Accounting 10 (2024) 221–228

Contents lists available at GrowingScience

Accounting

homepage: www.GrowingScience.com/ac/ac.html

An application of TOPSIS and BWM for portfolio allocation

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C H R O N I C L E

Article history:
Received January 15, 2024
Received in revised format April 16 2024
Accepted July 9 2024
Available online
July 9 2024

Keywords:
Financial metrics
MCDM
TOPSIS
BWM

A B S T R A C T

This article introduces a comprehensive analysis of 20 leading companies, scrutinized through their financial metrics across various sectors. By deploying multi-criteria decision-making (MCDM) techniques, we aim to offer investors a clear and objective perspective on which companies stand out as the best investment options. Among the MCDM techniques, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is utilized, renowned for its efficiency in handling complex decision-making scenarios which is conducted by two clauses. 1) Implementing TOPSIS with assigning equal weights and same share to every chosen metrics as criteria and 2) employ BWM (Best Worst Method) to calculate these weights base on their significance and relevancy to the prosses of ranking. According to the Result gained from the computation, ranks 1 to 5 belong to the similar companies with both assumptions which are Ford Motor Co, BP plc, Tesla Inc, General Motors Co and Exxon Mobil Corp. The consistency in rankings across two different weighting assumptions highlights the robustness of the criteria used, ensuring stable and reliable outcomes. This enhances the credibility of the findings, making them more trustworthy and citable for those who seek reliable and robust methodologies for informed investment decisions.

1. Introduction

In today's complex and rapidly changing financial landscape, investors continually seek robust and reliable methods to assess potential investment opportunities. The challenge is not only to identify companies that present a promising return but also to understand how various financial metrics influence these investment decisions. With the multitude of factors affecting company performance, the need for a systematic approach to evaluate and compare companies becomes imperative. This article attempts to provide valuable insights and data-driven analysis to help investors make informed decisions and highlights potential investment opportunities among top-performing companies, which can attract both novice and experienced investors.

In this article, multiple companies from all over the world with different work fields and industries have been chosen to be compared. This detailed analysis is designed to equip potential investors with the knowledge and insights needed to make informed decisions in the dynamic world of stock investments. This process happens through the companies` most critical financial metrics extracted from *https://finance.yahoo.com.*

The model that the article proposes for examining these alternatives and criteria is based on MCDM approaches. The development of MCDM methods has been motivated not only by a variety of real-life problems requiring the consideration of multiple criteria, but also by practitioners' desire to propose enhanced decision-making techniques using recent advancements in mathematical optimization, scientific computing, and computer technology (Toloie-Eshlaghy & Homayonfar, 2011). MCDM provides a structured approach to decision-making when there are multiple, often conflicting criteria to consider. It helps decision-makers evaluate, compare, and prioritize different alternatives based on these criteria.

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doi: 10.5267/j.ac.2024.7.001

The goal is to make decisions that best align with the objectives and constraints of a particular context, whether in business, engineering, healthcare, or public policy.TOPSIS is a popular and effective MCDM method that helps in ranking and selecting from a set of alternatives based on their distance from an ideal solution which stands for Technique for Order Preference by Similarity to Ideal Solution, was first introduced by Hwang and Yoon, and further developed by Lai et al., and Yoon and Hwang (Zavadska et al., 2016). This method is noted for requiring minimal subjective input from decision makers, with the primary subjective input being the assignment of weights. Moreover, TOPSIS has been adapted to use neural network methods for determining weights and has been extended to incorporate fuzzy set theories. It has also been applied in evaluating company performances and analyzing financial ratios within specific industries (Olson, 2004).

There are various applications of TOPSIS adopted in many areas of scientific societies and there are different extensions of TOPSIS such as fuzzy TOPSIS where we consider uncertainty with input parameters. This extension is more realistic since in today's world, uncertainty is an inevitable part of incidents (Aiello et al., 2009).

One of the strengths of the TOPSIS approach is its practical application across diverse fields. For instance, a study by Chou et al. (2008) demonstrated the application of TOPSIS in the telecommunications industry, where it was used to select the optimal network provider based on multiple criteria such as service quality, cost, and technology compatibility. This underscores the adaptability of TOPSIS to various decision-making scenarios where multiple conflicting criteria must be evaluated.

To enhance the robustness of the analysis, employment of two distinct assumptions within the TOPSIS framework has been done: the first treats all financial metrics as equally important, assuming equal weights to each; the second leverages a cutting-edge method known as the Best-Worst Method (BWM). BWM refines the weighting process by identifying the most and least significant criteria from the set, providing a nuanced approach to the weighting of financial metrics. The Best-Worst Method (BWM) was introduced by (Rezaei, 2015). It emerged from the need for a more reliable and consistent approach to multi-criteria decision-making (MCDM) compared to existing methods. Traditional methods like the Analytic Hierarchy Process (AHP) often faced challenges with consistency and the cognitive load on decision-makers when performing pairwise comparisons. BWM was developed to address these issues by reducing the number of comparisons and improving the consistency of the results.

Unlike methods that require extensive pairwise comparisons among all criteria, BWM significantly reduces the number of comparisons by focusing only on the best and worst criteria. The method inherently promotes higher consistency in the comparisons made by decision-makers, leading to more reliable and valid results.

By integrating these methodologies, this study not only compares these companies under a unified framework but also tests the consistency of results under different weighting scenarios. This approach provides a dual validation of our findings, ensuring that investors receive the most reliable guidance for their investment decisions.

2. Methodology

As mentioned, ranking these ten well-known companies is analyzed by two general methods of multiple-criteria decision making (MCDM). The main method used to compare these companies by their various financial metrics is **T**echnique for **O**rder **P**reference by **S**imilarity to **I**deal **S**olution or as it will be mentioned as TOPSIS. In this method, each criterion must be weighted to the priority of each over other be specified. For making this process of weighing more accurate and precise, another method called BWM or **B**est **W**orst **M**ethod is used to prioritize these criteria.

2.1. TOPSIS

Before delving into the detailed steps of the TOPSIS method, it is essential to understand its foundational principles. TOPSIS stands for "Technique for Order of Preference by Similarity to Ideal Solution." This decision-making approach evaluates various alternatives by comparing their similarity to an ideal solution, thereby assisting in the selection of the best possible option. The method is grounded in the concept that the chosen alternative should have the shortest distance from the ideal point and the farthest distance from the nadir point. TOPSIS is highly valued for its efficiency and minimal reliance on subjective inputs, making it a popular choice among decision-makers who seek a systematic and objective approach to complex decision problems. Here are sequential steps involved in implementing the TOPSIS methodology to ensure a clear and effective decision-making process.

Step 1 Begin by constructing an evaluation matrix composed of m alternatives and n criteria, denoted by x_{ij} .This results in a matrix $\left(x_{ij}\right)_{m\times n}$.

Assumptions: 1. The value and suitability of each criterion should be linearly decreasing or increasing.

2. The criterion should be independent.

Step 2 Normalize the matrix $(x_{ij})_{m\times n}$ by the method below to make matrix $R = (r_{ij})_{m\times n}$:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad i = 1,2,\dots,n \quad j = 1,2,\dots.,n$$

Step 3 W_j is the original weight given to the criterion v_j , $j = 1,2,\dots.,n$.

$$w_j = \frac{W_j}{\sqrt{\sum_{i=1}^{n} W_j}} \quad i = 1,2,\dots,n \quad j = 1,2,\dots.,n$$

So $\sum_{j=1}^{n} w_j = 1$.

Now form the weighted normalized decision matrix:

$V = (v_{ij})_{m\times n} = (w_j r_{ij})_{m\times n}$, $i = 1,2,\dots.,m.$,

Step 4 Determine the Positive Ideal and Negative Ideal Solutions:

The Positive Ideal Solution (PIS) is the best value for each criterion.

The Negative Ideal Solution (NIS) is the worst value for each criterion.

PIS: $A^+ = \{v_1^+ , v_2^+ , \dots., v_n^+\}$

NIS: $A^- = \{v_1^- , v_2^- , \dots., v_n^-\}$

Step 5 Minkowski`s L_p metrics is proposed to calculate distance measure between target alternative *i* and the worst condition A^-:

$$S^- = \left(\sum_{j=1}^{p} \left|v_{ij} - v_i^-\right|^p\right)^{\frac{1}{p}} , i = 1,2,\dots..m, j = 1,2,\dots,n$$

And distance measure between target alternative *i* and the worst condition A^+:

$$S^+ = \left(\sum_{j=1}^{p} \left|v_{ij} - v_i^+\right|^p\right)^{\frac{1}{p}} , i = 1,2,\dots..m, j = 1,2,\dots,n$$

If $p = n$ then Tchebycheff distance, [4]

$p = 2$ then Euclidean distance,

$p = 1$ then Manhattan (city block) distance.

Note: In most application, Euclidean distance is used.

Step 6 Calculate the relative closeness of each alternative to the ideal solution:

$$C_i = \frac{S^-}{(S^- + S^+)} , 0 \le C_i \le 1 , i = 1,2,\dots,m.$$

$C_i = 1$ if and only if the alternative solution has the best condition.

$C_i = 0$ if and only if the alternative solution has the worst condition.

Step 7 Rank the alternatives based on the relative closeness to the ideal solution.

The higher the C_i, the better the alternative rank.

As it is explained in step 3, it is essential to have the weight assigned to each criterion.

2.2. BWM

The Best-Worst Method is a structured technique for determining the relative importance of a set of decision criteria. It simplifies the decision-making process by focusing on the most and least important criteria, which are then used as benchmarks to evaluate the remaining criteria. This results in a more straightforward and less cognitively demanding approach compared to other MCDM methods. According to BWM, the best (e.g., most desirable, most important) and the worst (e.g., least desirable, least important) criteria are identified first by the decision-maker. Pairwise comparisons are then conducted between each of these two criteria (best and worst) and the other criteria. A maximin problem is then formulated and solved to determine the weights of different criteria. The weights of the alternatives with respect to different criteria are obtained using the same process. The final scores of the alternatives are derived by aggregating the weights from different sets of criteria and alternatives, based on which the best alternative is selected (Rezaei, 2015).

Based on BWM we need to track the following steps to calculate the vector $w = \{w_1, w_2, \dots, w_n\}$.

Step 1 List all the criteria relevant to the decision-making problem.

So, define a set of criteria ($\{c_1, c_2, \dots, c_n\}$) that is used to decide about alternatives.

Step 2 From the list of criteria, identify the criterion that is considered the best (most important) and the one that is considered the worst (least important).

Step 3 1) Form a Best-to-Others (BO) vector based on the comparisons of the best criterion with all others.

In BO vector, a_{Bj} represents the preference of the best factor ***B*** over selection factor *j* and $a_{BB} = 1$.

$$A_B = (a_{B1}, a_{B2}, \dots, a_{Bn})$$

2) Form an Others-to-Worst (OW) vector based on the comparisons of all other criteria with the worst criterion.

In the OW vector, a_{jW} represents the preference of selection factor *j* over the worst decision factor *W* and $a_{WW} = 1$.

$$A_W = (a_{1W}, a_{2W}, \dots, a_{nW})^T$$

Step 4 Determine the optimal weights of the criteria by solving a linear programming model that minimizes the maximum absolute difference between the pairwise comparison ratios and the actual ratios of the weights. Compute the best possible weights $w = \{w_1, w_2, \dots, w_n\}$ by:

$$\min max_j \left\{ \left| \frac{w_b}{w_j} - a_{Bj} \right|, \left| \frac{w_j}{w_W} - a_{jW} \right| \right\}$$
$$s.t \quad \sum_j w_{j=1}, w_j \geq 0$$

Or in the linear programming modeling:

$$\min \xi$$
$$\left| \frac{w_B}{w_j} - a_{B_j} \right| \leq \xi$$
$$\left| \frac{w_j}{w_W} - a_{jW} \right| \leq \xi$$
$$s.t \quad \sum_j w_{j=1}, w_j \geq 0$$

Step 5 Assess the consistency of the comparisons:

$$consistency\ ratio = \frac{\xi}{consistency\ index}$$

The "Consistency Index" can be seen in Table 1 (Rezaei, 2015).

Table 1
Consistency index

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency Index	0	0.44	1	1.63	2.3	3	3.73	4.47	5.23

A Consistency Ratio (CR) near zero signifies higher consistency, while a CR near one signifies lower consistency. Although BWM consistently yields reliable results, Rezaei (2015) highlighted that in Analytical hierarchy process (AHP) (Saaty, 2008), CR is utilized to check the validity of the comparisons. In contrast, in BWM, CR measures the degree of reliability of the comparisons.

3. The Proposed Model

The main purpose of the article is to rank High-profile companies based on their various performance metrics. This article tries to provide a clearer picture of the financial health, growth potential, and risk factors associated with each company and also helps investors diversify their portfolios by identifying a mix of high-performing stocks across various sectors.

So, it is essential to choose several companies as alternatives and various financial metrics as criteria.

3.1 Selection of Companies as Alternatives

The process of selecting prominent companies in order to compete with another by being evaluated by their financial metrics is very challenging since there are numerous variables to be compared. So, by restricting some of these variables, a few attributes of each company got examined.

The fundamental attribute which was considered was the company`s market cap. A company's market cap, more commonly referred to as its "market capitalization" is the total market value of a company's outstanding shares of stock. It is a key indicator used by investors to gauge the size, value, and overall financial health of a company. It is calculated using the following formula:

Market Cap= Share Price × Number of Outstanding Share.

The other attributes are general characteristics such as dominant market share, strong brand recognition, and leadership in their industry, reputation for excellent customer service, diverse global workforce, diverse global workforce, global fame, etc. (See appendix).

3.2 Selection of Financial Metrics as Criteria

As it was mentioned before, this article attempts to evaluate these chosen companies (alternatives) through some of their important Financial Metrics. When evaluating the financial health and potential of a company, several key financial metrics are crucial. Each metric provides different insights into the company's operational efficiency, profitability, liquidity, solvency, and market valuation. It is crucial to choose variables which project its profitability. These metrics assess a company's ability to generate earnings relative to its revenue, assets, and equity, which reflect its efficiency and potential for growth. The other significant category is the growth metrics which strongly indicate the company's future potential. These metrics focus on the growth aspects of a company, analyzing the increases in revenue, profit, and market share. There are some more aspects that need to be considered such as cash flow metrics which provide insight into the actual cash available for use in expanding operations, paying dividends, or reducing debt. Management Effectiveness is a category of financial metrics used to assess how well a company's management team utilizes its resources to generate profit and create value for shareholders. Therefore, these categories encompass a comprehensive range of financial metrics, each vital for understanding different facets of a company's financial health. By all these considerations 9 metrics have chosen to be examined as the role of criteria.

Table 2
Financial metrics used for the proposed model

Category	Sub-category	Definition	Formula
Profitability	Profit Margin	Measures the percentage of profit earned by a company in relation to its revenue.	$\frac{Sales - Total\ Expenses}{Revenue} \times 100$
	Operating Margin	Measures how much profit a company makes on sales after paying for variable costs of production	$\frac{Operating\ income}{Revenue} \times 100$
Management Effectiveness	Return on Assets	Shows the percentage of how profitable a company's assets are in generating revenue.	$\frac{Net\ inome}{Average\ Total\ Assests} \times 100$
	Return on Equity	A measure of the profitability of a business in relation to its equity	$\frac{Net\ inome}{Average\ Shareholders`\ Equity}$
Income Statement	Revenue Per Share	The monetary value of earnings per outstanding share of common stock for a company	$\frac{Profit\ -\ Preferred\ Dividends}{Weighted\ Average\ Common\ Shares}$
	Quarterly Revenue Growth	An increase in the company's sales from one quarter to the next quarter	$\frac{Revenue_{Quarter\ 2}\ - Revenue_{Quarter\ 1}}{Revenue_{Quarter\ 2}}$
	Quarterly Earnings Growth	An increase in the company's earnings from one quarter to the next quarter	$\frac{Earnings_{Quarter\ 2}\ - Earnings_{Quarter\ 1}}{Earnings_{Quarter\ 2}}$
Cash Flow Statement	Levered Free Cash Flow	The amount of money that a company has left remaining after paying all of its financial obligations.	$EBITDA^{1} - \Delta NWC^{2} - CapEx^{3} - D^{4}$
Share Statistics	Implied Shares Outstanding	All the shares of a corporation that have been authorized, issued and purchased by investors and are held by them	
	Cash Flow (per Share)	The percentage calculated by levered Free Cash Flow divided by implied shares outstanding	$\frac{Levered\ Free\ Cash\ Flow}{Implied\ Shares\ Outstanding} \times 100$

[1]EBITDA = Earnings before interest, taxes, depreciation, and amortization
[2]ΔNWC = Change in net working capital
[3]CapEx = Capital expenditures
[4]D = Mandatory debt payments

4. The Examination of The Proposed Model using TOPSIS and BWM

By determining the alternatives and criteria and extracting the exact amount of each metrics, the data is formed in Table 3.

Table 3
The information of data used for the proposed method

Company	Profitability		Management Effectiveness		Income Statement			Cash Flow (Per share)
	Profit Margin	Operating Margin	Return on Assets	Return on Equity	Revenue Per Share	Quarterly Revenue Growth	Quarterly Earnings Growth	
APPLE	26.31%	30.74%	22.07%	147.25%	24.54	-4.30%	-2.20%	5.52
MSFT	36.43%	44.59%	15.30%	38.49%	31.83	17.00%	19.90%	8.27
AMZN	6.38%	10.68%	5.95%	20.31%	57.13	12.50%	228.80%	5.50
GOOGLE	25.90%	32.52%	15.61%	29.76%	25.37	15.40%	57.20%	4.37
NVDA	53.40%	59.85%	49.10%	115.66%	32.34	262.10%	628.40%	11.38
TSLA	14.37%	5.50%	4.72%	23.74%	29.8	-8.70%	-55.10%	-0.19
LLY	17.08%	31.20%	12.60%	50.57%	39.92	26.00%	66.80%	-0.001
META	32.06%	38.58%	17.31%	33.36%	55.67	27.30%	116.70%	13.83
ABBV	11.02%	28.29%	7.71%	56.24%	30.77	0.70%	472.80%	13.33
XOM	9.78%	13.23%	7.83%	16.25%	83.3	-3.50%	-28.10%	5.88
BP	4.62%	11.07%	4.47%	11.47%	17.66	-13.10%	-72.50%	4.05
MRK	3.76%	42.47%	10.26%	5.31%	24.22	8.90%	68.80%	3.79
PEP	10.00%	15.97%	8.77%	50.95%	66.81	2.30%	5.70%	4.65
WMT	2.88%	4.24%	6.92%	23.46%	81.46	6.00%	205.10%	0.97
COST	2.73%	3.76%	8.35%	31.19%	560.61	9.10%	29.10%	8.9
PANW	31.42%	9.09%	3.42%	85.88%	24.75	15.30%	158.60%	7.58
F	2.21%	3.13%	1.12%	9.40%	44.43	3.10%	-24.20%	-0.43
GM	6.13%	8.88%	2.47%	14.43%	134.13	7.60%	24.40%	-1.73
TM	10.97%	10.05%	4.07%	15.72%	2085.76	14.30%	80.60%	1404.411
NFLX	18.42%	28.09%	10.01%	29.80%	79.7	14.80%	78.70%	0..04

4.1. Results Through Equal Weights

For the implementation of TOPSIS, we have assigned equal weights for all eight factors shown in Table 3 ($w_j = 0.125$). According to the survey, Table 4 is concluded.

Table 4
The results of ranking companies based on all factors with equal weights

Company	TOPSIS RESULT (Through Equal Weights)	Priority
APPLE	0.718247515	18
MSFT	0.767941666	15
AMZN	0.843214655	9
GOOGLE	0.808291759	13
NVDA	0.446321243	20
TSLA	0.929612318	3
LLY	0.815819649	12
META	0.76536815	16
ABBV	0.732515093	17
XOM	0.923412783	5
BP	0.960204433	2
MRK	0.836754362	11
PEP	0.879160782	6
WMT	0.856181183	8
COST	0.859175729	7
PANW	0.783454724	14
F	0.962765893	1
GM	0.92776586	4
TM	0.522890781	19
NFLX	0.839665382	10

4.1. Results Through the Weights calculated by BWM

Before the implementation of TOPSIS, computation of the weights is required. According to BWM method, *step 2* and *3* are determined as follows.

The selection of two metrics as the worst and best is based on their analogy to the outcome and also the direct correlation between them.

The best criterion: Cash Flow (per share). The worst criterion: Revenue per Share.

Table 5
The preference of the best factor (Cash Flow (per share)) over others

Best to Others	Profit Margin	Operating Margin	Return on Assets	Return on Equity	Revenue Per Share	Quarterly Revenue Growth	Quarterly Earnings Growth	Cash Flow (Per share)
Cash Flow (per share)	4	2	3	4	9	4	3	1

Table 6
The comparisons of all other criteria with the worst criterion

Others to the Worst	Revenue Per Share
Profit Margin	3
Operating Margin	4
Return on Assets	5
Return on Equity	6
Revenue Per Share	1
Quarterly Revenue Growth	7
Quarterly Earnings Growth	8
Cash Flow (Per share)	9

Therefore, the results after solving the linear programming model that minimizes the maximum absolute difference between the pairwise comparison ratios and the actual ratios of the weights, are listed in Table 7:

Table 7
The weights of criteria calculated by BWM

Weights	Profit Margin	Operating Margin	Return on Assets	Return on Equity	Revenue per Share	Quarterly Revenue Growth	Quarterly Earnings Growth	Cash Flow (per share)
	0.091149273	0.170409511	0.121532365	0.091149273	0.023778071	0.091149273	0.121532365	0.289299868

By the new computed weights by BWM method, TOPSIS will be implemented. According to the Table 7, the results of Table 8 are concluded.

Table 8
The results of ranking companies based on calculated weights by BWM

Company	TOPSIS Result (Through BWM Weights)	Priority
APPLE	0.80015672	18
MSFT	0.810628642	15
AMZN	0.880225127	9
GOOGLE	0.846375099	13
NVDA	0.602226378	20
TSLA	0.956118603	3
LLY	0.854303817	12
META	0.814494222	16
ABBV	0.786654166	17
XOM	0.939342663	5
BP	0.96277285	2
MRK	0.841449306	11
PEP	0.912476786	6
WMT	0.891656265	8
COST	0.934305991	7
PANW	0.858972353	14
F	0.975282807	1
GM	0.949607174	4
TM	0.366646383	19
NFLX	0.870649656	10

5. Conclusions

In this article, 20 companies with several evaluations through their general attributes in different financial fields have been chosen to compete in order to determine the best options for investment. This examination has happened through their 9 most related and significant financial metrics which also have been selected between various choices via their commensurability to the outcome. By specifying the exact alternatives (companies) and criteria (metrics), a new MCDM approach called TOPSIS has been implemented by two different assumptions. First by assigning equal weights to each criterion which means considering every metric with the same importance and influence on results. And second, the utilization of a brand-new method for allocating weights called BWM which works based on the selection of the best and worst criterion and others` preference of the best and the comparisons of all other criteria with the worst.

The result by two different assumptions were almost the same especially within rank 1 to 5 (by the order, Ford Motor Co, BP plc, Tesla Inc, General Motors Co, Exxon Mobil Corp) which suggests a strong consistency in the data and the ranking methodology, indicating that the chosen criteria were robust enough to yield stable outcomes regardless of the weighting approach. The use of two different weighting assumptions and achieving similar results adds credibility to the findings, making the recommendations reliable for potential investors.

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Appendix

Table A1

Apple Inc	Meta	Costco Wholesale Corporation
Microsoft Corp	AbbVie	Palo Alto Network Inc
Amazon.com Inc	Exxon Mobile Corp	Ford Motor Co
Alphabet Inc Class C (Google)	BP plc	General Motors Co
Nvidia Corp	Merck & Co Inc	Toyota Motor Corp
Tesla Inc	PepsiCo	Netflix Inc
Eli Lilly And Co	Walmart Inc