Applying an integrated data-driven weighting system – CoCoSo approach for financial performance evaluation of Fortune 500 companies

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Abstract: *Financial performance evaluation provides information about a firm's liquidity position, profitability, capital structure and asset utilization. Financial performance evaluation is considered as a multi-criteria decision making (MCDM) problem, as it is a multidimensional concept that is realized by bringing together multiple indicators. This study is aimed to evaluate the financial performance of the Fortune 500 companies by using the integrated data-driven weighting system (IDDWS) – combined compromise solution (CoCoSo) approach. The criteria weights were calculated with the IDDWS and the companies were ranked by the CoCoSo method. In the last stage, a three-stage sensitivity analysis was performed to test the robustness of the model. In the first stage, 15 scenarios were defined by changing the criteria weights. In the second stage, the rankings of the CoCoSo method were compared with the other MCDM methods [range of value (ROV), proximity indexed value (PIV), complex proportional assessment (COPRAS), Biswas and Saha's method]. In the third stage, a sensitivity analysis was conducted under five different scenarios based on different δ parameters. It was determined that the rankings obtained as a result of the sensitivity analysis show small deviations and except for a few companies, the ranking of most companies remained the same. The results show that the proposed model is suitable for measuring financial performance and Alphabet performs best. The suitability of the proposed model for measuring financial performance was tested for the first time. It is thought that the comparative use of many MCDM methods through a comprehensive sensitivity analysis will contribute to the literature.*

Keywords: *Financial performance, multi-criteria decision making (MCDM), data-driven weighting system (IDDWS), combined compromise solution (CoCoSo).*

JEL Classification: *C44, L25, C10.*

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Introduction

In today's global competitive world, the correct evaluation of the performance of companies is critical not only for themselves but also for their stakeholders and investors. Performance evaluation is one of the most significant tools for identifying a firm's strengths and weaknesses, external opportunities and threats, and it also enables companies to compare themselves with others (Farrokh et al., 2016). Financial performance evaluation, which is widely used to determine the performance of a firm and compare it with its competitors, allows making economic decisions and forecasting the company's

future cash flows (Berk et al., 2012). Financial ratios are convenient tools for measuring financial performance, which is expressed by various terms such as productivity, economic development and profitability. In general, companies want to know their place among their opponents in the same industry to follow appropriate strategies. Therefore, the ranking of companies in the business world is quite important (Abdel-Basset et al., 2020). The financial performance evaluation is a complex process involving multiple indicators and alternatives. Therefore, it is regarded as a multi criteria decision making (MCDM) problem. These techniques with different decision variables can monitor more than one target and specify the criteria weights using different decision variables and rank the alternatives. Therefore, MCDM techniques are among the most effective techniques for performance evaluation (Aldalou & Perçin, 2020).

This study is about the real-life application where the financial performances of the Fortune 500 companies are evaluated by integrated MCDM methods. The integrated approach proposed in this study was divided into three stages: (i) the criteria weights were calculated with the IDDWS using the weighting coefficients obtained by the CRITIC-entropy methods; (ii) the financial performance of the companies was evaluated using the combined compromise solution (CoCoSo) method; (iii) sensitivity analysis was performed to measure the consistency of the proposed model. The prominent advantages and originality of this study can be explained as follows: (i) the proposed approach has the ability to facilitate the decision-making process on financial performance; (ii) the criteria with the highest importance will be determined for financial performance evaluation; (iii) the criteria weights will be determined objectively, away from subjectivity; (iv) the suitability of the IDDWS-CoCoSo approach for the financial performance measurement will be tested for the first time; (v) the effect of different criterion weights, different MCDM methods, and different δ parameters on the ranking results were simultaneously examined through sensitivity analysis.

1. Literature review

Recently, various MCDM methods were proposed to evaluate financial performance. This section covers the studies in which financial performance measurement is handled by MCDM methods and the studies conducted using the CoCoSo method as separate sections.

1.1 MCDM studies on financial performance evaluation

Many studies in the literature on financial performance evaluation considered financial performance criteria when ranking the alternatives. Ghadikolaei et al. (2014) implemented fuzzy MCDM models for evaluating of Iranian companies' performance. They used the fuzzy analytic hierarchy process (FAHP) to specify the criteria weights. Then, fuzzy VIKOR-ARAS-COPRAS methods were used to rank the companies. Abdel-Basset et al. (2020) used MCDM methods to evaluate the steel firms in Egypt based on specified financial ratios. They determined the criteria weights using neutrosophic AHP. They used VIKOR and TOPSIS methods for ranking the ten major steel companies. Moghimi and Anvari (2014) used the fuzzy AHP-TOPSIS model to evaluate the financial performance of 8 Iranian cement companies traded in the Tehran Stock Exchange. Celen (2014) used the integrated fuzzy AHP-TOPSIS model to measure the financial performance of 44 banks in Turkey in the period of 2002–2010. Ignatius et al. (2012) used the PROMETHEE II method for measuring the financial performance of 8 Iranian automotive firms Pineda et al. (2018) measured the financial and operational performance of 12 airline companies operating in the USA using MCDM methods. The criteria weights were determined by the ANP method and DEMATEL, and the performance rankings of the alternatives were obtained using the VIKOR method. Varmazyar et al. (2016) applied integrated balanced scorecard (BSC) and MCDM methods for evaluating the financial performance of research and technology organizations. DEMATEL method was used to reveal the interdependencies between BSC perspectives. The ANP was used to specify the criteria weights while the ARAS, COPRAS, MOORA, and TOPSIS methods were used to rank the alternatives. Aldalou and Perçin (2020) proposed the fuzzy Shannon entropy and fuzzy ELECTRE I approach for evaluating the performance of the firms traded in the XUTEK. Baležentis et al. (2012) applied the fuzzy TOPSIS-ARAS-VIKOR methods for evaluating the financial performance of Lithuanian economic sectors. Marjanović and Popović (2020)

evaluated the financial performance of all banks that operated in the Republic of Serbia using the integrated CRITIC-TOPSIS model. CRITIC-TOPSIS model was used to obtain the criteria weights and to rank the alternatives, respectively. A summary of the aforementioned studies is presented in Tab. 1.

Tab. 1: Summary of studies evaluating financial performance with MCDM methods – Part 1

Study	Objectives	Criteria	Methods	Results
Ghadikolaei et al. (2014)	Financial performance evaluation of Iranian companies	ROA, ROE, operating profit growth, P/E, Tobin's Q, economic value added, market value added, cash value added, true value added, refined economic value added, created shareholder value	FAHP, FVIKOR, FARAS, FCOPRAS	The rankings obtained with the 3 different MCDM methods are different and Rena company took the first place
Abdel-Basset et al. (2020)	Financial performance evaluation of steel companies in Egypt	Current ratio, quick ratio, debt ratio, total debt to capitalization ratio, debt to worth ratio, debt to equity ratio, interest coverage ratio, debt-service coverage ratio, debt to capital ratio, ROA, ROE, asset turnover ratio, gross profit, P/E, net profit margin, ROIC, operating profit margin	AHP, VIKOR, TOPSIS	The rankings obtained by the TOPSIS and VIKOR methods are different
Moghimi and Anvari (2014)	Financial performance evaluation of Iranian cement companies	Current ratio, quick ratio, debt ratio, net profit margin, ROE, sales growth, current asset turnover ratio, total asset turnover ratio, inventory turnover ratio, account receivable turnover ratio, fixed assets to shareholder's equity ratio, fixed assets to long-term debt ratio	FAHP, TOPSIS	Sabhan company ranked first and the proposed model was found to be suitable for financial performance measurement
Celen (2014)	Financial performance evaluation of Turkish banking sector	Shareholders' equity/ total asset, TC assets/total assets, total deposits/total assets, financial assets (net)/ total assets, total loans and receivables/total assets, liquid assets/total assets, TC liquid assets/total assets, net profit/ losses/total assets, other operating expenses/total assets	FAHP, TOPSIS	Capital, assets quality and profitability ratios are almost equally the most important criteria while balance-sheets ratio is the least important criteria
Ignatius et al. (2012)	Financial performance evaluation of Iran's automotive sector	Sales growth, sales margin, ROA, ROE, current ratio, asset turnover, operating profit/ financial cost	PROMETHEE II	It has been determined that the PROMETHEE II method has a good potential for financial performance evaluation

Tab. 1: Summary of studies evaluating financial performance with MCDM methods – Part 2

Study	Objectives	Criteria	Methods	Results
Baležentis et al. (2012)	Financial performance evaluation of Lithuanian economic sectors	Gross profit margin, ROA, leverage ratio, current ratio, receivables turnover ratio, equity turnover ratio	FVIKOR, FARAS, FTOPSIS	It has been determined that the best performing sector is forestry and logging sector
Pineda et al. (2018)	Evaluation of airline financial and operational performance	Operative profit or loss/net income, net income, operative revenue, stock's price, operative expenses, operative profit/loss, reservation charges fees	DRSA, DANP, VIKOR	The proposed model is an effective tool in terms of revealing the strengths and weaknesses of airlines
Varmazyar et al. (2016)	Performance evaluation of research and technology organizations	Net profit rate, cost performance index, quality performance index, after-sales service offer, employee turnover, education metrics	Balanced scorecard, DEMATEL, ANP, ARAS, COPRAS, MOORA, TOPSIS	The rankings obtained by different methods differed; the correlation between the results obtained with COPRAS and MOORA is the highest
Aldalou and Perçin (2020)	Financial performance evaluation of companies listed at BIST Technology index of Turkey	Current ratio, acid test ratio, networking capital to asset ratio, stock turnover, account receivable turnover, total assets turnover, equity turnover, networking capital turnover, total debt ratio, debt to equity ratio, gross profit margin, operating profit margin, net profit margin, ROA, ROE, total assets growth ratio, sales growth ratio, equity growth ratio	Entropy, FSE, FELECTRE I	DESPEC was identified as the best company in the industry financially
Marjanović and Popović (2020)	Financial performance evaluation of banks in the Republic of Serbia	ROA, capital adequacy ratio, loan loss reserves to loans, loans-to-deposits, net interest margin, cash and cash equivalent to deposits	CRITIC, TOPSIS	CRITIC, TOPSIS techniques can be easily used to evaluate the financial performance of banks

Source: own

1.2 MCDM studies on the CoCoSo method

The CoCoSo is an effective MCDM technique used to choose from multiple alternatives. Although it is a new method, it has been used in a number of studies as a decision-support tool. Yazdani et al. (2019) introduced the CoCoSo method to select logistics and transportation companies in France. Ecer and Pamucar (2020) applied an integrated fuzzy CoCoSo-Bonferroni and fuzzy BWM model for sustainable supplier selection. Peng et al. (2019) used the Pythagorean fuzzy decision-making algorithm-CoCoSo-CRITIC approach for 5G industry evaluation. Ulutaş et al. (2020) applied the fuzzy SWARA and CoCoSo methods for selecting the logistics center location. Kharwar et al. (2020) used the CoCoSo method with neural network modeling for evaluating drilling performances in polymer nanocomposites. Torkayesh et al. (2021) used the integrated BWM-LBWA-CoCoSo model to assess healthcare sectors in Eastern Europe. Zolfani et al.

(2019) applied the integrated the BWM-CoCoSo model for supplier selection for the Steel Alborz Industrial company in Iran. Stanujkic et al. (2020) used the entropy-CoCoSo approach to evaluate the progress of EU countries in achieving sustainable development goals. Lahane and Kant (2021) used the integrated Pythagorean FAHP-CoCoSo model to rank the performance outcomes. Khan and Haleem (2021) applied the CoCoSo-based approach for evaluating sustainable and circular economy practices. Alrasheedi et al. (2021) proposed the IVT fuzzy CoCoSo approach to measure the green growth indicators. Kumar and Verma (2021) used the principal component analysis and CoCoSo method to investigate the processability of graphene nanocomposites. Deveci et al. (2021) offered the integrated fuzzy power heronian function-CoCoSo model to rank robotic vehicles.

2. Proposed methodology

This section describes the proposed methods in this paper. In this part, we suggest an approach composed of four techniques (Entropy-CRITIC--DDWS-CoCoSo) for evaluating the financial performance of the 10 Fortune 500 companies by 2021. As previously mentioned, the IDDWS was applied to specify the criteria weights and the CoCoSo method was used to rank the firms according to their financial performance. In the next steps, the mathematical notations and explanations of all the methods used in the study will be given.

2.1 CRITIC method

The CRITIC method is a technique that increases objectivity in the analysis process regarding the eliminating subjective evaluations of decision-makers. This method, proposed by Diakoulaki et al. (1995), is advantageous due to its objectivity, not requiring subjective judgments of the decision-maker, and having a simple calculation procedure. On the other hand, it is disadvantageous as it does not reflect certain characteristics of the data and does not express the relative importance of decision-makers reaching their targets (Siksnelyte-Butkiene et al., 2020). The algorithm of the method is given below (Diakoulaki et al., 1995).

Step 1: Decision matrix is normalized.

The decision matrix is normalized using the following formulas for benefit and cost criteria, respectively.

$$r_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}} \quad \text{benefit criteria} \tag{1}$$

$$r_{ij} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}} \quad \text{cost criteria} \tag{2}$$

where: $i = 1, \ldots, m$; $j = 1, \ldots, n$; x_j^{max} and x_j^{min} state the best and worst performance of the criterion j, respectively.

Step 2: Calculation of linear correlation matrix.

Linear correlation coefficients (ρ_{jk}) are using Formula (3) to measure the degree of relationship between evaluation criteria.

$$p_{jk} = \frac{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j) - (r_{ik} - \bar{r}_k)}{\sqrt{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)^2 - \sum_{i=1}^{m}(r_{ij} - \bar{r}_k)^2}}, \quad j,k = 1, \ldots, n \tag{3}$$

Step 3: Calculation of total information (TI; C_j) and standard deviation values (SD; σ_j).

The TI (C_j) and the SD (σ_j) are calculated using Formulas (4) and (5), respectively.

$$C_j = \sigma_j \sum_{k=1}^{n}(1 - p_{jk}) \tag{4}$$

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}(r_{ij} - \bar{r}_j)^2}{m}} \tag{5}$$

Step 4: Designation of the objective criteria weights.

The criteria weights are designated using Formula (6).

$$w_j = \frac{c_j}{\sum_{j=1}^{n} c_j}, \quad j = 1, 2, \ldots, n \tag{6}$$

2.2 Improved entropy method

Improved entropy is a method used to calculate objective weights based on decision matrix data. The method, which is advantageous in terms of converting a decision matrix with negative data into a positive one, is considered disadvantageous due to reasons such as being too objective (Yang et al., 2022). The steps of the method are as follows (Wang & Lee, 2009; Zhang et al., 2014).

Step 1: Decision matrix elements are transformed by Z-score standardization using Formula (7).

$$x_{ij} = \frac{x_{ij} - \overline{x_i}}{s_i} \quad (7)$$

where: x_{ij} – the standardized data of the index i in region j; X_{ij} – the original data; X_i and S_i – the arithmetic mean and standard deviation values, respectively.

Step 2: A positive decision matrix is formed using Formula (8).

$$x'_{ij} = x_{ij} + A, \ \ A > \left|\min x_{ij}\right| \quad (8)$$

where: x'_{ij} – the standard value after transformation; $\boldsymbol{x'_{ij}}$ must be >0.

Step 3: The decision matrix is normalized using Formula (9).

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (9)$$

where: P_{ij} – the value of the normalized decision matrix elements.

Step 4: Entropy measure of criteria is calculated using Formula (10).

$$e_j = -k \sum_{i=1}^{n} P_{ij} \, In \, P_{ij} \, , \forall j \quad (10)$$

where: k – a constant, represented by the formula $k = \frac{1}{In(m)}$; e_j – the entropy value of the criterion j; m – the number of alternatives.

Step 5: The differentiation degree of each criteria is calculated using Formula (11).

$$d_j = 1 - e_j, \ \ \forall j \quad (11)$$

where: d_j – the contrast density in the structure j.

Step 6: The criteria weights are calculated using Formula (12).

$$W_j = \frac{d_j}{\sum_{k=1}^{n} d_k}, \ \ \forall i \quad (12)$$

where: $0 \leq w_j \leq 1$ and $\sum_{j=1}^{n} w_j = 1$.

2.3 IDDWS approach

The IDDWS was proposed by Torkayesh et al. (2021) to designate the criteria weights. It is a combination of Shannon's entropy-CRITIC methods. Using this method, an addition operator was created to calculate the criteria weights with two methods (CRITIC, Entropy). These methods are advantageous because they use the initial decision matrix to determine weights, and there is no bias in the weight determination process (Torkayesh et al., 2021). The final weight of criteria is calculated using Formula (13).

$$w_j = \delta * \xi + (1 - \delta) * \zeta \quad (13)$$

where: w_j (j = 1, 2, ..., n) – the final weights of criteria; ξ_j – the weighting coefficient calculated by the entropy method; ζ_j – the weighting coefficient calculated by the CRITIC method; $\delta \in [0, 1]$ – the coefficient that identifies the percentage share of the final weights of the criteria.

Formula $\delta = 0.5$ is recommended to rank the alternatives. Because in such a case, both methodology are used equally in the weighting of the criteria. While $0.5 < \delta \leq 1$ values are preferred for Shannon entropy methodology, $0 \leq \delta < 0.5$ values are preferred for CRITIC methodology (Torkayesh et al., 2021).

2.4 CoCoSo method

The CoCoSo method introduced by Yazdani et al. (2019) is the integration of the SAW, WASPAS and EWP methods. The method is advantageous due to its ability to increase the reliability and robustness of decision-making results, as well as being easy to implement (Lai et al., 2020). However, it is disadvantaged due to its inability to calculate the weight coefficients of the criteria (Deveci et al., 2021). The steps are as follows (Yazdani et al., 2019).

Step 1: The decision matrix is created.

Step 2: The criteria are normalized.

$$r_{ij} = \frac{x_{ij} - \min\limits_i x_{ij}}{\max\limits_i x_{ij} - \min\limits_i x_{ij}} \ \text{benefit criteria} \quad (14)$$

$$r_{ij} = \frac{\max\limits_i x_{ij} - x_{ij}}{\max\limits_i x_{ij} - \min\limits_i x_{ij}} \ \text{cost criteria} \quad (15)$$

Step 3: S_i and P_i values are calculated.

$$S_i = \sum_{j=1}^{n} (w_j \, r_{ij}) \tag{16}$$

$$P_i = \sum_{j=1}^{n} (r_{ij})^{w_j} \tag{17}$$

The S_i and P_i values are obtained according to the gray relational analysis and WASPAS methodology, respectively.

Step 4: The assessment score strategies are calculated.

The alternatives' weights are calculated using the formulas below.

$$k_{ia} = \frac{P_i + S_i}{\sum_{i=1}^{m} (P_i + S_i)'} \tag{18}$$

$$k_{ib} = \frac{S_i}{\min\limits_i S_i} + \frac{P_i}{\min\limits_i P_i} \tag{19}$$

$$k_{ic} = \frac{\lambda(P_i) + (1-\lambda)(S_i)}{(\lambda \max\limits_i S_i + (1-\lambda) \max\limits_i P_i)} \tag{20}$$

Formulas (18) and (19) represent the sum of arithmetic mean and sum of relative scores of the WSM-WPM. The balanced reconciliation of WSM/WPM models scores are calculated using Formula (20). In Formula (20), λ is usually chosen as 0.5 by the decision makers.

Step 5: The performance scores of alternatives are calculated.

The alternatives' performance scores are computed using Formula (21). The highest performance score is desired.

$$k_i = (\text{“}k_{ia}\, k_{ib}\, k_{ic}\text{”})^{1/3} + \frac{1}{3}(\text{“}k_{ia} + k_{ib} + k_{ic}\text{”}) \tag{21}$$

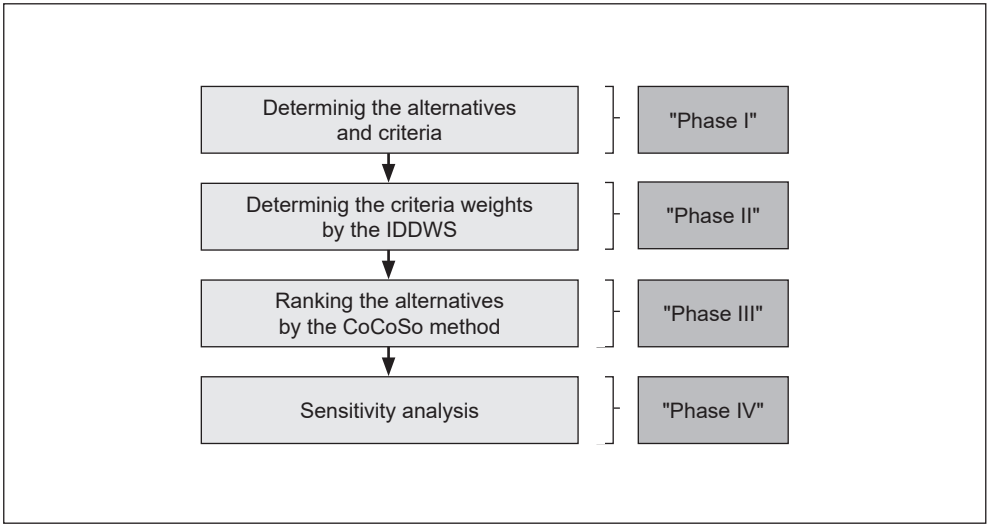

Fig. 1: Flowchart of research framework

Source: own

3. Results

In this section, the IDDWS and CoCoSo approachs were applied to evaluate the financial performance of Fortune 500 companies by 2021. A similar study using the proposed model has not been found in the literature. The proposed model is given in Fig. 1.

3.1 Determining the alternatives

The top 10 companies of Fortune 500 list are alternatives to the study (Tab. 2).

3.2 Determining the indicators

A comprehensive literature review was carried out to determine the indicators used in

Tab. 2: Alternatives

Rank	Company's name
1	Walmart
2	Amazon
3	Apple
4	CVS Health
5	UnitedHealth Group
6	Berkshire Hathaway
7	McKesson
8	AmerisourceBergen
9	Alphabet
10	Exxon Mobil

Source: Fortune (2021)

Tab. 3: Criteria and disclosures

Code	Ratios	Stimulants (S)/ destimulants (D)
Liquidity ratios		
CR	Current ratio = current assets/current liabilities	S
QR	Quick ratio = (current assets − ınventories)/current liabilities	S
Leverage ratios		
LR	Leverage ratio = total liabilities/total assets	D
Profitability ratios		
ROA	Return on assets = net ıncome (annual)/total assets	S
EPS	Earnings per share = profit for the period/number of shares	S
Efficiency ratios		
ATR	Asset turnover rate = net sales/total assets	S

Source: own

the research and previous financial studies examined. The financial ratios used in the research were chosen to provide information about the ability of companies to pay their short-term debts, their financial structure, profitability, and effective use of assets and resources. The financial data required for the analysis were obtained through the financial statements of the companies included in the research. The criteria are given in Tab. 3.

3.3 Results of the CRITIC method

The decision matrix (Tab. 4) was used to perform the steps of the CRITIC method. The results are presented in Tab. 5.

3.4 Results of the improved entropy method

The results of improved entropy method are presented in Tab. 6.

Tab. 4: Decision matrix

Alternatives	Criteria					
	CR	QR	LR	ROA	EPS	ATR
Walmart (F1)	0.79	0.22	1.94	6.70	5.19	2.25
Amazon (F2)	1.05	0.86	2.44	7.88	14.09	1.43
Apple (F3)	1.16	1.13	1.25	19.44	3.28	0.89
CVS Health (F4)	0.91	0.61	2.31	3.09	5.46	1.16
UnitedHealth Group (F5)	0.74	0.00	1.76	8.00	16.03	1.35
Berkshire Hathaway (F6)	0.32	0.26	0.73	5.23	17.77	0.31
McKesson (F7)	1.01	0.55	9.11	−6.91	4.95	3.92
AmerisourceBergen (F8)	0.99	0.61	0.98	−7.45	2.18	4.50
Alphabet (F9)	3.07	3.05	0.44	14.82	22.30	0.67
Exxon Mobil (F10)	0.80	0.46	1.07	−6.37	−5.25	0.52

Source: own

Tab. 5: Criteria weights

	CR	QR	LR	ROA	EPS	ATR
w_j	0.1109	0.1148	0.1793	0.1538	0.1293	0.3119

Source: own

Tab. 6: Criteria weights for the improved entropy method

	CR	QR	LR	ROA	EPS	ATR
w_j	0.1435	0.1448	0.1378	0.2027	0.2086	0.1626

Source: own

Tab. 7: Weights for the IDDWS approach

Criteria	CRITIC	Rank	Entropy	Rank	Final aggregated weight	Final ranking
CR	0.1109	6	0.1435	5	0.1272	6
QR	0.1148	5	0.1448	4	0.1298	5
LR	0.1793	2	0.1378	6	0.1585	4
ROA	0.1538	3	0.2027	2	0.1783	2
EPS	0.1293	4	0.2086	1	0.1689	3
ATR	0.3119	1	0.1626	3	0.2372	1

Source: own

Tab. 8: Result of the CoCoSo method

	k_{ia}	k_{ib}	k_{ic}	k_i	Rank
F1	0.109	3.486	0.873	2.18	4
F2	0.114	3.757	0.909	2.32	3
F3	0.113	3.827	0.902	2.34	2
F4	0.106	3.135	0.851	2.02	7
F5	0.095	3.362	0.763	2.03	6
F6	0.079	2.874	0.63	1.72	8
F7	0.085	2.675	0.681	1.68	9
F8	0.098	3.595	0.785	2.14	5
F9	0.125	5.170	1.000	2.96	1
F10	0.076	2.017	0.611	1.36	10

Source: own

3.5 Determination of criteria weights using the IDDWS approach

The criteria weights were determined using Formula 14 (Tab. 7).

3.6 Results of the CoCoSo method

The results of the CoCoSo method are presented in Tab. 8. The results show that Alphabet performs best in terms of financial performance. Apple and Amazon were selected as the second and third top firms for financial performance, respectively. AmerisourceBergen and Walmart were observed in the fourth and fifth places. McKesson and Exxon Mobil took the last places.

4. Sensitivity analysis

A sensitivity analysis of the CoCoSo method was carried out in three phases. In the first phase, the differences in the ranking results were analyzed by changing the criteria weights. In the second phase, the results of the CoCoSo method were compared with the other MCDM methods (ROV, PIV, COPRAS, Biswas and Saha's method). In the third phase, a sensitivity analysis was conducted based on different δ parameters. The δ parameter expresses the percentage share of the criteria weights in the final ranking.

4.1 Changing the criteria weights

The sensitivity analysis was conducted in previous studies to examine the suitability of assigned criterion weights. Some studies only applied the same weights for all criteria (Höfer et al. 2016); however, some changed their criterion weights with each other (Colak & Kaya, 2020). In some studies, sensitivity analysis was performed by changing the most important criteria weight (Torkayesh et al. 2021). In this study, similarly to Colak and Kaya's (2020), 15 scenarios were defined by changing the criteria weights to check the variations of final suitable maps and fluctuations in results. The 15 different scenarios were obtained by changing the criteria weights with each other. The criteria weights and the results for all scenarios are summarized in Tab. 9 and Fig. 2.

As seen in Tab. 9, changing the criteria weights affected the ranking. This proves that criterion weights have an effect on the results. On the other hands, the alternative Alphabet was determined as the most suitable alternative for all scenarios.

4.2 Comparing the CoCoSo results with other MCDM methods

In this section, the CoCoSo method was compared with the four MCDM methods (ROV, PIV, COPRAS, Biswas and Saha's method). The features, such as the suitability of the methods for real-world problems and their ease of application, were effective in the selection process. The results obtained with the selected methods are presented in Tab. 10.

As a result of the Spearman rank correlation test in Tab. 11, a high positive correlation was detected between the rankings obtained by ROV and PIV methods.

Tab. 9: Stability of the solution for the CoCoSo method under 15 scenarios

Scenarios	CR	QR	LR	ROA	EPS	ATR	Ranking of alternatives	Compromise solution(s)
1 (CR-QR)	**0.130**	**0.127**	0.159	0.178	0.169	0.237	4-3-2-7-6-8-9-5-1-10	Alphabet
2 (CR-LR)	**0.159**	**0.130**	**0.127**	0.178	0.169	0.237	4-3-2-7-6-9-8-5-1-10	Alphabet
3 (CR-ROA)	**0.178**	**0.130**	0.159	**0.127**	0.169	0.237	5-2-3-6-7-9-8-4-1-10	Alphabet
4 (CR-EPS)	**0.169**	**0.130**	0.159	0.178	**0.127**	0.237	4-3-2-6-7-9-8-5-1-10	Alphabet
5 (CR-ATR)	**0.237**	**0.130**	0.159	0.178	0.169	**0.127**	4-3-2-5-6-8-9-7-1-10	Alphabet
6 (QR-LR)	0.127	**0.159**	**0.130**	0.178	0.169	0.237	4-3-2-7-6-9-8-5-1-10	Alphabet
7 (QR-ROA)	0.127	**0.178**	0.159	**0.130**	0.169	0.237	5-2-3-6-7-9-8-4-1-10	Alphabet
8 (QR-EPS)	0.127	**0.169**	0.159	0.178	**0.130**	0.237	4-3-2-6-7-9-8-5-1-10	Alphabet
9 (QR-ATR)	0.127	**0.237**	0.159	0.178	0.169	**0.130**	4-3-2-5-6-8-9-7-1-10	Alphabet
10 (LR-ROA)	0.127	**0.130**	**0.178**	**0.159**	0.169	0.237	4-3-2-6-7-8-9-5-1-10	Alphabet
11 (LR-EPS)	0.127	**0.130**	**0.169**	0.178	**0.159**	0.237	4-3-2-6-7-8-9-5-1-10	Alphabet
12 (LR-ATR)	0.127	**0.130**	**0.237**	0.178	0.169	**0.159**	4-3-2-5-6-8-9-7-1-10	Alphabet
13 (ROA-EPS)	0.127	**0.130**	0.159	**0.169**	**0.178**	0.237	4-3-2-7-6-8-9-5-1-10	Alphabet
14 (ROA-ATR)	0.127	**0.130**	0.159	**0.237**	0.169	**0.178**	4-3-2-6-5-8-9-7-1-10	Alphabet
15 (EPS-ATR)	0.127	**0.130**	0.159	0.178	**0.237**	**0.169**	4-2-3-6-5-8-9-7-1-10	Alphabet

Note: The criteria weights that replace each other are expressed with bolded value.

Source: own

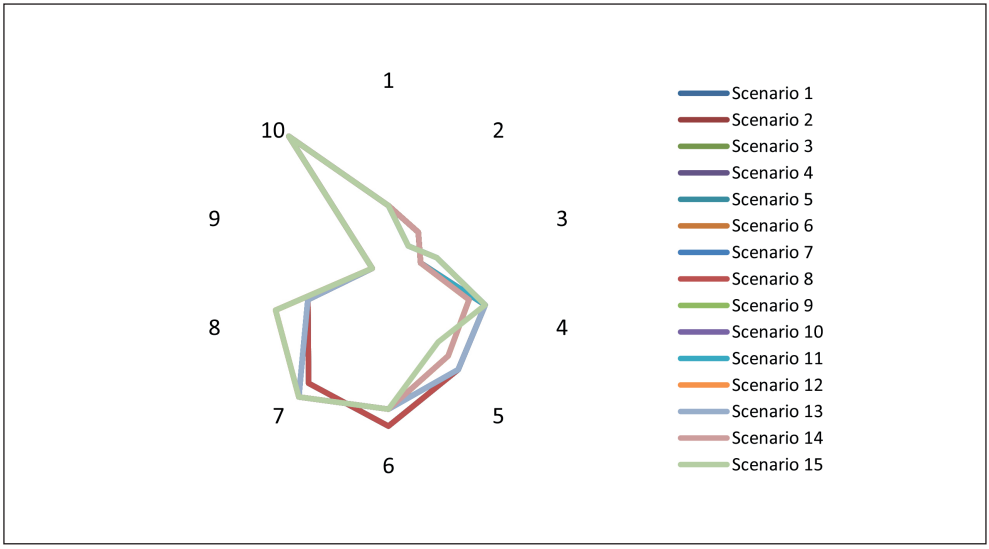

Fig. 2: Stability of the solution for the CoCoSo method under 15 scenarios

Source: own

Tab. 10: Comparison of MCDM methods

	ROV	PIV	COPRAS	Biswas and Saha's methods	CoCoSo
Walmart	6	6	6	7	4
Amazon	4	4	4	3	3
Apple	2	2	2	4	2
CVS Health	8	8	9	9	7
UnitedHealth Group	5	5	5	5	6
Berkshire Hathaway	7	7	8	6	8
McKesson	9	9	7	8	9
AmerisourceBergen	3	3	3	2	5
Alphabet	1	1	1	1	1
Exxon Mobil	10	10	10	10	10

Source: own

Tab. 11: Spearman rank correlation coefficients

Spearman *p*	ROV	PIV	COPRAS	Biswas and Saha's method	CoCoSo
ROV	**1**	1.000	0.964*	0.939*	0.927*
PIV		**1**	0.964*	0.939*	0.927*
COPRAS			**1**	0.927*	0.891*
Biswas and Saha's method				**1**	0.806*
CoCoSo					**1**

Note: *Indicates significance at the 1% level.

Source: own

4.3 Changing the parameter Δ in the algorithm of IDDWS

In the third section, a sensitivity analysis was carried on based on the δ parameter. The parameter δ is the coefficient that expresses the percentage share of the criteria weights in the final decision. In this section, five different scenarios were established for the δ parameter, and the results are compared. The results are presented in Tab. 12.

According to Tab. 12 and Fig. 3, the ranking results obtained with different δ parameter values are different. While the rankings of other firms changed, the rankings of Amazon, Alphabet, and Exxon Mobil remained the same in all scenarios.

5. Discussion

This study is aimed to evaluate the financial performance of top 10 companies of Fortune 500 list by using the MCDM methods. The criteria weights were calculated with the IDDWS and the companies were ranked by the CoCoSo method. A three-stage sensitivity analysis was conducted to test the robustness of the model. Firstly, 15 scenarios were established by changing the criterion weights. Then, the CoCoSo method was compared to ROV, PIV, COPRAS, Biswas and Saha's

Tab. 12: The effect of different δ parameters on the results

Alternatives	Scenario 1 (δ = 0.50)		Scenario 2 (δ = 0.40)		Scenario 3 (δ = 0.30)		Scenario 4 (δ = 0.20)		Scenario 5 (δ = 0.10)	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Walmart	2.182	4	2.180	4	2.179	5	2.177	5	2.176	5
Amazon	2.322	3	2.302	3	2.282	3	2.263	3	2.245	3
Apple	2.344	2	2.321	2	2.299	2	2.278	2	2.258	4
CVS Health	2.021	7	2.011	7	2.001	6	1.992	6	1.983	6
UnitedHealth Group	2.032	6	2.013	6	1.995	7	1.977	7	1.960	7
Berkshire Hathaway	1.717	8	1.698	8	1.679	9	1.662	9	1.644	9
McKesson	1.684	9	1.698	9	1.711	8	1.724	8	1.738	8
AmerisourceBergen	2.144	5	2.165	5	2.186	4	2.206	4	2.226	4
Alphabet	2.963	1	2.911	1	2.861	1	2.812	1	2.764	1
Exxon Mobil	1.356	10	1.356	10	1.356	10	1.357	10	1.358	10

Source: own

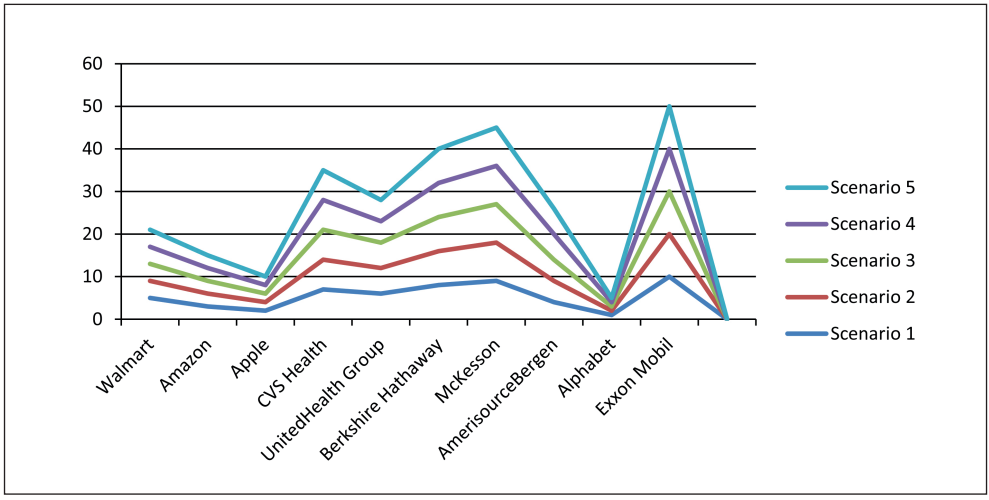

Fig. 3: The effect of different δ parameters on the results

Source: own

methods. Finally, five different scenarios were established using different δ parameters.

According to the IDDWS results, ATR was identified as the most important criterion, while CR was identified as the least important criterion. According to the CoCoSo results, Alphabet, Apple, Amazon, AmerisourceBergen, and Walmart ranked in the top five, while Exxon Mobil, McKesson, Berkshire Hathaway, CVS Health, and UnitedHealth Group were in the bottom five. As part of the sensitivity analysis, 15 scenarios were established by

using different criterion weights. Accordingly, although the positions of the first and last-ranked firms remained the same, the overall ranking changed. There are many examples of this situation in the literature (Alemi-Ardakani et al. 2016; Kumar & Parimala, 2019; Zavadskas & Podvezko, 2016). In the second stage of the sensitivity analysis, the CoCoSo method was compared to ROV, PIV, COPRAS, Biswas, and Saha's methods. Although the positions of the first and last-ranked firms remained the same, the rankings obtained by different MCDM methods generally differed. There are studies in the literature that can be examples of this situation, such as Mathew and Sahu (2018), Goswami et al. (2021), Ecer and Pamucar (2022), Nguyen et al. (2022), and Pamučar and Ćirović (2015). In the final stage of sensitivity analysis, five different scenarios were established for the δ parameters. As a result, there were small deviations in the rankings obtained based on different δ parameters. In the study conducted by Torkayesh et al. (2021), 100 scenarios were established based on different δ parameters, and it was found that different δ parameter values changed the scores of alternatives, but not their ranking.

No study has been found in the literature that measures financial performance using MCDM methods with the same dataset and sample. However, Ersoy (2022) measured the financial performance of 10 companies from the Fortune 500 list using five normalization techniques based on equal weights – Biswas and Saha models. It has been determined that Apple, Berkshire Hathaway, AmerisourceBergen, and McKesson are among the top-ranking companies, while Exxon Mobil, AT&T, and Walmart are among the bottom-ranking companies. Ersoy (2021) measured the financial performance of 10 companies on the Fortune 500 list in 2020 using the Entropy-ROV model. As a result of the study, ATR and LR were identified as the criteria with the highest and lowest importance degrees, respectively. Apple, Unitedhealth Group, Amazon, AmerisourceBergen, and Berkshire Hathaway ranked in the top five, while AT&T, CVS Health, Exxon Mobil, Walmart, and McKesson ranked in the bottom five.

Conclusions

Ranking companies according to their financial performance is one of the most important problems in the MCDM field. The selection of the method to be used in this area can be as complex as the process itself. This study is about the application of the hybrid IDDWS-CoCoSo model in the process of evaluating the financial performance of Fortune 500 companies. The performance of the companies was evaluated based on six main financial ratios. The IDDWS and CoCoSo method was used to specify the criteria weights, and to evaluate the alternatives, respectively. The sensitivity analysis of the CoCoSo method was applied in three phases. In the first phase, the differences in the ranking results were analyzed by changing the criteria weights. In the second phase, the results of the CoCoSo method were compared with the four MCDM methods (ROV, PIV, COPRAS, Biswas and Saha's method). In the third phase, a sensitivity analysis was conducted based on the δ parameter.

Tab. 10 displays the ranking of the top 10 Fortune 500 firms based on their financial performance. Accordingly, Alphabet was the firm with the highest financial performance. This was followed by Apple, Amazon, AmerisourceBergen, Walmart, UnitedHealth Group and CVS Health, respectively. The firm with the lowest financial performance was Exxon Mobil. This was followed by McKesson and Berkshire Hathaway, respectively. The following results were obtained with the three-stage sensitivity analysis:

(i) The 15 different scenarios were obtained by replacing the criteria weights with each other. Accordingly, the rankings obtained with each scenario are different from each other.
(ii) The results of the CoCoSo method were compared with four MCDM methods (ROV, PIV, COPRAS, Biswas and Saha's method). Accordingly, the rankings obtained by different methods are different (excluding ROV and PIV).
(iii) By changing the δ parameter in the clustering function of weight coefficients, 5 scenarios were obtained. The ranking results obtained with different δ parameter values are different. Accordingly, while the rankings of other firms changed, the rankings of Amazo, Alphabet, Exxon Mobil remained the same in all scenarios.

It has been determined that the criterion weights obtained with different parameter δ values affect the results. The rankings obtained by the different MCDM methods used in the study showed minor deviations. This

indicates the robustness of the rankings obtained by the CoCoSo method.

When examining the decision matrix, it was determined that firms with negative and low profitability ratios were ranked at the bottom. On the other hand, firms with high benefit-oriented criteria (CR, QR, ROA, EPS, ATR) and low cost-oriented criteria (LR) were still ranked at the top. It has been found that companies with high profitability are ranked at the top in the rankings.

This study is important as it is the first to address financial performance measurement with the hybrid IDDWS-CoCoSo model. The proposed model is based on the real data from the annual reports of each firm. In addition, analyzing only the year 2021, using six indicators, and using only objective methods can be considered as limitations of the study. For future work, the proposed model can be used for financial evaluation of other departments. Instead of the indicators in this study, other similar ratios (ROE, cash ratio, debt/equity ratio, stock turnover ratio) that reflect the profitability, asset structure, assets and liabilities of the companies can be preferred and the results obtained can be compared. The financial performance comparison of the same companies over the years will be conducted by the author of the study in the future, using both objective and subjective MCDM methods.

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