.6223	0.6184	0.6259	0.6273	0.6182
A_8	0.1300	7.7900	0.1449	0.1203	0.2056	15.5200	1.8000	2.1300	7.1200	1.7700	118.8000	0.6747	0.6700	0.6819	0.6750	0.6695
A_9	0.9300	2.5200	0.0735	-0.0926	0.7023	97.1500	6.7200	90.9200	28.0100	8.4700	154.1000	0.7061	0.7111	0.6980	0.7058	0.7115
A_{10}	0.3600	2.3800	-0.1033	-0.2995	0.0679	84.4900	4.7600	31.0000	23.8900	5.2800	170.9000	0.6559	0.6513	0.6521	0.6588	0.6593

Step 2-5: The first normalized decision matrix is created as in Table 14.

Table 14. The first normalization decision matrix $(\mathcal{N}_{it}^{1})$

	$c_1^{\mathbb{T}}$	$c_2^{\mathbb{T}}$	$c_3^{\mathbb{T}}$	$c_4^{\mathbb{T}}$	$c_5^{\mathbb{T}}$	$c_6^{\mathbb{T}}$	$c_7^{\mathbb{T}}$	$c_8^{\mathbb{T}}$	$c_9^{\mathbb{T}}$	$c_{10}^{\mathbb{T}}$	$c_{11}^{\mathbb{T}}$	$c_{12}^{\mathbb{T}}$	$c_{13}^{\mathbb{T}}$	$c_{14}^{\mathbb{T}}$	$c_{15}^{\mathbb{T}}$	$c_{16}^{\mathbb{T}}$
A_1	0.1250	1.0000	1.0000	1.0000	0.3695	0.1844	0.2214	0.7124	0.0749	0.3196	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
A_2	0.3625	0.0015	0.7959	0.7777	0.4943	1.0000	1.0000	0.0000	1.0000	1.0000	0.9080	0.7867	0.8223	0.8373	0.6619	0.5350
A_3	0.4375	0.0694	0.5584	0.8154	0.2671	0.5783	0.6271	0.4551	0.2163	0.7614	0.6376	0.1792	0.1985	0.1600	0.1523	0.1996
A_4	0.0125	0.0860	0.1301	0.5914	0.0000	0.4534	0.2024	0.3112	0.1309	0.6090	0.3818	0.3893	0.3815	0.3977	0.4013	0.3811
A_5	0.3625	0.1086	0.4256	0.0000	0.1959	0.3467	0.0000	0.6228	0.1462	0.0452	0.3885	0.0807	0.1230	0.0375	0.0200	0.1254
A_6	0.5875	0.1041	0.0739	0.5637	0.4094	0.2194	0.2423	0.8181	0.0915	0.1740	0.1783	0.4425	0.4790	0.4045	0.3888	0.4810
A_7	0.5125	0.0332	0.1924	0.6585	0.4175	0.3165	0.2560	0.7195	0.0991	0.2121	0.2129	0.0000	0.0000	0.0000	0.0000	0.0000
A_8	1.0000	0.8160	0.8304	0.8842	0.5488	0.0000	0.0652	1.0000	0.0000	0.0000	0.0000	0.3320	0.3184	0.3629	0.3120	0.3166
A_9	0.0000	0.0211	0.5915	0.6896	1.0000	0.3105	0.2887	0.4994	0.0579	0.2502	0.0871	0.5306	0.5726	0.4672	0.5133	0.5759
A_{10}	0.7125	0.0000	0.0000	0.5005	0.4237	0.2623	0.1996	0.8372	0.0465	0.1311	0.1285	0.2130	0.2029	0.1699	0.2063	0.2536

Step 2-6: The second normalized decision matrix is created as in Table 15.

Table 15. The second normalization decision matrix $\left(\mathcal{N}_{it}^{2}\right)$

	$\boldsymbol{c}_{\mathbf{1}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{2}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{3}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{4}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{5}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{6}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{7}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{8}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{9}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{10}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{11}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{12}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{13}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{14}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{15}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{16}}^{\mathbb{T}}$
A_1	0.5942	0.6337	0.5874	0.2467	0.0093	0.1547	0.1754	0.8099	0.0866	0.2340	0.5375	0.3595	0.3594	0.3593	0.3604	0.3616
A_2	0.6871	0.1681	0.4042	0.0038	0.1658	0.6730	0.7493	0.3578	0.9340	0.6468	0.4993	0.3440	0.3462	0.3477	0.3365	0.3267
A_3	0.7165	0.1997	0.1910	0.0449	-0.1191	0.4050	0.4744	0.6466	0.2162	0.5021	0.3869	0.2997	0.2997	0.2996	0.3005	0.3015
A_4	0.5502	0.2075	-0.1934	-0.1998	-0.4539	0.3256	0.1614	0.5553	0.1379	0.4096	0.2806	0.3150	0.3133	0.3165	0.3181	0.3152
A_5	0.6871	0.2180	0.0718	-0.8460	-0.2083	0.2578	0.0122	0.7530	0.1520	0.0675	0.2833	0.2926	0.2941	0.2909	0.2911	0.2959
A_6	0.7751	0.2159	-0.2438	-0.2301	0.0593	0.1770	0.1908	0.8770	0.1019	0.1457	0.1960	0.3189	0.3206	0.3169	0.3172	0.3227
A_7	0.7458	0.1829	-0.1375	-0.1264	0.0695	0.2387	0.2009	0.8144	0.1088	0.1688	0.2103	0.2867	0.2849	0.2882	0.2897	0.2865
A_8	0.9364	0.5479	0.4351	0.1202	0.2341	0.0375	0.0603	0.9924	0.0181	0.0401	0.1218	0.3109	0.3086	0.3140	0.3118	0.3103
A_9	0.5454	0.1772	0.2207	-0.0925	0.7998	0.2348	0.2250	0.6747	0.0711	0.1919	0.1580	0.3253	0.3276	0.3214	0.3260	0.3298
A_{10}	0.8240	0.1674	-0.3102	-0.2991	0.0773	0.2042	0.1594	0.8891	0.0607	0.1196	0.1752	0.3022	0.3000	0.3003	0.3043	0.3056

Step 2-7: The aggregated normalized decision matrix was created as in Table 16.

Table 16. The aggregated normalization decision matrix $(\mathcal{N}_{it}^{*})$

	$\boldsymbol{c}_{\mathbf{1}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{2}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{3}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{4}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{5}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{6}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{7}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{8}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{9}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{10}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{11}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{12}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{13}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{14}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{15}}^{\mathbb{T}}$	$\boldsymbol{c}_{\mathbf{16}}^{\mathbb{T}}$
A_1	0.1798	0.4084	0.3968	0.3117	0.0947	0.0848	0.0992	0.3806	0.0404	0.1384	0.3844	0.3399	0.3399	0.3398	0.3401	0.3404
A_2	0.2624	0.0424	0.3000	0.1954	0.1650	0.4183	0.4373	0.0895	0.4835	0.4117	0.3518	0.2827	0.2921	0.2963	0.2496	0.2154
A_3	0.2885	0.0673	0.1873	0.2151	0.0370	0.2458	0.2754	0.2754	0.1081	0.3159	0.2561	0.1197	0.1245	0.1149	0.1132	0.1253
A_4	0.1407	0.0734	-0.0158	0.0979	-0.1135	0.1947	0.0909	0.2166	0.0672	0.2547	0.1656	0.1761	0.1737	0.1785	0.1798	0.1741
A_5	0.2624	0.0817	0.1243	-0.2115	-0.0031	0.1511	0.0031	0.3439	0.0746	0.0282	0.1680	0.0933	0.1043	0.0821	0.0778	0.1053
A_6	0.3407	0.0800	-0.0425	0.0834	0.1172	0.0991	0.1083	0.4238	0.0483	0.0799	0.0936	0.1903	0.1999	0.1804	0.1765	0.2009
A_7	0.3146	0.0540	0.0137	0.1330	0.1217	0.1388	0.1142	0.3835	0.0520	0.0952	0.1058	0.0717	0.0712	0.0720	0.0724	0.0716
A_8	0.4841	0.3410	0.3164	0.2511	0.1957	0.0094	0.0314	0.4981	0.0045	0.0100	0.0305	0.1607	0.1667	0.1692	0.1559	0.1667
A_9	0.1363	0.0496	0.2031	0.1493	0.4499	0.1363	0.1284	0.2935	0.0323	0.1105	0.0613	0.2140	0.2250	0.1971	0.2098	0.2264
A_{10}	0.3841	0.0418	-0.0775	0.0503	0.1253	0.1166	0.0898	0.4316	0.0268	0.0627	0.0759	0.1288	0.1257	0.1175	0.1277	0.1398

Step 2-8: The weighted aggregated normalized decision matrix was created as in Table 17.

Table 17. The weighted aggregated normalization decision matrix ($\mathcal{N}_{it}^{*}$)

	$c_1^{\mathbb{T}}$	$c_2^{\mathbb{T}}$	$c_3^{\mathbb{T}}$	$c_4^{\mathbb{T}}$	$c_5^{\mathbb{T}}$	$c_6^{\mathbb{T}}$	$c_7^{\mathbb{T}}$	$c_8^{\mathbb{T}}$	$c_9^{\mathbb{T}}$	$c_{10}^{\mathbb{T}}$	$c_{11}^{\mathbb{T}}$	$c_{12}^{\mathbb{T}}$	$c_{13}^{\mathbb{T}}$	$c_{14}^{\mathbb{T}}$	$c_{15}^{\mathbb{T}}$	$c_{16}^{\mathbb{T}}$
A_1	0.0077	0.0335	0.0419	0.0110	0.0011	0.0056	0.0027	0.0015	0.0008	0.0135	0.0195	0.0252	0.0199	0.0412	0.0385	0.0306
A_2	0.0113	0.0035	0.0316	0.0069	0.0019	0.0278	0.0120	0.0003	0.0094	0.0402	0.0179	0.0210	0.0171	0.0359	0.0283	0.0194
A_3	0.0124	0.0055	0.0198	0.0076	0.0004	0.0163	0.0075	0.0011	0.0021	0.0308	0.0130	0.0089	0.0073	0.0139	0.0128	0.0113
A_4	0.0060	0.0060	-0.0017	0.0034	-0.0013	0.0129	0.0025	0.0008	0.0013	0.0249	0.0084	0.0131	0.0102	0.0216	0.0204	0.0156
A_5	0.0113	0.0067	0.0131	-0.0074	0.0000	0.0100	0.0001	0.0013	0.0015	0.0028	0.0085	0.0069	0.0061	0.0099	0.0088	0.0095
A_6	0.0146	0.0066	-0.0045	0.0029	0.0014	0.0066	0.0030	0.0017	0.0009	0.0078	0.0048	0.0141	0.0117	0.0218	0.0200	0.0181
A_7	0.0135	0.0044	0.0014	0.0047	0.0014	0.0092	0.0031	0.0015	0.0010	0.0093	0.0054	0.0053	0.0042	0.0087	0.0082	0.0064
A_8	0.0208	0.0280	0.0334	0.0088	0.0023	0.0006	0.0009	0.0019	0.0001	0.0010	0.0015	0.0119	0.0092	0.0205	0.0177	0.0141
A_9	0.0059	0.0041	0.0214	0.0052	0.0053	0.0091	0.0035	0.0011	0.0006	0.0108	0.0031	0.0159	0.0132	0.0239	0.0238	0.0203
A_{10}	0.0165	0.0034	-0.0082	0.0018	0.0015	0.0077	0.0025	0.0017	0.0005	0.0061	0.0039	0.0096	0.0074	0.0142	0.0145	0.0126

Step 2-9: The total weighted decision matrix values were summed as in Table 18.

Table 18. The total weighted decision matrix values

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
$\mathcal{C}_i^-$	0.0092	0.0116	0.0135	0.0069	0.0126	0.0163	0.0150	0.0227	0.0070	0.0182
$\mathcal{C}_i^+$	0.2850	0.2728	0.1573	0.1374	0.0764	0.1152	0.0729	0.1499	0.1602	0.0774

Step 2-10 and 2-11: The ranking of the alternatives is shown in Table 19.

Table 19. The ranking and final ranking values of the alternatives

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
Δ_i	0.8900	0.8939	0.7819	0.7128	0.6844	0.7486	0.6927	0.8132	0.7392	0.7126
∇_i	0.1160	0.1166	0.1019	0.0929	0.0892	0.0976	0.0903	0.1060	0.0964	0.0929
Ranking	2	1	4	7	10	5	9	3	6	8

3.3 For Year 2022

The initial decision matrix for year 2022 is shown in Table 20.
The ranking of the alternatives for year 2022 is shown in Table 21.

Table 20. The initial decision matrix for year 2022 $(\mathrm{A} = [\mathrm{A}_{it}]_{mT})$

	$c_1^{\mathbb{T}}$	$c_2^{\mathbb{T}}$	$c_3^{\mathbb{T}}$	$c_4^{\mathbb{T}}$	$c_5^{\mathbb{T}}$	$c_6^{\mathbb{T}}$	$c_7^{\mathbb{T}}$	$c_8^{\mathbb{T}}$	$c_9^{\mathbb{T}}$	$c_{10}^{\mathbb{T}}$	$c_{11}^{\mathbb{T}}$	$c_{12}^{\mathbb{T}}$	$c_{13}^{\mathbb{T}}$	$c_{14}^{\mathbb{T}}$	$c_{15}^{\mathbb{T}}$	$c_{16}^{\mathbb{T}}$
A_1	0.7800	7.8000	0.0079	0.0970	0.1770	49.4900	6.2400	38.7100	28.5400	8.2800	347.6000	0.7803	0.7803	0.7803	0.7803	0.7803
A_2	0.6500	2.6300	0.1271	0.1864	0.1290	250.3000	20.1200	163.9600	324.1600	28.4400	495.4000	0.7466	0.7515	0.7552	0.7285	0.7049
A_3	0.5900	3.0500	-0.1461	-0.1337	0.0376	187.3800	17.9400	110.5700	80.0600	21.2100	461.8000	0.6506	0.6506	0.6506	0.6506	0.6506
A_4	0.8700	2.9300	0.0330	0.1445	0.1199	138.8100	11.7800	121.5200	58.0500	22.6000	285.7000	0.6838	0.6802	0.6873	0.6887	0.6800
A_5	0.5700	3.2900	0.1956	0.2485	0.2039	109.1600	14.5200	63.1000	58.4700	19.5000	281.3000	0.6350	0.6383	0.6317	0.6303	0.6385
A_6	0.5000	3.0300	0.0134	-0.0911	0.0245	74.4400	6.9100	37.5300	43.6500	8.3600	191.4000	0.6922	0.6960	0.6883	0.6868	0.6962
A_7	0.5400	2.7700	0.1455	-0.1788	0.0774	97.1500	6.9500	53.0100	44.9100	8.5300	217.0000	0.6223	0.6184	0.6259	0.6273	0.6182
A_8	0.1400	7.3900	0.0897	-0.1339	-0.0702	12.9700	1.3200	1.8600	6.2200	1.5800	93.7700	0.6747	0.6700	0.6819	0.6750	0.6695
A_9	0.9400	3.0900	0.0040	0.0200	-0.4536	65.1200	6.5500	61.4600	26.0900	9.3400	140.1000	0.7061	0.7111	0.6980	0.7058	0.7115
A_{10}	0.4000	2.6900	-0.0954	-0.0639	0.1088	84.3500	7.2100	34.2600	26.6400	7.5400	193.2000	0.6559	0.6513	0.6521	0.6588	0.6593

Table 21. The ranking and final ranking values of the alternatives

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
Δ_i	0.8541	0.8962	0.7471	0.7659	0.7921	0.7682	0.7263	0.7920	0.7208	0.7255
∇_i	0.1097	0.1151	0.0959	0.0983	0.1017	0.0986	0.0933	0.1017	0.0926	0.0932
Ranking	2	1	7	6	3	5	8	4	10	9

3.4 For Year 2021

The initial decision matrix for year 2021 is shown in Table 22.

Table 22. The initial decision matrix for year 2021 $(\mathrm{A} = [\mathrm{A}_{it}]_{mT})$

	$c_1^{\mathbb{T}}$	$c_2^{\mathbb{T}}$	$c_3^{\mathbb{T}}$	$c_4^{\mathbb{T}}$	$c_5^{\mathbb{T}}$	$c_6^{\mathbb{T}}$	$c_7^{\mathbb{T}}$	$c_8^{\mathbb{T}}$	$c_9^{\mathbb{T}}$	$c_{10}^{\mathbb{T}}$	$c_{11}^{\mathbb{T}}$	$c_{12}^{\mathbb{T}}$	$c_{13}^{\mathbb{T}}$	$c_{14}^{\mathbb{T}}$	$c_{15}^{\mathbb{T}}$	$c_{16}^{\mathbb{T}}$
A_1	0.8100	6.0100	0.1540	0.1021	0.5716	48.8100	5.5800	39.6500	28.3200	7.5500	250.4000	0.7803	0.7803	0.7803	0.7803	0.7803
A_2	0.6400	2.8300	0.1184	0.0699	0.0842	215.7500	17.2900	139.2800	287.6000	23.9700	472.9000	0.7466	0.7515	0.7552	0.7285	0.7049
A_3	0.5900	3.0670	0.1355	0.1961	0.1698	182.0200	20.8800	108.0000	93.7600	24.4800	450.4000	0.6506	0.6506	0.6506	0.6506	0.6506
A_4	0.8900	2.5200	0.2269	0.2635	0.1786	146.5300	11.4700	131.0900	56.2000	19.7500	239.4000	0.6838	0.6802	0.6873	0.6887	0.6800
A_5	0.6300	2.4600	0.1774	0.5526	0.5059	105.6900	13.0500	67.4400	48.9100	15.6200	193.6000	0.6350	0.6383	0.6317	0.6303	0.6385
A_6	0.5200	3.6800	0.2447	0.7388	0.0915	75.2000	7.0400	39.1700	43.0800	9.2000	241.4000	0.6922	0.6960	0.6883	0.6868	0.6962
A_7	0.5600	3.3300	0.2171	0.3066	0.1872	95.1200	7.7200	54.1500	39.2100	10.3200	262.9000	0.6223	0.6184	0.6259	0.6273	0.6182
A_8	0.1100	9.5900	0.3101	0.7366	0.2247	13.5500	1.7000	1.6000	5.7000	1.8200	128.4000	0.6747	0.6700	0.6819	0.6750	0.6695
A_9	0.8900	2.9200	0.0294	0.0213	-0.2879	61.1600	5.8900	54.4700	25.9900	9.1500	126.7000	0.7061	0.7111	0.6980	0.7058	0.7115
A_{10}	0.4500	3.2800	0.3217	0.8669	0.1358	83.1800	6.4300	38.0100	29.4500	8.0500	235.1000	0.6559	0.6513	0.6521	0.6588	0.6593

The ranking of the alternatives for year 2021 is shown in Table 23.

Table 23. The ranking and final ranking values of the alternatives

	$\boldsymbol{A_1}$	$\boldsymbol{A_2}$	$\boldsymbol{A_3}$	$\boldsymbol{A_4}$	$\boldsymbol{A_5}$	$\boldsymbol{A_6}$	$\boldsymbol{A_7}$	$\boldsymbol{A_8}$	$\boldsymbol{A_9}$	$\boldsymbol{A_{10}}$
Δ_i	0.8263	0.8597	0.7923	0.7565	0.7407	0.8022	0.7318	0.8283	0.7068	0.7880
∇_i	0.1055	0.1098	0.1012	0.0966	0.0946	0.1024	0.0934	0.1057	0.0902	0.1006
Ranking	3	1	5	7	8	4	9	2	10	6

3.5 For Year 2020

The initial decision matrix for year 2020 is shown in Table 24.

Table 24. The initial decision matrix for year 2020 $(\mathrm{A} = [\mathrm{A}_{it}]_{mT})$

	$\boldsymbol{c_1^{\mathbb{T}}}$	$\boldsymbol{c_2^{\mathbb{T}}}$	$\boldsymbol{c_3^{\mathbb{T}}}$	$\boldsymbol{c_4^{\mathbb{T}}}$	$\boldsymbol{c_5^{\mathbb{T}}}$	$\boldsymbol{c_6^{\mathbb{T}}}$	$\boldsymbol{c_7^{\mathbb{T}}}$	$\boldsymbol{c_8^{\mathbb{T}}}$	$\boldsymbol{c_9^{\mathbb{T}}}$	$\boldsymbol{c_{10}^{\mathbb{T}}}$	$\boldsymbol{c_{11}^{\mathbb{T}}}$	$\boldsymbol{c_{12}^{\mathbb{T}}}$	$\boldsymbol{c_{13}^{\mathbb{T}}}$	$\boldsymbol{c_{14}^{\mathbb{T}}}$	$\boldsymbol{c_{15}^{\mathbb{T}}}$	$\boldsymbol{c_{16}^{\mathbb{T}}}$
A_1	0.8700	4.1500	0.0995	0.1831	1.1582	46.6300	6.1900	40.8100	24.5400	6.8500	153.1000	0.7803	0.7803	0.7803	0.7803	0.7803
A_2	0.6400	2.3000	0.0619	0.1382	0.1348	200.6800	15.4000	130.1400	257.1400	22.4100	332.7000	0.7466	0.7515	0.7552	0.7285	0.7049
A_3	0.6300	3.0070	0.0056	-0.0502	0.0640	174.8900	14.7100	111.6200	82.5700	20.4700	414.3000	0.6506	0.6506	0.6506	0.6506	0.6506
A_4	0.9100	2.1600	0.3769	0.1232	0.1000	150.5600	4.5600	137.4700	45.8000	15.6300	189.2000	0.6838	0.6802	0.6873	0.6887	0.6800
A_5	0.7200	2.9800	-0.1084	-0.2537	-0.0230	91.5900	7.0700	66.1800	41.5400	10.0600	207.0000	0.6350	0.6383	0.6317	0.6303	0.6385
A_6	0.5400	3.1300	0.0848	0.1525	0.0544	72.5500	4.4700	39.5500	34.6100	5.2900	187.6000	0.6922	0.6960	0.6883	0.6868	0.6962
A_7	0.5000	3.1700	0.2614	0.8542	0.1632	69.0500	6.3800	34.5300	32.2200	7.9000	184.6000	0.6223	0.6184	0.6259	0.6273	0.6182
A_8	0.1200	8.7300	-0.0268	-0.2374	0.1780	11.1700	1.0600	1.4100	4.3600	1.0500	96.1700	0.6747	0.6700	0.6819	0.6750	0.6695
A_9	0.8500	2.9700	0.0853	-0.0639	-0.0273	62.9500	7.2600	53.5400	25.2500	8.9600	133.9000	0.7061	0.7111	0.6980	0.7058	0.7115
A_{10}	0.4700	2.5400	0.2441	0.2824	0.3136	76.1600	3.6500	36.3800	22.2800	4.3100	157.8000	0.6559	0.6513	0.6521	0.6588	0.6593

The ranking of the alternatives for year 2020 is shown in Table 25.

Table 25. The ranking and final ranking values of the alternatives

	$\boldsymbol{A_1}$	$\boldsymbol{A_2}$	$\boldsymbol{A_3}$	$\boldsymbol{A_4}$	$\boldsymbol{A_5}$	$\boldsymbol{A_6}$	$\boldsymbol{A_7}$	$\boldsymbol{A_8}$	$\boldsymbol{A_9}$	$\boldsymbol{A_{10}}$
Δ_i	0.8169	0.8633	0.7777	0.7675	0.6822	0.7696	0.7542	0.7725	0.7436	0.7595
∇_i	0.1060	0.1120	0.1009	0.0996	0.0885	0.0999	0.0979	0.1002	0.0965	0.0985
Ranking	2	1	3	6	10	5	8	4	9	7

3.6 For Year 2019

The initial decision matrix for year 2019 is shown in Table 26.

Table 26. The initial decision matrix for year 2019 ($\mathrm{A} = [\mathrm{A}_{it}]_{mT}$)

	$c_1^{\mathbb{T}}$	$c_2^{\mathbb{T}}$	$c_3^{\mathbb{T}}$	$c_4^{\mathbb{T}}$	$c_5^{\mathbb{T}}$	$c_6^{\mathbb{T}}$	$c_7^{\mathbb{T}}$	$c_8^{\mathbb{T}}$	$c_9^{\mathbb{T}}$	$c_{10}^{\mathbb{T}}$	$c_{11}^{\mathbb{T}}$	$c_{12}^{\mathbb{T}}$	$c_{13}^{\mathbb{T}}$	$c_{14}^{\mathbb{T}}$	$c_{15}^{\mathbb{T}}$	$c_{16}^{\mathbb{T}}$
A_1	0.9300	4.1400	0.0384	0.0070	-0.7500	39.2900	4.6400	36.5900	22.3200	5.7900	126.2000	0.7803	0.7803	0.7803	0.7803	0.7803
A_2	0.6400	2.2200	0.0703	0.1350	0.1056	176.7600	13.8400	114.5900	242.1600	19.6800	278.5000	0.7466	0.7515	0.7552	0.7285	0.7049
A_3	0.6200	3.0500	0.0071	0.0014	-0.0047	157.7300	15.1200	98.2600	82.1100	21.5500	383.9000	0.6506	0.6506	0.6506	0.6506	0.6506
A_4	1.0900	2.3000	0.0157	0.1464	0.0324	89.1100	7.8400	97.2900	33.2700	13.9100	130.9000	0.6838	0.6802	0.6873	0.6887	0.6800
A_5	0.6900	3.4300	0.0975	0.3920	-0.0328	84.4000	9.8400	58.4000	46.5900	13.4800	231.6000	0.6350	0.6383	0.6317	0.6303	0.6385
A_6	0.5300	2.8000	0.0434	0.1943	0.0188	67.8900	3.6700	36.5900	31.9000	4.5900	153.6000	0.6922	0.6960	0.6883	0.6868	0.6962
A_7	0.4900	2.7200	0.0486	0.0999	0.0757	58.3800	3.7000	28.7100	25.5400	4.2600	130.3000	0.6223	0.6184	0.6259	0.6273	0.6182
A_8	0.1400	7.1300	0.2025	0.1048	0.2388	9.7300	1.3800	1.4500	4.4800	1.3800	68.3200	0.6747	0.6700	0.6819	0.6750	0.6695
A_9	0.8300	3.2300	-0.0213	-0.0729	-0.2262	59.7100	7.8400	50.0300	23.2600	9.5700	143.2000	0.7061	0.7111	0.6980	0.7058	0.7115
A_{10}	0.5100	2.2900	0.0506	0.0952	0.0728	62.0800	2.5600	31.8000	17.9100	3.3600	110.5000	0.6559	0.6513	0.6521	0.6588	0.6593

The ranking of the alternatives for year 2019 is shown in Table 27.

Table 27. The ranking and final ranking values of the alternatives

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
Δ_i	0.8070	0.8765	0.7938	0.7175	0.7709	0.7777	0.7133	0.8312	0.7484	0.7346
∇_i	0.1038	0.1128	0.1021	0.0923	0.0992	0.1001	0.0918	0.1070	0.0963	0.0945
Ranking	3	1	4	9	6	5	10	2	7	8

3.7 For Year 2018

The initial decision matrix for year 2018 is shown in Table 28.

Table 28. The initial decision matrix for year 2018 ($\mathrm{A} = [\mathrm{A}_{it}]_{mT}$)

	$c_1^{\mathbb{T}}$	$c_2^{\mathbb{T}}$	$c_3^{\mathbb{T}}$	$c_4^{\mathbb{T}}$	$c_5^{\mathbb{T}}$	$c_6^{\mathbb{T}}$	$c_7^{\mathbb{T}}$	$c_8^{\mathbb{T}}$	$c_9^{\mathbb{T}}$	$c_{10}^{\mathbb{T}}$	$c_{11}^{\mathbb{T}}$	$c_{12}^{\mathbb{T}}$	$c_{13}^{\mathbb{T}}$	$c_{14}^{\mathbb{T}}$	$c_{15}^{\mathbb{T}}$	$c_{16}^{\mathbb{T}}$
A_1	0.7500	3.4000	-0.0603	0.1732	-0.0650	43.9100	3.1500	33.0000	21.4900	5.7900	116.7000	0.7803	0.7803	0.7803	0.7803	0.7803
A_2	0.6300	2.1890	0.1247	0.1404	0.0808	154.2200	11.9900	98.0000	226.2500	17.3400	239.7000	0.7466	0.7515	0.7552	0.7285	0.7049
A_3	0.6000	2.8700	0.0661	0.0989	-0.0068	152.9500	15.3000	93.2000	81.5300	21.2500	346.1000	0.6506	0.6506	0.6506	0.6506	0.6506
A_4	1.1400	2.9000	0.1608	0.1490	-2.6571	59.3500	5.6600	67.8000	32.7500	12.1400	138.7000	0.6838	0.6802	0.6873	0.6887	0.6800
A_5	0.6700	3.0700	0.0617	0.3179	-0.2224	82.6400	6.2200	55.7600	42.4500	9.6800	198.7000	0.6350	0.6383	0.6317	0.6303	0.6385
A_6	0.5400	2.4300	0.1164	0.9493	-0.0121	67.1700	2.3500	36.4500	30.5800	3.8400	127.0000	0.6922	0.6960	0.6883	0.6868	0.6962
A_7	0.5000	2.1100	0.1645	0.1852	0.0855	56.2300	2.9400	28.6500	24.3600	3.8700	90.0900	0.6223	0.6184	0.6259	0.6273	0.6182
A_8	0.1400	7.8500	0.1867	0.1437	0.3989	7.8500	1.1300	1.1600	3.7200	1.2400	54.6900	0.6747	0.6700	0.6819	0.6750	0.6695
A_9	0.8100	2.6700	0.0432	0.0307	-0.5048	66.4200	8.3900	53.9200	23.7700	10.3300	124.0000	0.7061	0.7111	0.6980	0.7058	0.7115
A_{10}	0.4000	1.9200	-0.0699	-0.0252	0.0705	47.8300	2.6500	19.6100	17.0500	3.0700	72.2700	0.6559	0.6513	0.6521	0.6588	0.6593

The ranking of the alternatives for year 2018 is shown in Table 29.

Table 29. The ranking and final ranking values of the alternatives

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
Δ_i	0.8163	0.8814	0.8167	0.7360	0.7449	0.8010	0.7331	0.8211	0.7759	0.7110
∇_i	0.1042	0.1125	0.1042	0.0939	0.0950	0.1022	0.0935	0.1048	0.0990	0.0907
Ranking	4	1	3	8	7	5	9	2	6	10

3.8 Comparative Analysis

A comparative analysis for the data in year 2023 is shown in Table 30. Methods including the AROMAN, measurement of alternatives and ranking according to compromise solution (MARCOS) [35], and root assessment method (RAM) [36] were used in the comparative analysis. Based on the findings, the best alternative in all methods was determined to be alternative A_2 and the second-best alternative was determined to be alternative A_1. And also, company evaluations by year are shown in Figure 1.

Table 30. Comparison of AROMAN, MARCOS, and RAM methods

	AROMAN		**MARCOS**		**RAM**	
	Values	**Ranking**	**Values**	**Ranking**	**Values**	**Ranking**
A_1	0.9815	2	0.1529	2	0.8639	2
A_2	1.0000	1	1.0000	1	1.0000	1
A_3	0.4654	4	0.1471	3	0.5439	5
A_4	0.1358	7	0.0143	9	0.1337	7
A_5	0.0000	10	0.0893	4	0.3817	6
A_6	0.3066	5	0.0323	6	0.0779	9
A_7	0.0400	9	0.0000	10	0.1220	8
A_8	0.6150	3	0.0798	5	0.5960	3
A_9	0.2619	6	0.0299	8	0.5442	4
A_{10}	0.1346	8	0.0312	7	0.0000	10

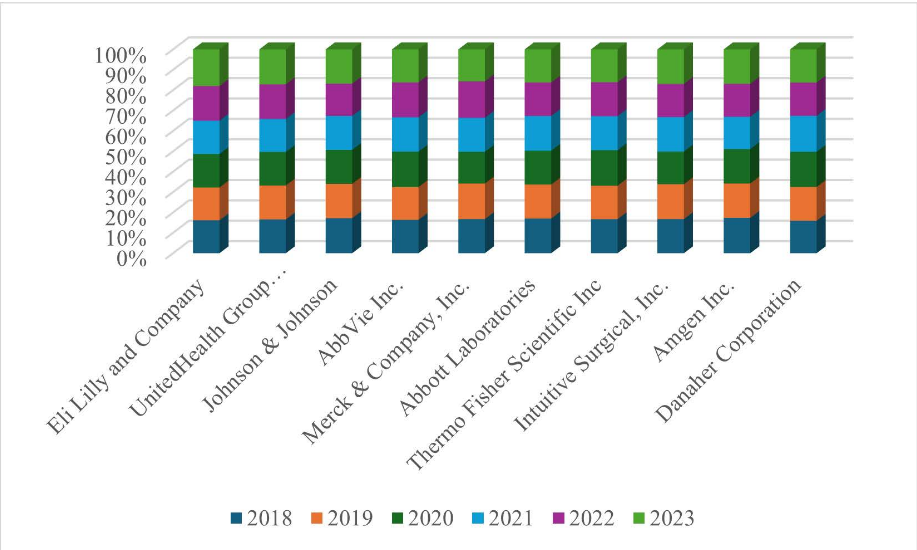

Figure 1. Evaluations of the companies by year

4 Conclusions

This study proposed a robust hybrid framework integrating Spherical Cubic Fuzzy (SCF) sets, the Aczel–Alsina aggregation operator, and two advanced MCDM methods, i.e., the RANCOM and AROMAN, to evaluate the financial performance of healthcare companies listed in the S&P 500 index. The evaluation covers the period from year 2018 to 2023, a time frame that includes the peak impacts of the COVID-19 pandemic on global markets. By combining both financial and non-financial indicators, the model provides a holistic assessment structure that captures firm performance beyond traditional metrics for profitability.

The decision model was built upon 16 criteria, including classical financial ratios such as revenue growth, operating profit, leverage, and market capitalization, alongside non-financial dimensions like environmental management, business ethics, human resources, supply chain robustness, and crisis preparedness. Expert evaluations, modeled on SCF sets and aggregated with the Aczel–Alsina operator, were obtained from ten professionals with strong backgrounds in finance, accounting, and healthcare operations.

The results indicated that Company A_2 consistently ranked first across all years from 2018 to 2023, hence demonstrating high resilience and performance stability during the pandemic. Company A_1 closely followed to secure second in most years. In contrast, Company A_5 and A_{10} often appeared in the bottom rankings, thus reflecting comparatively weaker financial and organizational responses to the crisis.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors confirm that there are no conflicts of interest related to the research or its publication.

References

[1] R. E. Freeman, *Strategic Management: A Stakeholder Approach*. Cambridge University Press, 2010.

[2] F. Modigliani and M. H. Miller, "The cost of capital, corporation finance and the theory of investment," *Amer. Econ. Rev.*, vol. 48, no. 3, pp. 261–297, 1958.

[3] D. M. Li, G. R. Wan, and Y. Rong, "An enhanced spherical cubic fuzzy WASPAS method and its application for the assessment of service quality of crowdsourcing logistics platform," *Spect. Decis. Mak. Appl.*, vol. 3, no. 1, pp. 100–123, 2026. https://doi.org/10.31181/sdmap31202641

[4] J. Aczél and C. Alsina, "Characterizations of some classes of quasilinear functions with applications to triangular norms and to synthesizing judgements," *Aequat. Math.*, vol. 25, no. 1, pp. 313–315, 1982. https://doi.org/10.1007/BF02189626

[5] J. Więckowski, B. Kizielewicz, A. Shekhovtsov, and W. Sałabun, "RANCOM: A novel approach to identifying criteria relevance based on inaccuracy expert judgments," *Eng. Appl. Artif. Intell.*, vol. 122, p. 106114, 2023. https://doi.org/10.1016/j.engappai.2023.106114

[6] G. Ali, M. Nabeel, and A. Farooq, "Extended ELECTRE method for multi-criteria group decision-making with spherical cubic fuzzy sets," *Knowl. Inf. Syst.*, vol. 66, no. 10, pp. 6269–6306, 2024. https://doi.org/10.1007/s10115-024-02132-4

[7] S. Bošković, L. Švadlenka, M. Dobrodolac, S. Jovčić, and M. Zanne, "An extended AROMAN method for cargo bike delivery concept selection," *Decis. Mak. Adv.*, vol. 1, no. 1, pp. 1–9, 2023. https://doi.org/10.31181/v120231

[8] Y. Liu and Z. P. Li, "Establishment of bankruptcy courts and corporate investment decisions," *Int. Rev. Econ. Finance*, p. 104195, 2025. https://doi.org/10.1016/j.iref.2025.104195

[9] N. A. de Oliveira and L. F. C. Basso, "The impact of value creation (Tobin's Q), total shareholder return (TSR), and survival (Altman's Z) on credit ratings," *Int. J. Financ. Stud.*, vol. 12, no. 2, p. 44, 2024. https://doi.org/10.3390/ijfs12020044

[10] J. Tobin, "A general equilibrium approach to monetary theory," *J. Money Credit Bank.*, vol. 1, no. 1, pp. 15–29, 1969. https://doi.org/10.2307/1991374

[11] O. R. Vila, S. G. Bharadwaj, and S. C. Bahadir, "Exploration-and exploitation-oriented marketing strategies and sales growth in emerging markets," *Cust. Needs Solut.*, vol. 2, no. 4, pp. 277–289, 2015. https://doi.org/10.1007/s40547-015-0053-0

[12] Y. Q. Fang and F. Li, "Deep-Learning Earnings," *SSRN*, 2025. https://doi.org/10.2139/ssrn.5196742

[13] T. Guliyev and M. Muzaffarov, "Deciphering sustainable growth: The influence of corporate financial metrics on SGR and stock returns," *WSB J. Bus. Finance*, vol. 58, no. 1, pp. 114–121, 2024. https://doi.org/10.2139/ssrn.4883487

[14] J. Hu, J. M. Chen, and S. Zaib, "Financial resource curse and firms' accessibility to financing in resource-based countries," *Heliyon*, vol. 10, no. 17, 2024. https://doi.org/10.1016/j.heliyon.2024.e36644

[15] H. Amsal, “Performance review of profitability ratio of PT Mayora Indah Tbk: Comparison of profitability ratios in 2022 and 2023,” *SSRN*, 2025. https://doi.org/10.2139/ssrn.5125287

[16] L. J. Abbott, S. Parker, and T. J. Presley, “Female board presence and the likelihood of financial restatement,” *Account. Horiz.*, vol. 26, no. 4, pp. 607–629, 2012. https://doi.org/10.2308/acch-50249

[17] O. Meier, P. Naccache, and G. Schier, “Exploring the curvature of the relationship between HRM–CSR and corporate financial performance,” *J. Bus. Ethics*, vol. 170, no. 4, pp. 857–873, 2021. https://doi.org/10.1007/s10551-019-04332-3

[18] B. D. Chali and V. Lakatos, “The impact of human resource management on financial performance: A systematic review in cooperative enterprises,” *J. Risk Financ. Manag.*, vol. 17, no. 10, p. 439, 2024. https://doi.org/10.3390/jrfm17100439

[19] M. Cheshmberah and S. Beheshtikia, “Supply chain management maturity: An all-encompassing literature review on models, dimensions and approaches,” *LogForum*, vol. 16, no. 1, pp. 103–116, 2020. https://doi.org/10.17270/J.LOG.2020.377

[20] O. E. Okeke-Uzodike and E. P. Ngo Henha, “Resilience during crisis: COVID-19 and the new age of remote work in higher education—A systematic literature review,” *Adm. Sci.*, vol. 15, no. 3, p. 92, 2025. https://doi.org/10.3390/admsci15030092

[21] R. R. Ahmed, M. H. Pahi, S. Nadeem, R. H. Soomro, V. Parmar, F. Nasir, and F. Ahmed, “How and when ethics lead to organizational performance: Evidence from South Asian firms,” *Sustainability*, vol. 15, no. 10, p. 8147, 2023. https://doi.org/10.3390/su15108147

[22] Y. J. Zhou, J. W. Li, H. Rechberger, G. S. Wang, S. Y. Chen, W. L. Xing, and P. Y. Li, “Dynamic criticality of by-products used in thin-film photovoltaic technologies by 2050,” *J. Clean. Prod.*, vol. 263, p. 121599, 2020. https://doi.org/10.1016/j.jclepro.2020.121599

[23] S. Nazir, L. Zhaolei, S. Mehmood, and Z. Nazir, “Impact of green supply chain management practices on the environmental performance of manufacturing firms considering institutional pressure as a moderator,” *Sustainability*, vol. 16, no. 6, p. 2278, 2024. https://doi.org/10.3390/su16062278

[24] S. Aslam, M. H. Elmagrhi, R. U. Rehman, and C. G. Ntim, “Environmental management practices and financial performance using data envelopment analysis in Japan: The mediating role of environmental performance,” *Bus. Strategy Environ.*, vol. 30, no. 4, pp. 1655–1673, 2021. https://doi.org/10.1002/bse.2700

[25] Eli Lilly and Company, “Key facts,” 2025. https://www.lilly.com/about/key-facts

[26] UnitedHealth Group, “Our businesses,” 2025. https://www.unitedhealthgroup.com/uhg/businesses.html

[27] Johnson & Johnson, “Our company history,” 2025. https://www.jnj.com/CH/our-company-history

[28] AbbVie Incorporated, “Science,” 2025. https://www.abbvie.com/science.html

[29] Merck & Co., Inc., “History,” 2025. https://www.merck.com/company-overview/history/

[30] Abbott Laboratories, “Our heritage,” 2025. https://www.abbott.com/about-abbott/our-heritage.html

[31] Thermo Fisher Scientific Inc., “About,” 2025. https://corporate.thermofisher.com/us/en/index/about.html

[32] Intuitive Surgical, Inc., “Ion,” 2025. https://www.intuitive.com/en-us/products-and-services/ion

[33] Amgen Inc., “Amgen history,” 2025. https://www.amgen.com/about/amgen-history

[34] Danaher Corporation, “About danaher,” 2025. https://danaher.com/about-danaher

[35] Ž. Stević, D. Pamučar, A. Puška, and P. Chatterjee, “Sustainable supplier selection in healthcare industries using a new MCDM method: Measurement of alternatives and ranking according to COmpromise solution (MARCOS),” *Comput. Ind. Eng.*, vol. 140, p. 106231, 2020. https://doi.org/10.1016/j.cie.2019.106231

[36] A. Sotoudeh-Anvari, “Root assessment method (RAM): A novel multi-criteria decision making method and its applications in sustainability challenges,” *J. Clean. Prod.*, vol. 423, p. 138695, 2023. https://doi.org/10.1016/j.jclepro.2023.138695