Stochastic TOPSIS Employment in Stock Ranking for the Stock Exchange of Thailand

Pinporn Maikaew
Industrial Engineering Department, Faculty of Engineering
Kasetsart University, Thailand

Patcharaporn Yanpirat
Industrial Engineering Department, Faculty of Engineering
Kasetsart University, Thailand
Email : fengppy@ku.ac.th

Abstract

In the Stock Exchange of Thailand (SET), the SET100 index is a composite index serving as a benchmark for making financial investment decisions in the stock market. The index is ranked using the single criterion in terms of market capitalization that represents the common stock price movement for the top 100 listed companies on SET. Because of the insufficient information obtained from the provided single criterion based on the SET100 to judge the overall performance of stocks, the objective of this paper is to propose a multiple criteria stock ranking model. With the uncertainty resulting from complex global market environments, a hierarchy of combined financial and non-financial criteria is developed in determining criteria weights which are integrated into a technique for ordering performance by similarity to ideal solutions (TOPSIS) for stock ranking on overall performance under a stochastic environment. The proposed model displays the ability to provide better information on the overall performance of particular stocks to investors and the ability to be used as supplementary information with the SET100.

***Keywords**: AHP; Market capitalization; Multiple criteria stock ranking model; Stock ranking; TOPSIS*

INTRODUCTION

In financial markets, stock investments are a very popular activity and represent a portfolio selection problem in evaluating and selecting the stock securities and in deciding the amount of capital to be invested in the selected stocks. The evaluation and selection stage is necessary to limit the number of stocks under consideration and to meet the investor's preferences. With the emphasis on this stage and based on previous literature, common points of view on the problem of stock selection can be classified into two groups with single criterion and multiple criteria. For a single criterion on the expected returns, optimization methods are widely used, such as the constraint generation method (Nguyen & Lo, 2012), linear programming and fuzzy compromise programming (Bilbao-Terol et al. 2006) and algorithmic complexity theory (Giglio & Silva, 2009). Statistical techniques such as upper and lower exponential possibility distributions (Tanaka & Guo, 1999), the combined possibisitic regression model and the mean–variance method (Barber & Lyon, 1997 and Huang et al. 2006), nonlinear dependence (Lim, 2007), z-score (Scinto & Hardin, 2009) are also used for such criterion. The aforementioned studies reveal rigidity only on the single criterion and are focused on methodological issues, rather than applications. Extensions of the evaluation and selection criteria are undertaken in multiple criteria decision making in order to support decisions in real world situations as demonstrated in Barber and Lyon (1997), Sevastjanov and Dymova (2009), Xidonas et al. (2009), Moradzadehfard et al. (2011), and Vetschera and Almeida (2012). However, the proposed criteria are still dominated by the financial performance in terms of financial ratios, such as return on assets, return on equity, net profit margin, asset turnover, revenue percent change, current ratio, stock price, and market value, etc. Various approaches in dealing with multiple criteria decision making in stock selection have been proposed. Examples are the bi-objective linear programming method (Sevastjanov & Dymova, 2009), the fuzzy analytic hierarchy process (FAHP) and graph theory with a matrix approach (GTMA) methods (Tiryaki & Ahlatcioglu, 2005), and the expert systems method (Xidona et al. 2009). In accordance with the previous researches in this field, the rigidity of financial criteria indicates that whereas nonfinancial criteria have been scarce. in the context of nonfinancial criteria, Tiryaki and Ahlatcioglu (2009) combined criteria on economics, politics, and technology with the financial criteria under uncertain environments using fuzzy set theory. However, those criteria are in terms of a quantitative aspect. The stock selection problem is very complicated; not only would the financial and nonfinancial criteria in terms of the quantitative aspects be considered in making the decisions but also some nonfinancial criteria in terms of qualitative aspects, such as perception of the investor of the stocks considered, risk attitude, or economic environments, are also important. In cases where the qualitative aspect or variable is considered in the measuring and ranking problems, the technique of scale transformation could be applied to convert it into a variable with exact data. This technique is widely used in measuring performance problems with the DEA model (Cook et al. 1993, Cook & Seiford, 2009 and Zhu, 2003). The aforementioned technique generally pertains to single level criterion. In the situation of multilevel criteria, the combination of AHP and TOPSIS was first proposed by Zeydan et al. (2011) by transforming the multilevels of qualitative criteria into a single quantitative measure. However the combined method is still focused and used in performance evaluation and selection of the suppliers as appeared in Torfi et al. (2010) and Aydogan (2011). Therefore, taking some advantages from those techniques is a challenging implementation in the problems of stock selection. The objective of this paper is to propose a stock ranking model by means of multiple criteria approaches. The corporate financial and nonfinancial performances of the firms are considered under uncertain environments. The extension of the technique order performance by similarity to ideal solution (TOPSIS) to the stochastic process for quantitative criteria and to the qualitative criteria is undertaken for such circumstances. The application of the proposed model is undertaken in the market of the Stock Exchange of Thailand (SET). In Section 2, a proposed ranking framework is presented. Section 3 illustrates its application. Finally, conclusions are drawn in Section 4.

STOCK RANKING FRAMEWORK

The aim of the proposed ranking framework is to reflect the overall corporate performance of the firms under consideration by significant financial and nonfinancial performance which could be classified into quantitative and qualitative criteria. The technique to order performance by similarity to ideal solution (TOPSIS) and/or a stochastic technique using the interval data are utilized and realized to make rational and non-speculative investment decisions, within a long-term horizon. The proposed framework is shown in Fig.1 with the details as follows.

Step 1: the individual–based approach is recommended for criteria selection in order to avoid the dominated outcome resulting from large numbers of members of the group (Tsiporkova & Boeva, 2006). At the initial stage, an open-ended questionnaire with respect to the selected criteria obtained from the literature is recommended in the design of the questionnaire which is then followed by a closed-ended questionnaire to reconfirm the selected criteria for stock ranking.

Step 2: criteria hierarchy is constructed based on the selection criteria in step 1.

Step 3: the important weights of criteria are calculated at each level of the hierarchy. The methods used at this step could be the analytic hierarchy process (AHP) or the voting analytic hierarchy process (VAHP) depending upon the number of criteria considered. Because the strongest features of the AHP in generating numerical priorities/weight of alternatives/criteria from the subjective knowledge with the pairwise comparison technique are employed, widespread applications have been found in decision making problems (Al-Harbi, 2001). In case where there are many alternatives/criteria, pairwise comparisons are cumbersome and tend to increase the inconsistency of the judgment of the decision makers. The VAHP proposed by Liu and Hai (2005) and Soltanifar and Hosseinzadeh (2011), is an alternative method with an easier weighting procedure in place of AHP's pairwise comparison. In cases where large number of criteria occurs, in this paper the VAHP will be used in weight determination for the particular level of the criteria hierarchy having the procedure as expressed in equations (1)-(4).

$$z = max \sum_{s=1}^{r} u_{rs} x_{rs} \qquad (1)$$

$$s.t. \sum_{s=1}^{r} u_{rs} x_{ps} \leq 1 \ (p = 1,2, \dots, R) \quad (2)$$

$$u_{r1} \geq 2u_{r2} \geq 3u_{r3} \geq \cdots \geq Su_{rs} \qquad (3)$$

$$u_{rs} \geq \varepsilon = \frac{1}{(1+2+\cdots+S)*n}$$

$$= 2/(n * S(S+1)) \qquad (4)$$

where n is the number of the voters, S is the number of the priorities (s = 1,2,…,S), i is the number of the criteria (i = 1,2,…,M), U_{is} is the weight of the s^{th} priority of the i^{th} criterion, and X_{is} is the total number of the votes of i^{th} criteria for the s^{th} priority.

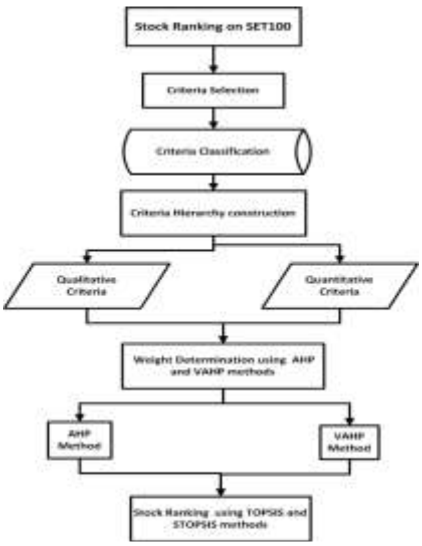
Step 4: The overall corporate performance of the anticipated firms is measured and ranked by TOPSIS with the following procedures (Mahmoodzadeh et al. 2007).

- Calculate the normalized decision matrix using equation (5).

$$\mathrm{a_{ij}} = \frac{\mathrm{x_{ij}}}{\sqrt{\sum_{i=1}^{m} \mathrm{x_{ij}^2}}} \qquad (5)$$

where $\mathrm{a_{ij}}$ is the normalized value, and $\mathrm{x_{ij}}$ is the observed data of the i^{th} criterion and the j^{th} stock security for j = 1, 2,…., J.

Figure 1 Stock Ranking Framework



- Calculate the weighted normalized decision matrix using equation (6).

$$V_{ij} = w_i a_{ij} \qquad (6)$$

where V_{ij} is the weight normalized value, and w_i is the weight of the i^{th} criterion obtained from step 3.

- Determine the positive ideal and negative ideal solutions using equations ((7)-(8), respectively.

$$A^+ = \{v_1^+, \dots, v_n^+\}$$

$$= \{(\text{Max } v_{ij} | j \in J), (\text{Min } v_{ij} | j \in J')\} \quad (7)$$

$$A^- = \{v_1^-, \dots, v_n^-\}$$

$$= \{(\text{Min } v_{ij} | j \in J), (\text{Max } v_{ij} | j \in J')\} \quad (8)$$

where *J* is a set of benefit criteria, and *J'* is a set of cost criteria.

- Calculate the separation measures, using the n-dimensional Euclidean distance as expressed in equations (9)-(10), respectively.

$$D_j^+ = \sqrt{\sum_{i=1}^{m} (v_{ij} - v_i^+)^2} \quad (9)$$

$$D_j^- = \sqrt{\sum_{i=1}^{m} (v_{ij} - v_i^-)^2} \quad (10)$$

where D_j^+ and D_j^- are positive and negative ideal solutions of the j^{th} sock security, respectively.

- Calculate the relative closeness to the ideal solution using equation (11).

$$\overline{C_j} = \frac{D_j^-}{D_j^+ + D_j^-} \quad (11)$$

where the value of $\overline{C_j}$ is between 0 to 1.

- Rank the order of preferences in terms of the value of $\overline{C_j}$ in the descending order.

Step 5: in dealing with an uncertain situation by means of the stochastic process, the interval data estimated from the time series data of the selected criteria will be used in the TOPSIS (Giove, 2002, Jahanshahloo et al. 2009 and Wentao & Huan, 2010). The procedures are explained as follows.

- Calculate the normalized decision matrix (x_{ij}) using equation (12).

$$X_{\mathrm{ij}} = \begin{bmatrix} [a_{11}, b_{11}] & [a_{12}, b_{12}] \dots & [a_{1m}, b_{1m}] \\ [a_{21}, b_{21}] & [a_{22}, b_{22}] \dots & [a_{2m}, b_{2m}] \\ \vdots & \vdots & \vdots \\ [a_{n1}, b_{n1}] & [a_{i2}, b_{i2}] & [a_{nm}, b_{nmj}] \end{bmatrix} \quad (12)$$

where a_{ij} and b_{ij} are the lower bound and the upper bound of the interval data, respectively.

- Calculate the weighted normalized decision matrix using vector normalized as expressed in equations (13)-(14).

$$r_{ij}^{l} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{n} a_{ij}^{2} + \sum_{i=1}^{n} b_{ij}^{2}}};$$
$$r_{ij}^{u} = \frac{b_{ij}}{\sqrt{\sum_{i=1}^{n} a_{ij}^{2} + \sum_{i=1}^{n} b_{ij}^{2}}} \quad (13)$$

$$v_{\mathrm{ij}}^{\mathrm{l}} = \mathrm{w_i r_{ij}^{l}};$$

$$v_{\mathrm{ij}}^{\mathrm{u}} = \mathrm{w_i r_{ij}^{u}} \quad (14)$$

where r_{ij}^{l} and r_{ij}^{u} are the normalized values of the lower and the upper bounds of the interval data estimated by equation (12). And w_i is the weighted value of the i^{th} criterion obtained from step 3.

- Determine the positive and negative interval ideal solutions as shown in equations (15)-(18), respectively.

$$A_{\mathrm{k}}^{+\mathrm{u}} = \{(\mathrm{v_1^{+u}, v_2^{+u}, \dots, v_n^{+u}})\}$$
$$= \{(\max \mathrm{v_{ij}^{u}} | \mathrm{i} \in \mathrm{O}), (\min \mathrm{v_{ij}^{u}} | \mathrm{i} \in \mathrm{I})\} \quad (15)$$

$$A_{\mathrm{k}}^{+\mathrm{l}} = \{(\mathrm{v_1^{+l}, v_2^{+l}, \dots, v_n^{+l}})\}$$
$$= \{(\max \mathrm{v_{ij}^{l}} | \mathrm{i} \in \mathrm{O}), (\min \mathrm{v_{ij}^{l}} | \mathrm{i} \in \mathrm{I})\} \quad (16)$$

$$A_{\mathrm{k}}^{-\mathrm{u}} = \{(\mathrm{v_1^{-u}, v_2^{-u}, \dots, v_n^{-u}})\}$$

$$= \{(\min \mathrm{v_{ij}^{u}} | \mathrm{i} \in \mathrm{O}), (\max \mathrm{v_{ij}^{u}} | \mathrm{i} \in \mathrm{I})\} \quad (17)$$

$$A_{\mathrm{k}}^{-\mathrm{l}} = \{(\mathrm{v_1^{-l}, v_2^{-l}, \dots, v_n^{-l}})\}$$

$$= \{(\min \mathrm{v_{ij}^{l}} | \mathrm{i} \in \mathrm{O}), (\max \mathrm{v_{ij}^{l}} | \mathrm{i} \in \mathrm{I})\} \quad (18)$$

where O and I are sets of benefit and cost criteria, respectively.

- Calculate the separation measures, using the n-dimensional Euclidean distance as shown in equations (19)-(22), respectively.

$$d_k^{+u} = \sqrt{\sum_{i \in I}\left(v_i^{+u} - v_{ij}^{u}\right)^2 + \sum_{i \in O}\left(v_i^{+u} - v_{ij}^{l}\right)^2} \quad (19)$$

$$d_k^{+l} = \sqrt{\sum_{i \in I}\left(v_i^{+l} - v_{ij}^{l}\right)^2 + \sum_{i \in O}\left(v_i^{+l} - v_{ij}^{u}\right)^2} \quad (20)$$

$$d_k^{-u} = \sqrt{\sum_{i \in I}\left(v_i^{-u} - v_{ij}^{l}\right)^2 + \sum_{i \in O}\left(v_i^{-u} - v_{ij}^{u}\right)^2} \quad (21)$$

$$d_k^{-l} = \sqrt{\sum_{i \in I}\left(v_i^{-l} - v_{ij}^{u}\right)^2 + \sum_{i \in O}\left(v_i^{-l} - v_{ij}^{l}\right)^2} \quad (22)$$

where $d_k^{+l} \leq d_k^{+u}$ and $d_k^{-l} \leq d_k^{-u}$.

- Calculate the interval efficiency of similarities to positive ideal solution using equation (23).

$$\frac{d_k^{-l}}{d_k^{-u}+d_k^{+u}} \leq C_i \leq \frac{d_k^{-u}}{d_k^{-l}+d_k^{+l}} \quad (23)$$

- Calculate the mid-point (mean, *m*(*E*)) of interval efficiency and the half-width (medium, *HW*(*E*)) of interval efficiency using equations (24)-(25).

$$m(E) = \frac{1}{2}(e^l + e^u) \quad (24)$$

$$HW(E) = \frac{1}{2}(e^u - e^l) \quad (25)$$

- Rank order of performances using the mid-point values in descending order as in step 4.

APPLICATION

Stock Exchange of Thailand (SET)

In the Stock Exchange of Thailand (SET), SET100 index is a composite market capitalization-weighted price index. It is formulated by comparing the current market value of all listed common stocks with its market value on the base date of April 30, 1975 (Stock Exchange of Thailand, 2011). It also serves as a benchmark for making financial investment decisions in the stock market. The requirements of the recruited stocks in the SET100 are:

- Being registered in the SET for at least 6 months.
- 12-month retrospection with trading of at least 9 months.
- Minimum of 20 percent of free float shareholders.
- Minimum of 50 percent of market value per share is outstanding within the trading month.
- Ranking will be revised for every 6 months, normally in June and December.

Stock Ranking Model for Anticipated Firms in SET100

For criteria selection, the preliminary survey, treated as the screening process, was undertaken using an open-ended questionnaire with respect to the selected criteria obtained from the literature. The target group is brokers and investors with a sample size of 30. Based on the information obtained from the first screening process, the second closed-ended questionnaire was developed with the stratified sampling technique of size 70 for banks, brokers, and domestic investors (with a 49% response rate). Thereafter, criteria obtained from the anticipated groups were classified as main criteria, sub-criteria, and detailed criteria for constructing criteria hierarchy. The resulting hierarchy is shown in Fig. 2. The main criteria consist of the characteristics of stocks, financial performance, and economic environmental criteria. The characteristics of stocks consist of reputation and the type of anticipated firms in the industry. Economic environmental criteria consist of risk ratios and investor perceptions on the overall operating performance of the firm. Financial criteria consist of 4 sub-criteria; liquidity with the detailed criteria of current ratio and quick ratio; profitability with detailed criteria of dividend yield, net profit, return on equity, earnings per share, and the benefits of shareholders; market value with detailed criteria of price-book value, price-earning, book value per share, market capital and listed shares; and leverage ratio with detailed criteria of debt ratio, total debt to common equity.

To determine important weight, the same aforementioned sample group and size was used with a 91% response rate. The AHP method was used for the main and sub-criteria at levels 2 and 3, respectively whereas at level 4, the VAHP was used due to the large number of detailed criteria (18 criteria). The resulting weights of each criterion are shown in Table 1.

Figure 2 Criteria Hierarchical Structure of the Proposed Stock Ranking Model

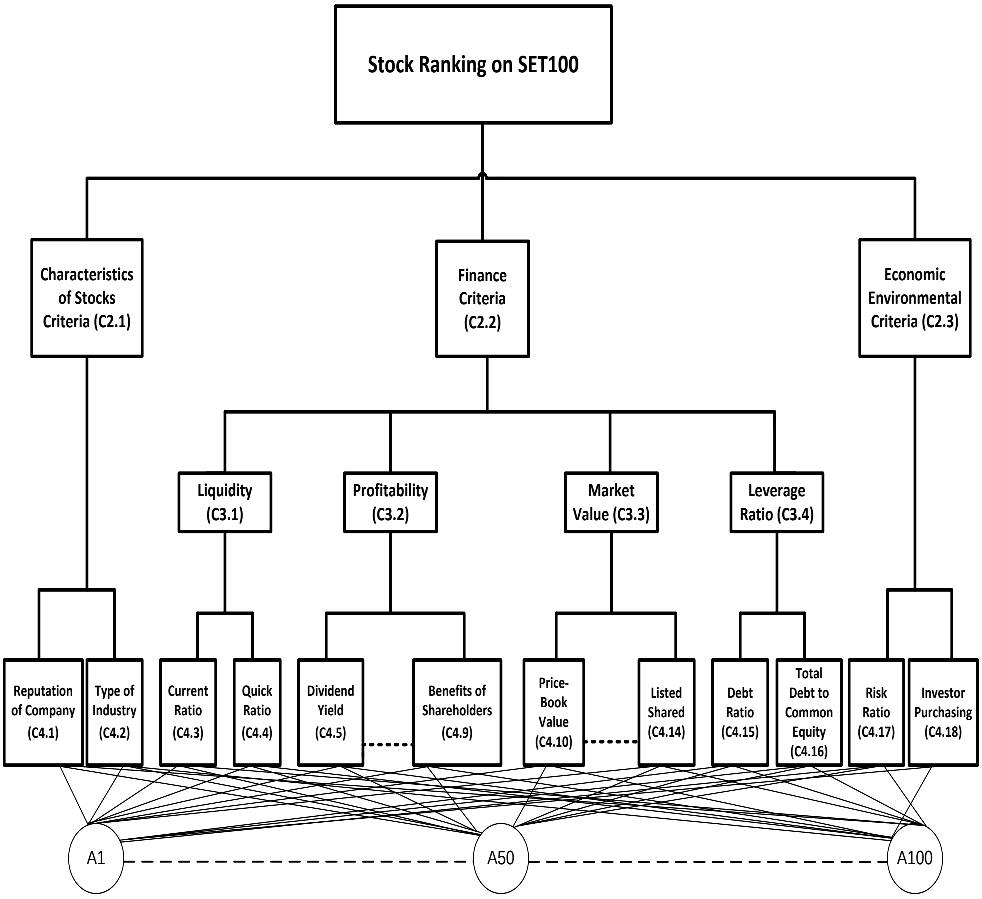


Table 1 Criteria Hierarchy and Criteria Weights of the Proposed Stock Ranking Model

Main Criteria (Level 2)	Weights of Main Criteria	Sub-Criteria (Level 3)	Local Weights of Sub-Criteria	Detailed Criteria (Level 4)	Local Weight of Detailed Criteria	Goal Weights of Detailed Criteria
Characteristics of stocks (C2.1)	0.49			Reputation (C4.1)	0.48	0.2348
				Type of Industry (C4.2)	0.52	0.2552
Financial (C2.2)	0.38	Liquidity (C3.1)	0.20	Current ratio (C4.3)	0.51	0.0395
				Quick ratio (C4.4)	0.49	0.0379
		Profitabilit y(C3.2)	0.37	Dividend Yield (C4.5)	0.27	0.0382
				Net profit (C4.6)	0.17	0.0241
				Return on Equity (C4.7)	0.23	0.0314

				Earning per share (C4.8)	0.17	0.0232
				Benefits of Shareholders (C4.9)	0.16	0.0224
		Market Value (C3.3)	0.29	Price-Book value (C4.10)	0.21	0.0228
				Price-Earning (C4.11)	0.21	0.0228
				Book value per share (C4.12)	0.19	0.0207
				Market Capital (C4.13)	0.20	0.0225
				Listed Shared (C4.14)	0.19	0.0208
		Leverage ratio (C3.4)	0.14	Debt ratio (C4.15)	0.54	0.0291
				Total debt to common equity (C4.16)	0.46	0.0246
Economic Environmental (C2.3)	0.13			Risk Perception (C4.17)	0.49	0.0636
				Investor's Perception (C4.18)	0.51	0.0664

In addition, in level 4 of the hierarchy the entire financial criteria are the quantitative measures whereas the non-financial criteria are the qualitative ones. Therefore, at the measuring and ranking step as at step 5, therefore the overall corporate performance of the 100 anticipated firms in SET100, data of qualitative criteria (C4.1, C4.2, C4.9, C4.17 and C4.18), were collected and measured from the same aforementioned sample group in terms of the preference level based on the scaling score of 1-5 and was implemented by employing TOPSIS as in step 4. The results are shown in Tables A1-A4 of the Appendix. For quantitative criteria (C4.3-C4.15), data were collected as time series data between 1 January 1996 – 31 December 2011 which revealed the uncertain performance of the anticipated firms. The Interval estimation with 95% confidence interval of the random measures for each criterion and each firm were undertaken and implemented for ranking by step 5. The results are shown in Tables A5-A6 of the Appendix. The results of the proposed ranking model are shown in Table 2.

Table 2 Comparison of Ranking Order of stocks by TOPSIS method and SET100 Index

Anticipated Firms	Symbol	TOPSIS		SET 100 Index	
		Mean Value	Rank	Rank	Market Capitalization Value
PTT	A62	0.6690	1	1	591,633,591
BEC	A11	0.5985	2	22	46,975,000
SCB	A72	0.5970	3	10	117,186,596
EGCO	A28	0.5869	4	27	37,275,460
ROBINS	A67	0.5847	5	60	9,514,927
SCC	A73	0.5837	6	4	197,564,999
PTTEP	A63	0.5800	7	3	257,126,020
BANPU	A7	0.5777	8	17	57,734,028
MCOT	A55	0.5752	9	41	16,676,878
GSTEEL	A33	0.5741	10	67	7,851,099
⋮	⋮	⋮	⋮	⋮	⋮
BTS	A19	0.3773	100	74	6,529,843

CONCLUSIONS

The ranking order of the entire anticipated firms obtained from the proposed multiple criteria stock ranking model are significantly different from those obtained from the SET100 index except the first rank; firm PTT or A62. It is evident that the SET100 index is formulated based on a single criterion of market capitalization value at the current value whereas the proposed model considers multiple criteria whether financial and nonfinancial criteria using the past corporate performance including financial and nonfinancial measures. Not only does it provide the ranking order, but also weighting information is provided to the investors in this paper. The proposed model may be not the best one, but it provides better information on the overall performance of the particular stocks to the investors and could be used as supplementary information of the SET100 index.

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APPENDIX

Table A1 Matrix of Data

		Reputation (C4.1)	Type of Industry (C4.2)	Current ratio (C4.3)		Quick ratio (C4.4)		…….	Investor's Perception (C4.18)
Anticipated Firms	Symbol	Avg.	Avg.	LC	UC	LC	UC	…….	Avg.
ADVANC	A1	3.794	3.324	0.827	0.928	0.676	0.771	…….	4.059
AJ	A2	3.824	3.206	0.527	0.553	0.306	0.327	…….	3.765
AOT	A3	3.853	3.324	1.988	2.146	1.912	2.070	…….	3.824
AMATA	A4	3.794	3.676	0.000	0.000	0.000	0.000	…….	3.706
AP	A5	3.706	3.676	0.900	0.900	0.510	0.510	…….	3.941
⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮	⋮ ⋮ .
TVO	A100	3.971	3.794	1.189	1.261	0.320	0.344	…….	3.971

Table A2 Normalized Decision Matrix

		Reputation (C4.1)	Type of Industry (C4.2)	Current ratio (C4.3)		Quick ratio (C4.4)		…….	Investor's Perception (C4.18)
Weight (W_j)		0.2348	0.2552	0.0395		0.0379			0.0664
Anticipated Firms	Symbol	Avg.	Avg.	LC	UC	LC	UC	…….	Avg.
ADVANC	A1	0.099	0.093	0.036	0.041	0.043	0.050	…….	0.104
AJ	A2	0.099	0.090	0.023	0.024	0.020	0.021	…….	0.096
AOT	A3	0.100	0.093	0.087	0.094	0.123	0.133	…….	0.098
AMATA	A4	0.099	0.103	0.000	0.000	0.000	0.000	…….	0.095
AP	A5	0.096	0.103	0.039	0.039	0.033	0.033	…….	0.101
⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮	⋮ ⋮ .
TVO	A100	0.103	0.107	0.052	0.055	0.021	0.022	…….	0.102

Table A3 Weighted normalized Decision Matrix

		Reputation (C4.1)	Type of Industry (C4.2)	Current ratio (C4.3)		Quick ratio (C4.4)		…….	Investor's Perception (C4.18)
Anticipated Firms	Symbol	Avg.	Avg.	LC	UC	LC	UC	…….	Avg.
ADVANC	A1	0.023	0.024	0.001	0.002	0.002	0.002	…….	0.007
AJ	A2	0.023	0.023	0.001	0.001	0.001	0.001	…….	0.006
AOT	A3	0.023	0.024	0.003	0.004	0.005	0.005	…….	0.006
AMATA	A4	0.023	0.026	0.000	0.000	0.000	0.000	…….	0.006
AP	A5	0.023	0.026	0.002	0.002	0.001	0.001	…….	0.007
⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮ .	⋮ ⋮	⋮ ⋮ .
TVO	A100	0.024	0.027	0.002	0.002	0.001	0.001	…….	0.007

Table A4 Positive Ideal Solution and Negative Ideal Solution of each criterion

Criteria and Type of Criteria	Reputation (C4.1)	Type of Industry (C4.2)X2	Current ratio (C4.3)	Quick ratio (C4.4)	……	Risk Ratio (C4.17)	Investor's Perception (C4.18)
	Benefit	Benefit	Benefit	Benefit		Cost	Benefit
A^{+l}	0.02744	0.02850	0.00904	0.01061	……	0.00527	0.00723
A^{+u}	0.02744	0.02850	0.00904	0.01061	……	0.00527	0.00723
A^{-l}	0.02116	0.02301	0.00000	0.00000	……	0.00745	0.00604
A^{-u}	0.02116	0.02301	0.00000	0.00000	……	0.00745	0.00604

Table A5 Distance from the Ideal Solution Classified by the Anticipated Firms

Anticipated Firms	Symbol	d_k^{+L}	d_k^{+U}	d_k^{-L}	d_k^{-U}
ADVANC	A1	0.029344	0.030197	0.038637	0.039024
AJ	A2	0.033770	0.034154	0.037261	0.037685
AOT	A3	0.028452	0.030377	0.037809	0.038460
AMATA	A4	0.033532	0.033889	0.037722	0.037985
AP	A5	0.033409	0.033643	0.037553	0.037778
⋮ ⋮	⋮ ⋮	⋮ ⋮	⋮ ⋮	⋮ ⋮	⋮ ⋮
TVO	A100	0.032325	0.032683	0.038241	0.038920

Table A6 Interval Efficiency, Mean and Medium Classified by the Anticipated Firms

Anticipated Firms	Symbol	Interval efficiency		Mean Value	Medium Value
ADVANC	A1	0.558174	0.574038	0.566106	0.007932
AJ	A2	0.538287	0.554343	0.546315	0.008028
AOT	A3	0.546207	0.565752	0.55598	0.009772
AMATA	A4	0.544958	0.558753	0.551855	0.006897
AP	A5	0.542512	0.555711	0.549111	0.006599
⋮ ⋮	⋮ ⋮	⋮ ⋮	⋮ ⋮	⋮ ⋮	⋮ ⋮
TVO	A100	0.552450	0.572519	0.562484	0.010034