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Multi-Criteria Decision-Making for Investment Portfolio Selection in Thailand's Stock Market

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Abstract. This research aimed to determine the relative importance of four criteria for decision-making by using each one with a popular decision-making method and evaluating the outcomes and using these criteria to provide ranked alternatives (according to each criterion's relative importance) for making an investment decision. The four criteria were obtained from a comprehensive literature review related to securities investment. The investment data analyzed were past investment data on trading securities under the Energy and Utilities category of the SET50 index in the Stock Exchange of Thailand. The analysis was done through an Analytic Hierarchy Process (AHP) and a Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS). Opinions of three experts with experience in giving securities investment advice were collected and arranged into pair-wise comparison matrices that were used in AHP. AHP and TOPSIS calculations were done in Microsoft Excel. The results of the study show that the most important criterion was financial fundamentals with a weight of 44.59%; the second rank criterion was technical factors with a weight of 20.15%; the third-rank criterion was risk factors with a weight of 19.64%; and the last rank criterion was fundamentals of structure and sustainable development with a weight of 15.62%. In addition, the outcome of security ranking by TOPSIS and the past security ranking data were significantly similar as analyzed by a hypothesis statistical test with two dependent samples.

Keywords. Analytic Hierarchy Process, Multi-criteria Decision Making, Stock Investment, Technique for Order Preference by Similarity to Ideal Solution

1. Introduction

Financial investment is the dedication of an investor's money to buy various securities in order to generate income in the future. The revenue or return depends on the conditions and agreements of the securities. Generally, under a low-interest rate state, assets will be able to generate a higher revenue than the interest that must be paid. Thus, shareholders can make a lot of profit using low personal investment. On the other hand, if investing in high-interest rates, the interest burden will rise and will make less profit to shareholders. Securities have different risks. There are many forms of returns from investment in securities, such as capital gain, dividend, and rights offering.

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The fluctuations in stock prices may be the result of several factors. Investors in securities need to have basic knowledge, such as reading financial statements, understanding the basic factors of the company, and studying techniques for stock analysis. Therefore, investors need to study various information before deciding to invest and to find new methods that can make a profit as needed. However, most investors make investment decisions based mainly on their intuition [1], which requires a reasonable decision. A good decision depends on the decision-making processes. Important decisions require a process with steps relying on the reason to lead to the correct and successful path. The important step in the decision-making process is to determine the importance of the criteria that will affect the choice of options to invest, especially for new investors or small investors who still lack experience [2].

[3] applied non-parametric statistical analysis to determine ranking criteria, ANP Multi-Fuzzy technique to determine the weights. The Fuzzy TOPSIS technique was then used to rank the top 50 stocks. Some experts believe that 80 percent of ranking results are based on the first three factors that carry more weight. In addition, the results of expert surveys about being ranked in the rankings show that the results are very close to reality. [17] have proposed a model for evaluating India's best pharmaceutical stocks. using Multi-criteria Decision Making (MCDM). The weights are calculated from pairwise comparisons based on the best and worst criteria. The main criteria are the likelihood of bankruptcy score, Z-score, total debit bonus, cash per share, book value per share, operating profit margin, price-earnings ratio, and revenue. As a result, Wipro is a stable stock, while Tech Mahindra became the stock with the highest price increase.

The objectives of the study are to study criteria used in making investment decisions in energy and utility sectors in the Stock Exchange of Thailand, to determine the weight of the criteria and prioritize the criteria by using the Analytic Hierarchy Process (AHP) method, and to apply AHP and Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS) in making investment decisions in energy and utility sectors.

1.1. Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process is the widely popular method of multicriteria decision-making techniques. It is the process to support a complex decision, which can be broken down into a set of criteria relating to the overall goal by the pairwise comparison method and calculating a rating of criteria and alternatives [4, 5]. Moreover, it can help to make good decisions in situations of several choices [6, 7, 8].

There are three parts: the goal, all of the possible solutions, called alternatives, and the criteria on which decision-makers will judge the alternatives. The step-by-step approach for AHP is followed as:

Step 1: Define the problem and criteria.
Step 2: Define alternatives.
Step 3: Establish priority amongst criteria and alternatives using pairwise comparisons.
Step 4: Check consistency amongst the pairwise comparisons.

To calculate consistency for scoring criteria by pairwise comparison. It takes the sum of the values for each criterion in the vertical row. Each row is multiplied by the sum of the mean values in each horizontal row, then add the multiplied results obtained together. as in equation (1).

$$AW = \lambda_{\max} W \tag{1}$$

Where A denotes a reciprocal matrix by a numerical value normalized to 1.

W denotes eigenvectors that show the relative importance of criteria of the same hierarchy.

$\lambda_{\max}$ denotes maximum eigenvalue.

In the next step, to validate the results of the AHP, the Consistency Ratio (CR) is calculated using the formula, CR = CI/RI in which the Consistency Index (CI) is, in turn, measured through the equation (2):

$$C.I. = \frac{(\lambda_{\max} - \mathrm{n})}{(\mathrm{n}-1)} \tag{2}$$

Random Consistency Index (R.I) is obtained by experimentally sampling from 64,000 sample matrices proposed by Saaty [4] as shown in Table 1.

Table 1. The value of the Random Consistency Index

Dimension	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Step 5: Evaluate relative weights from the pairwise comparisons and get the calculated overall priorities for the alternatives.

1.2. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

The Technique for Order Preference by Similarity to Ideal Solution is one of the multicriteria decision-making techniques. [9] stated that the main concept is based on an ideal solution technique. The alternative which is close to the positive ideal solution and far from the negative ideal solution is the best. The importance weights of the criterion are defined by the expert's opinion numerically and the ranking results can be obtained corresponding to the importance weights of the criteria.

Step 1: Construct the decision matrix and determine the weights of the criteria.

Let $X = \left(x_{ij}\right)$ be a decision matrix and $W = \left[w_{\mathbf{1}}, w_{\mathbf{2}}, ..., w_n\right]$ be a weight vector, where $x_{ij} \in \Re, w_j \in \Re$

Step 2: Calculate the normalized decision matrix.

The normalized decision matrix is defined in (3).

$$r_{ij} = x_{ij} \Big/ \sqrt{\sum x_{ij}^{\mathbf{2}}} \tag{3}$$

Step 3: Calculate the weighted normalized decision matrix

The weighted normalized decision matrix is defined in (4).

$$v_{ij} = w_j r_{ij} \tag{4}$$

Step 4: Determine the positive idea and negative ideal solutions.

Positive ideal solution A^+ has the form shown in (5):

$$A^+ = \left\{v_1^+, v_2^+, v_3^+, ...v_j^+, ...v_n^+\right\} \tag{5}$$

$$= \left\{\left(\max_i v_{ij} \,|\, j \in j_1\right), \left(\min_i v_{ij} \,|\, j \in j_2\right), i = 1,2,3,...,m\right\}$$

Negative ideal solution A^- has the form shown in (6):

$$A^- = \left\{v_1^-, v_2^-, v_3^-, ...v_j^-, ...v_n^-\right\} \tag{6}$$

$$= \left\{\left(\min_i v_{ij} \,|\, j \in j_1\right), \left(\max_i v_{ij} \,|\, j \in j_2\right), i = 1,2,3,...,m\right\}$$

Step 5: Calculate the separation measure from the positive ideal solution and negative ideal solution.

The separation of each alternative from the positive ideal solution is given in (7).

$$s^+ = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - Aj^+\right)^2}, i = 1,2,3,...,m \tag{7}$$

The separation of each alternative from the negative ideal solution is given in (8).

$$s^- = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - Aj^-\right)^2}, i = 1,2,3,...,m \tag{8}$$

Step 6: Calculate the relative closeness to the positive ideal solution.

The relative closeness to the positive ideal solution is defined in (9).

$$c_i^+ = \frac{s_i^-}{\left(s_i^+ + s_i^-\right)}, i = 1,2,3,...,m \tag{9}$$

Step 7: Rank the preference order or select the alternative closest to 1.

2. Research Methodology

The data used in this study are divided into 3 parts: 1) primary data collected from experts 2) secondary data collected from industrial sector securities, energy, and utilities listed on the Stock Exchange of Thailand. A total of 12 securities are shown in Table 2 and 3) technical analysis data from the efin Stock Pick Up® program. Data is collected from 2021 until 3 March 2022.

Table 2. The name of the securities company in the research

No	Company Name	Abbreviation
1	Banpu Public Company Limited	BANPU
2	B.Grimm Power Public Company Limited	BGRIM
3	Banpu Power Public Company Limited	BPP
4	Energy Absolute Public Company Limited	EA
5	Electricity Generating Public Company Limited	EGC
6	Global Power Synergy Public Company Limited	GPSC
7	Gulf Energy Development Public Company Limited	GULF
8	IRPC Public Company Limited	IRPC
9	PTT Public Company Limited	PTT
10	PTT Exploration and Production Public Company Limited	PTTEP
11	RATCH Group Public Company Limited	RATCH
12	Thai Oil Public Company Limited	TOP

The main criteria have been selected to use in a decision in securities investment consisting of four main criteria and 11 sub-criteria as shown in Table 3. The experts, who have experience in advising securities investment, have been selected to evaluate the relative importance scores. There are three experts, consisting of the first expert working as a Wealth Relationship Manager, the second expert as a Senior Director of Human Resources, and the last expert working as Dealer & Products (Global Markets). Those experts have the following qualifications: 1) Able to give advice for trading or investing in the stock market. 2) Have basic knowledge of finance and investment in several types of financial securities, including the ethic of conduct for giving appropriate investment advice.

Table 3. Main criteria and sub-criteria used in making investment decisions in securities.

Main Criteria	Sub-criteria	Related Research	Description
Financial Infrastructure	Return on Equity Price to Earnings Ratio Price to Book Value Ratio	[10,11,12,13]	All sources of funds provided by the business for its operations, both short-term and long-term sources of funds.
Technical Indicators	Oscillator Relative Strength Index Simple Moving Average	[1,14]	Tools Selection helps make a profit from the market which can help to spot signals. or an opportunity to make a buy signal or a sell signal
Basic Structure and Sustainable Development	Governance Corporate Image	[15]	Concrete practice for sustainable growth goals of the business
Investment Risk Factors	Beta Standard Deviation Liquidity Ratio	[9,16,17]	Changes that cause the actual yield to deviate from the expected rate of return.

3. Result

All criteria and alternatives mentioned above have been used to formulate a hierarchical diagram of decision-making. The objective at level 1 is to select securities in the energy and utilities group. The main criteria are at level 2, sub-criteria are at level 3, and alternatives are at level 4. Then, the geometric mean of the pairwise comparisons of criteria obtained by the three experts was calculated as in Table 4, dividing each pairwise comparison by the sum of the numbers in the vertical column of the main criteria. It is normalized by having the sum of the main criteria in each column equal to 1.00 and calculating the importance of the main criteria by calculating the mean of the main criteria in each row shown in Table 5. It can be seen that the top priority criterion in making a decision to invest in securities is the financial infrastructure, followed by technical indicator, investment risk factor, and basic structural & sustainable development respectively.

Table 4. Consistency analysis of the main criteria

Main Criteria	Financial Infrastructure	Basic structure and sustainable development	Technical Indicators	Investment Risk Factors	Eigenvector	Product	Product/ Eigenvectors
Financial Infrastructure	1.0000	2.7589	3.3019	1.6134	0.4459	1.8591	4.1694
Basic Structure and Sustainable Development	0.3624	1.0000	0.7306	0.8707	0.1562	0.6360	4.0727
Technical Indicators	0.3018	1.3821	1.0000	1.3572	0.2015	0.8185	4.0620
Investment Risk Factors	0.6136	1.1447	0.7368	1.0000	0.1964	0.7973	4.0586
			λ_{max}				4.0907
C.I.			0.0302	C.R.			0.0336

Table 5. Weights of the main criteria.

Main Criteria	Weights	Priority Orders
1 Financial Infrastructure	0.4459	1
2 Basic Structure and Sustainable Development	0.1562	4
3 Technical Indicators	0.2015	2
4 Investment Risk Factors	0.1964	3

After that, the maximum Eigenvector (λ_{max}) was calculated by multiplying the product of eigenvalues from Table 5 in each row by the mean of pairwise comparisons by experts of all criteria from Table 4, then calculating the Consistency Index (C.I.) by subtracting the number of criteria, which in this research is 4, dividing by the number of criteria minus 1, then calculating the Consistency Ratio (C.R.) from C.I. divided by the Random Consistency Index (R.I.), which is a sampling of 64,000 samples from the matrix. In this study, there were 4 main criteria for sampling. Therefore, the value is 0.90,

indicating that the Consistency Ratio: C.R.) has a value of 0.0336, which is not more than the specified value, which is 0.10, as shown in Table 4.

In the same way, the researcher used the results of comparing the sub-criteria significance from all experts to calculate the average significance weight. as well as checking the consistency ratio, which must not exceed 0.10. The calculation results of the weighting of the sub-criteria under the financial infrastructure criteria show that the first-ordered priority in deciding to invest in securities is the Price to Earnings Ratio representing 26.27 percent. The second-ordered priority is the Price to Book Value Ratio. representing 10.18 percent. The third-ordered priority is the return on equity ratio. accounted for 8.13 percent.

The result of the significant weight of sub-criteria under the Basic Structure and Sustainability Criteria shows that top priority in deciding to invest in securities is the image of the company, representing 9.22 percent, and good governance representing 6.40 percent. The results of calculating the weight of the sub-criteria under the technical indicators show that the top priority is the simple moving average (9.33 percent), followed by the Stochastic Oscillator (5.91 percent), and a relative strength index (4.91 percent). The results of calculating the weight of the sub-criteria under the risk factor, it was found that the liquidity ratio is 9.19 percent, the beta value is 5.51 percent, and the standard deviation accounted for 4.94 percent.

Then, TOPSIS was applied to help rank securities. All 11 sub-criteria were collected as follows: Return on Equity Ratio, Price to Earnings Ratio, Market Price to Book Value Ratio, Good Governance, Company Image, Relative Strength Index, Stochastic Oscillator, Simple Moving. Average, Beta, Standard Deviation, and Liquidity Ratio. They are determined as the benefit criteria (+) and cost criteria (-) and determining the final weight derived from the hierarchical analysis process (AHP) as in Table 6.

Table 6. AHP weights and benefit/cost of all 11 sub-criteria

Main Criteria	Sub Criteria	Symbol	AHP Weights	Relative Weights	Benefit/Cost Criteria
Financial Infrastructure	Return Ratio to Shareholders	C1	0.0813	0.1824	+
	Price Ratio Per Profit	C2	0.2627	0.5893	+
	Accounting Market Price Ratio	C3	0.1018	0.2283	-
Basic structure and sustainable development	Governance	C4	0.0640	0.4095	+
	Image	C5	0.0922	0.5905	+
Technical Indicators	Relative Strength Index	C6	0.0491	0.2436	+
	Stochastic Oscillator	C7	0.0591	0.2932	-
	Simple Moving Average	C8	0.0933	0.4632	+
Investment Risk Factors	Beta	C9	0.0551	0.2804	-
	Standard Deviation	C10	0.0494	0.2515	-
	Liquidity Ratio	C11	0.0919	0.4681	+

The researcher collected data for all 11 sub-criteria as mentioned above, of 12 securities in the energy and utilities category of the SET50 listed on the Stock Exchange of Thailand in 2021, between the first quarter of 2021 and the fourth quarter of 2021, all 12 securities are alternatives for making investment decisions. and then create a 12 x 11 decision matrix to calculate the stock rankings. Then adjust the data by vector normalization method and calculate the standard weight by multiplying the standard of each alternative and each criterion with the AHP weight.

After that, determining the ideal solution matrix of the positive ideal solution with the highest value of each criterion (V^+) and the negative ideal solution with the lowest value of each criterion (V^-) were calculated. Then calculate an alternative distance from the positive ideal solution (S_i^+) and an alternative distance from the negative ideal solution (S_i^-) and find the consistency value to be a positive ideal solution weight (C_i^+). Table 7 shows the values S_i^+, S_i^- and C_i^+ of securities used in making investment decisions in the first quarter of 2021.

Table 7. S_i^+, S_i^- and C_i^+ of securities used in making investment decisions in the first quarter of 2021

Securities	S_i^+	S_i^-	$S_i^+ + S_i^-$	C_i^+	Order
BANPU	0.1709	0.0860	0.26	0.3346	11
BGRIM	0.1065	0.1169	0.22	0.5233	2
BPP	0.1560	0.0862	0.24	0.3558	8
EA	0.1356	0.0965	0.23	0.4157	3
EGCO	0.1725	0.1048	0.28	0.3781	6
GPSC	0.1422	0.0897	0.23	0.3867	4
GULF	0.0802	0.1692	0.25	0.6786	1
IRPC	0.1679	0.0844	0.25	0.3346	12
PTT	0.1662	0.0852	0.25	0.3388	10
PTTEP	0.1562	0.0857	0.24	0.3543	9
RATCH	0.1564	0.0882	0.24	0.3606	7
TOP	0.1581	0.0981	0.26	0.3830	5

The Sign Test for Two Related Samples is used to compare actual rankings of securities based on the percentage change of securities and securities rankings using TOPSIS.

Statistical Hypothesis

H_0: The securities ranked by TOPSIS did not differ from the actual ranks.

H_1: The securities ranked by TOPSIS differ from the actual ranks.

The results of the hypothesis test obtained from the IBM SPSS analysis between the securities ranked by TOPSIS and the actual ranks of securities, at a significance level of 0.05. The first quarter of 2021 has a p-value of 0.388, which is higher than the significance level. Therefore, the null hypothesis cannot be rejected. Namely, the securities ranked by using the TOPSIS method and the actual ranks are not different. As same as, the securities ranked by using the TOPSIS method and the actual ranks in the other quarters are not different.

4. Conclusions

The ranking of the main criteria for stock market investment on the AHP. It was obtained by experts. The experts have given importance to the main criteria in descending order

as follows: First, the financial infrastructure (0.4459), followed by the technical indicators (0.2015), the investment risk factor (0.1964), and basic structure and sustainable development (0.1562).

The researcher used the TOPSIS method to analyze alternative priorities of 12 securities in the Stock Exchange of Thailand during the 1st - 4th quarter of the year 2021, using statistics to test using the Sign Test for Two Related Samples to test for consistency. between the securities ranks using the TOPSIS method and the actual ranks of securities at the significance level of 0.05. The results showed that there was no difference between the two groups, ranks by TOPSIS are no different from actual ranks of securities.

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