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Comparison of multicriteria decision-making methods in portfolio formation

Comparación de métodos de toma de decisiones multicriterio en la formación de carteras

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Abstract

Investors apply various methods to select stocks and construct an investment portfolio. In the majority of methods, the principle of diversification is relevant. Also, sometimes investors' behaviour generate biases related to portfolio formation. Multicriteria decision-making methods can overcome such shortcomings of investors' decision-making; thus, they are widely used for portfolio selection. In the performed research, the portfolio is constructed from the stocks of the Spanish stock market. Stocks are selected based on financial indicators. SAW and TOPSIS multicriteria methods are used to range the suitable stocks. Portfolio weights are proportionate to the obtained multicriteria rank. Characteristics of the final selected stocks are presented graphically. Expected portfolio return and risk are also described when comparing two portfolios. The results of the research prove that multicriteria decision-making methods are suitable for portfolio formation. However, such portfolios should be kept for a long time in order to receive a return.

Keywords: Portfolio; Multicriteria decision-making methods; Stock market; Risk, Return.

Resumen

Los inversores aplican varios métodos para seleccionar acciones y construir una cartera de inversiones. En la mayoría de los métodos, el principio de diversificación es relevante. Además, a veces el comportamiento de los inversores forma sesgos relacionados con la formación de la cartera. Los métodos de toma de decisiones de criterios múltiples pueden superar tales deficiencias en la toma de decisiones de los inversores; por lo tanto, se utilizan ampliamente para la selección de carteras. En la investigación realizada, la cartera se construye a partir de las acciones del mercado de valores español. Las acciones se seleccionan en función de los indicadores financieros. Los métodos multicriterio SAW y TOPSIS se utilizan para clasificar las existencias adecuadas. Los pesos de la cartera son proporcionales al rango multicriterio

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obtenido. Las características de las existencias finales seleccionadas se presentan gráficamente. El rendimiento y el riesgo esperados de la cartera también se describen al comparar dos carteras. Los resultados de la investigación demuestran que los métodos de toma de decisiones multicriterio son adecuados para la formación de carteras. Sin embargo, dichas carteras deben conservarse durante mucho tiempo para recibir una devolución.

Palabras clave: Carteras de inversión; Métodos de toma de decisiones multicriterio; Mercado de valores; Riesgo; Rentabilidad.

1. Introduction

Portfolio diversification and selection of optimal investment portfolio have been topical problems among scientists for many years. Since Modern portfolio theory development by H. Markowitz, it has received substantial criticism and many improvement attempts (Rodríguez *et al.*, 2021). Besides return and risk, other parameters are increasingly included in portfolio selection: liquidity (García *et al*., 2020a), sustainability in the form of environmental, social and governance (ESG) scores (García *et al.*, 2019), skewness (Liechty & Saglam, 2017; Pahade & Jha, 2021), and kurtosis (Naqvi *et al.*, 2017). Sometimes psychological factors impact investor decision-making. New assets, such as cryptocurrencies (Pho *et al.*, 2021), included in portfolios demand a more comprehensive range of methods applied for portfolio formation. In order to reduce the number of behavioral errors and obtain a rational solution, mathematical methods are applied that would arrange a set of financial instruments according to a particular set of criteria. Portfolio decision-making becomes a multicriteria problem to a greater extent.

The selection of stocks for the portfolio can be treated as a complex solution. The complexity increases with an increasing number of stocks and criteria. Thus, it is helpful for an investor to apply multicriteria decision-making methods to distinguish attractive stocks for investment. Also, multicriteria assessment methods are usually non-subjective, and their application allows to systemize the information and make objective decisions on company financial feasibility and operational efficiency.

The objective of the paper is to investigate the selection of stocks for portfolio applying multicriteria decision-making methods and evaluate its results. The investigated portfolio formation methods can be used in algorithmic trading.

2. Literature review

Portfolio diversification is a vital risk management tool for the investor, but the abundance of investment instruments creates the illusion of unlimited opportunities for the investor. Here, investors face the problem of choosing investment instruments in different asset classes and securities. Portfolio diversification strategies often include only methods of analysis of already selected investment instruments (Liesiö *et al.*, 2021; Lim & Ong, 2021), examine the impact of including different asset classes financial instruments on portfolio efficiency (Akhtaruzzaman *et al.*, 2020; Alkhazali & Zoubi, 2020), and compare geographical and global market portfolios (Sandeepani & Herath, 2020; Trabelsi *et al.*, 2020).

Investor behavior also plays an important role in the choice of investment instruments. The investors work with information, its systematization, classification, acceptance, and rejection influences portfolio diversification. Researchers study the influence of familiarity (Nurcahya & Maharani, 2021), loss aversion, disposition effect and representativeness (Moosa & Ramiah, 2017), herd behavior (Gavrilakis & Floros, 2021), and other biases on portfolio formation. In this context, multicriteria decision-making methods receive considerable attention.

Researchers (Feitosa & Costa, 2021; Jayasekara *et al.*, 2020; Kumar *et al*., 2017; Mardani *et al.*, 2016) propose various multicriteria methods, such as Analytic Hierarchy Process (AHP), COmplex PRoportional ASsessment (COPRAS), VIseKriterijuska Optimizacija I Komoromisno Resenje (VIKOR), The Weighted Aggregates Sum Product Assessment (WASPAS), Multi-Objective Optimization by Ratio Analysis (MOORA), The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Simple Additive Weighting (SAW), Evaluation based on Distance from Average Solution (EDAS), Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH), ELimination and Choice Expressing REality (ELECTRE), etc.

Calık *et al*., (2019) compared the results of MOORA and SAW methods and found out that SAW method allows assessment of results more precisely. After comparing VIKOR and TOPSIS methods, Calik *et al*., (2019) determined that this method allows specifying results close to positive ideal solution and results close to negative ideal solution. Zamani-Sabzi *et al*., (2016) made a conclusion that ELECTRE and VIKOR methods are not preferable when full, sorted ranks are required. Zamani-Sabzi *et al*., (2016) found out that SAW and TOPSIS methods had similar statistical performances. Moreover, SAW was simple to apply. This would give us a possibility to effectively compare results of the two methods in solving one problem. VIKOR method proved to be better to select the manufacturing process (Ghaleb *et al*., 2020). VIKOR, TOPSIS, MOORA, SAW and AHP were used to assess the environmental issues (Mardani *et al.*, 2016).

In the selection of investment portfolio, multicriteria methods are widely applied nowadays. They help to overcome the disadvantage of linking portfolio selection to only two criteria – return and risk and allow to incorporate more decision-making parameters into portfolio formation process (Xidonas *et al*., 2021a). Pätäri *et al*., (2018) compare several multicriteria methods for portfolio selection. They found out that AHP and TOPSIS methods are suitable for assessing investment opportunities because they can distinguish outperforming stocks from underperforming ones, which is of substantial importance in investment decision-making. Stock selection has been performed using a combination of TOPSIS and other methods by Xidonas *et al*., (2021b). Multicriteria decision-making methods for portfolio selection often incorporate fuzzy sets (Gupta *et al.*, 2013; Frej *et al.*, 2021) as portfolio selection problem usually appears under uncertainty conditions. AHP is often regarded as suitable for portfolio formation only under fuzzy framework (Fouladgar *et al.*, 2012; Zhao *et al*., 2020; Meniz *et al.*, 2021). Narang *et al*., (2021) point out the advantages of COPRAS method, however, they advise to apply it under fuzzy environment. García *et al*., (2020b) propose a credibilistic multiobjective model where return and liquidity were treated as fuzzy variables. More and more portfolio selection parameters are considered fuzzy thus improving investment portfolio formation and management, but making it more complex.

To summarize, there is a broad discussion in the scientific literature on the advantages and disadvantages of multicriteria decision-making methods, as well as on their applicability in various fields. Great attention is given to portfolio selection using

multicriteria methods, often in fuzzy environment. The research performed in the paper continues studies on multicriteria portfolio selection topic, exploring the period of the COVID-19 pandemic. After analysing some of the application cases, we selected SAW and TOPSIS methods for portfolio formation to apply in our study. The reasons for selection were simplicity of their application and comparability of results. In this research, we do not apply fuzzy versions of these methods, but it can be a possibility for further research.

3. Methodology

In the current research, the selection of stocks for the portfolio will be performed using multicriteria methods. Thus, we need specific criteria to distinguish between suitable and not suitable stocks. Here some elements of fundamental analysis will be applied, as financial indicators will be used.

Six criteria are selected for the analysis. First criterion is P/E, or price-earnings ratio. The ratio measures the company's current share price relative to its earnings per share. It determines the relative value of company's stocks. High P/E ratio usually means that company stocks are overvalued. Conversely, if ratio is low, the stocks may be undervalued and thus have a growth potential. In such a case, company stocks would be a good investment. For this reason, this criterion will be minimized in our research. However, if company has no profit, this ratio is not calculated, so such stocks will be eliminated from further analysis.

Next ratio is EPS, or earnings per share. EPS is an indicator of company's profitability. The higher is the ratio, the more profitable is the company. Thus, the ratio is maximized. Negative EPS means the activity of the company is not profitable, which usually corresponds to missing P/E ratio, and the stock is eliminated from further calculations. The third ratio is dividend yield and determines how much a company pays out in dividends each year relative to its stock price. The ratio is measured in percentage. Dividend yield does not always indicate a good investment alternative, because if dividend yield is high, stock price usually decreases. For this reason it was decided to minimize this criterion.

The fourth criterion is ROE, or return on equity. It measures the profitability of a company compared to stockholders' equity. Higher ROE indicated better company position. However, it should be compared to industry average. It can be negative or missing for not profitable companies. The criterion is maximized for multicriteria analysis. The next indicator is price/sales ratio. The market capitalization of a company is divided by company's total sales or revenue for the last year. Lower indicator indicates better position of the company – its stocks are undervalued and thus, can be suitable for investment. Thus the criterion is minimized. And finally, book value per share is calculated. Company's common equity is divided by its number of shares outstanding. Undervalued stocks have higher book value per share. For this reason, the ratio is maximized for further analysis.

A summary of indicators and their type in the multicriteria analysis is presented in Table 1.

Table 1. Financial criteria used for the analysis

No	Criterion	Type
1	Price/earnings (P/E) ratio	min
2	Earnings per share (EPS)	max
3	Dividend yield	min
4	Return on equity (ROE)	max
5	Price/sales ratio	min
6	Book value per share	max

Source: Authors' elaboration

After deciding on criteria, we need to select particular methods of multicriteria decision-making that will be applied in our research. SAW and TOPSIS methods are selected. The criterion Sj in SAW method expresses the combination of indicators' values and weights into one ratio (Kalayci, 2019). The method returns the sum Sj of normalized values of all indicators for every object j. It is obtained using formula (1) (Basilio, 2018).

$$S_j = \sum_{i=1}^{m} w_i \grave{r}_{ij}, \tag{1}$$

where: *w* – the weights of indicator *i*;

$\grave{r}_{ij}$ – the normalized value of indicator *i* for object *j*.

A necessary premise of SAW method application is determining indicator's type – is it maximized or minimized. Only then the normalization of initial data is performed, according to formulas (2) and (3).

$$\grave{r}_{ij} = \frac{r_{ij}}{\max\limits_{j} r_{ij}}, \tag{2}$$

$$\grave{r}_{ij} = \frac{\min\limits_{j} r_{ij}}{r_{ij}}, \tag{3}$$

where:

$\grave{r}_{ij}$ – normalized value of indicator *i* for object *j*;

r_{ij} – value of indicator *i*.

The second method that will be applied in portfolio selection is TOPSIS. It states that the best alternative is in the smallest distance from a positive ideal decision and the greatest distance from an ideal negative decision (Chen, 2019). A positive-ideal solution is a solution that maximizes maximizing criteria and decreases minimizing criteria, while a negative ideal solution acts vice-versa. In short, a positive-ideal solution consists of all the best criteria that can be achieved at the maximum since an ideal negative decision consists of all minimizing criteria. The TOPSIS method uses vector normalization:

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad (4)$$

where: n_{ij} is the normalized value of the *j-th* object of the *i-th* indicator.

The main criterion P_i of the TOPSIS method is calculated according to the formula (5):

$$P_i = \frac{s_i^-}{s_i^- + s_i^+} \quad (5)$$

where: P_i is the relative distance from the ideal variant,

s_i^- and s_i^+ – distances from each *i-th* indicator to ideal negative and positive variants.

According to the values obtained by P_i, the shares of companies are arranged. Values of the TOPSIS index range from 0 to 1. The higher the index value, the more attractive the stock is (Dash *et al.*, 2019).

Also, in order to apply multicriteria methods, criteria weights should be determined. Some methods always require participation of experts to determine criteria weights, for example, AHP. Other, such as SAW, TOPSIS and COPRAS, can use expert valuation or assign equal importance to all criteria. Moreover, with the emergence of new analytical instruments and databases, criteria can be rated on the basis of information from databases, and with the help of artificial intelligence-based forecasting. Since we will use SAW and TOPSIS methods in our research, we assume that all six criteria are equally important and assign them 0,166 weight. Participation of experts to determine the importance of the criteria could be a trend for further research.

4. Results

To construct investment portfolios, the Spanish stock market (Madrid stock exchange) was selected to avoid the effects of certain differences between the relevant geographic markets (regulatory, tax policy, etc.) The market index is IBEX 35. During the analyzed period (2020-08-01 – 2021-07-31), its value increased by 24.82 percent; thus, in general, the market has growth potential. The index consists of 35 stocks, but 30 top components were selected for further analysis. The companies from utilities, financial services, basic materials, healthcare, communication services, and other sectors were included in the list. Financial data of indicators described in the Methodology section was gathered for these stocks from Yahoo Finance website.

After analysing the indicators' data, we found out that MAP.MC stock had the lowest (best) P/E ratio (8.69). The maximum EPS had ANA.MC stock (7.31). The minimum dividend yield had PHM.MC (0.79%). The greatest ROE had CABK.MC (20.33%). The lowest price/sales ratio had ACS.MC (0.18). And the biggest book value per share had ANA.MC (66.17). Eleven stocks were considered not profitable and excluded from further analysis because their EPS ratio was negative. Consequently, the P/E ratio was not presented for these stocks, and the ROE ratio was negative or missing. Thus, 19 stocks were left for further analysis and portfolio formation.

Using SAW and TOPSIS methods, 19 previously selected stocks were ranked. The results are presented in Table 2.

Out of the 19 stocks ranked, ten stocks that have the first ten positions in ranking are selected for further portfolio analysis. The majority of stocks are included in both – SAW and TOPSIS – portfolios, but they take different positions and will have different weights in final portfolios.

Table 2. Ranking results performed by SAW and TOPSIS methods

Stocks	SAW		TOPSIS	
	Sj	Rank	Pi	Rank
ITX.MC	0.155169	17	0.298094	18
MAP.MC	0.319994	6	0.369488	8
IBE.MC	0.153199	18	0.342129	14
ACS.MC	0.425361	4	0.421988	4
MRL.MC	0.110752	19	0.190661	19
FDR.MC	0.217762	11	0.316021	17
VIS.MC	0.256637	8	0.410238	5
ENG.MC	0.231455	10	0.320712	16
BBVA.MC	0.339398	5	0.384955	7
TEF.MC	0.234159	9	0.355351	10
ANA.MC	0.506085	2	0.628551	1
ELE.MC	0.178532	15	0.349396	11
BKT.MC	0.195511	14	0.348101	12
PHM.MC	0.563484	1	0.579684	2
REE.MC	0.203189	12	0.327194	15
CABK.MC	0.304003	7	0.384974	6
GRF.MC	0.197813	13	0.356193	9
ACX.MC	0.15647	16	0.344805	13
MTS.MC	0.443049	3	0.473962	3

Source: Authors' elaboration

Next, the correlation between the selected stocks is calculated to ensure proper portfolio diversification and eliminate stocks with high correlation. To calculate the correlation, weekly stock data for the period 2020-08-01 – 2021-07-31 was analyzed. The correlation results are presented in Table 3.

Table 3. Correlation coefficients of stocks

	MAP	ACS	VIS	ENG	BBVA	TEF	ANA	PHM	CABK	GRF	MTS
MAP.MC	1										
ACS.MC	0.48	1									
VIS.MC	0.41	0.11	1								
ENG.MC	0.17	-0.49	0.27	1							
BBVA.MC	0.88	0.61	0.25	-0.12	1						
TEF.MC	0.91	0.55	0.41	0.03	0.92	1					
ANA.MC	0.81	0.69	0.26	-0.30	0.87	0.86	1				
PHM.MC	-0.65	-0.14	-0.44	-0.45	-0.48	-0.47	-0.29	1			
CABK.MC	0.95	0.56	0.27	0.01	0.91	0.92	0.88	-0.50	1		
GRF.MC	-0.45	-0.08	-0.23	0.15	-0.50	-0.49	-0.52	0.23	-0.50	1	
MTS.MC	0.88	0.59	0.19	-0.11	0.95	0.88	0.89	-0.44	0.91	-0.45	1

Source: Authors' elaboration

After estimating the correlation among stocks, the stocks with a correlation coefficient higher than 0.9 were distinguished. If they possess a lower rating in the rating table, they were eliminated from the portfolios. From the SAW portfolio CABK.MC and TEF.MC was eliminated and from the TOPSIS portfolio BBVA.MC and MAP.MC was eliminated. Thus, each portfolio is composed of 8 stocks. The weights of stocks in portfolios (Table 4) were calculated proportionally to the stock rating obtained by SAW and TOPSIS methods.

Table 4. Portfolio composition and weights

	SAW	TOPSIS	Weight
1	PHM.MC	ANA.MC	0.22
2	ANA.MC	PHM.MC	0.19
3	MTS.MC	MTS.MC	0.17
4	ACS.MC	ACS.MC	0.14
5	BBVA.MC	VIS.MC	0.11
6	MAP.MC	CABK.MC	0.08
7	VIS.MC	GRF.MC	0.06
8	ENG.MC	TEF.MC	0.03

Source: Authors' elaboration

Weights of stocks in portfolios range from 0.03 to 0.22. PHM.MC in the SAW portfolio and ANA.MC in the TOPSIS portfolio has the most significant weights.

Next, some characteristics of stocks included in either portfolio are estimated (Figure 1). This data is required to calculate the overall portfolio return and risk. Parameters are estimated during the same analysis period (2020-08-01 – 2021-07-31). First, the annual return of each stock is calculated. Seven stocks demonstrated positive returns, while four stocks have negative annual returns. MTS.MC demonstrated the highest annual return (205.3%). While PHM.MC showed the biggest negative return (-16.6%). The average weekly return was positive in 8 cases, and three stocks had negative weekly returns. MTS.MC stock again demonstrated the highest positive weekly return (2.36%). GRF.MC stock demonstrated the lowest negative weekly return

(-0.14%). PHM.MC stock showed the highest standard deviation (8.3%) and VIS.MC stock had the lowest standard deviation (2.16%).

After considering the weights of the stocks in SAW and TOPSIS portfolios, annual portfolio return, weekly portfolio return, and standard deviation were calculated (Table 5). To calculate the annual portfolio return, the real annual return of each stock during the analyzed year was applied. To calculate the weekly portfolio return, the weekly return of each stock was forecasted for the next period using the 20-week moving average.

After comparing the results of the two portfolios, we can see that both portfolios are expected to be profitable after a year. Such results can be partly explained by the COVID-19 pandemic and further recovery period data used to analyze a stock market. Both portfolios were unprofitable after a week. Thus they are not suitable for short-time investment. In general, the SAW portfolio is slightly better than the TOPSIS portfolio. Also, both portfolios demonstrate a substantial standard deviation. Thus, it can be stated that the proposed investment portfolios should be kept for about a year in order to receive profit.

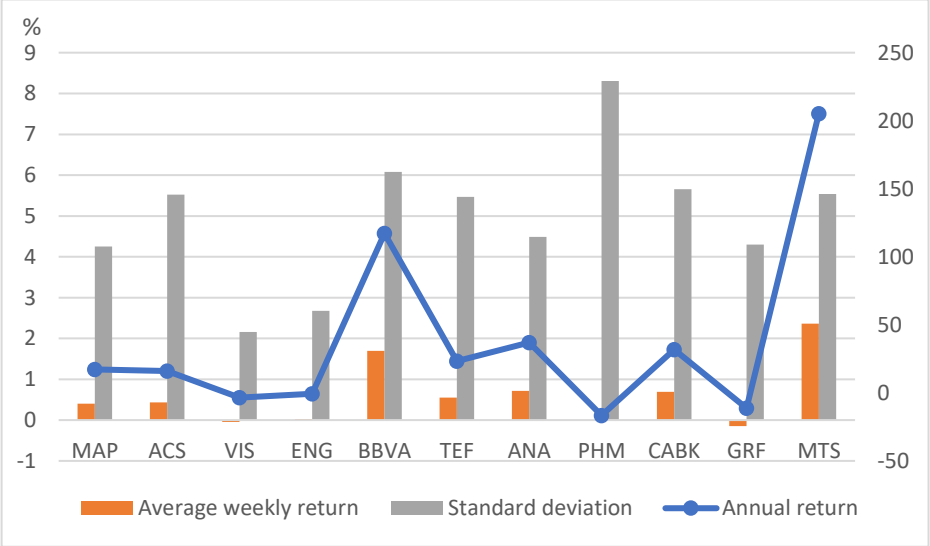

Figura 1. Characteristics of stocks included in portfolios
Source: Authors' elaboration
Note: Values of average weekly return and standard deviation are presented on the primary axis, while annual return is on the secondary axis. All values in percentage.

Table 5. Results of two portfolios

	Annual portfolio return	Weekly portfolio return	Standard deviation
SAW	54.55	-0.03	5.61
TOPSIS	44.30	-0.07	5.39

Source: Authors' elaboration

5. Conclusions

The research was aimed at constructing an investment portfolio in the Spanish stock market using multicriteria decision-making methods. The results proved that multicriteria methods are suitable for portfolio formation, even during the COVID-19 pandemic period. Multicriteria decision-making methods combine various technical, fundamental, and other analysis indicators and obtain a unique stock rank.

In the paper, two portfolios using SAW and TOPSIS methods were formed. Their expected profitability and risk are similar. Fundamental analysis was included as selection criteria in the analysis. It is worth noticing that portfolios formed using multicriteria methods should be kept for a long-time period in order to achieve better results.

Having a tool for selecting financial instruments allows one to avoid investor biases such as availability heuristics, representativeness heuristics, and herding behavior. A tool based on mathematical calculations can be integrated into investor support systems and automated. Such a tool would be helpful for individual and institutional investors and help them make adequate investment decisions in uncertain financial markets.

The study is not without limitations. First, only one particular market, the Spanish stock market, was selected for the analysis. In other markets, the results of the formed portfolios could be different. Second, the annual portfolio return was estimated on actual data of the previous period, which was impacted by the COVID-19 pandemic. Future studies would be interesting to perform calculations over a more extended period to minimize the pandemic's effect, make precise forecasts of annual stock return, and analyze different markets.

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