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A Mixed Method based on MADM and Genetic Algorithm for Selecting Optimum Portfolio of Stocks

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Abstract
The major purpose of the current survey was to select the optimum portfolio using a mixed method of MADM and genetic algorithm. Using operations research methods such as analytical hierarchy process, TOPSIS VIKOR and SAW for ranking the companies listed in Tehran Stock Exchange and finally by depicting the efficient border of ten superior companies by means of genetic algorithm and sharp standard it was tried in this survey to compare the methods. This research can be defined at two levels. At one level the investment experts and decision-makers are employed in order to determine the criterions for portfolio selection and importance of each one in so doing. Sixteen experts and decision-makers were considered here. They were directing managers or investment managers of the investment companies. The second level contained seven industries (such as the automobile industry, pharmaceutics, real estate, cement, chemicals, parent metals and metal ores) which include one-hundred fifty three companies. Having omitted the companies with less than twenty five transactional months, one-hundred forty three companies were listed in Tehran Stock Exchange. The obtained results reveal efficiency of SAW-based method and the obtained efficient border is higher than other models in order to select the optimum portfolio.

Key words: stock exchange, portfolio, efficient border, genetic algorithm, MADM decision-making

Introduction

Economic prosperity and increased level of national income in recent years have been led to increased consumption level and thus prosperity of manufacturing and economic units from one side and enhanced saving of families and investment prosperity from the other side. Capital has been overflowed towards financial properties such as deposit in banks and buying the stock and securities from the scope of tangible assets like gold and automobile through

relative balance of the market and inflation control. Achieving long-term and permanent economic growth requires optimal mobilization and allocation of resources at national economy level. This will not easily be possible without assistance of financial markets especially the extensive and efficient capital market. Existence of an efficient financial system in a healthy economy for suitable distribution of capital and financial resources play a major role.

People and organizations in financial markets which do not have sufficient resources are faced with those which have excessive financial resources (Raee & Telengi, 2005). Financial market is a center for collecting the savings and liquidity of the private sector to finance the investment plans. Also this market is a secure official source in which saving account holders can execute their excess funds for investment in companies or enjoy a certain profit in a cooperative structure by purchasing public bonds of reputable companies.

Therefore, given to importance of the issue of investment especially investment in companies listed in the stock exchange it was tried to identify the effective croterions on stocks selection based on research literature; investigate the importance and priority of each standard from the viewpoint of investment experts; rank the companies and select the optimum portfolio and finally optimize the selected portfolio.

Research literature

Portfolio investment

The criterions for a suitable selection regarding investment depend on the viewpoint and taste of the investor. Organizational considerations, legal limitations and relations between return on total investment and cost of living might be important for one investor while they may not important for another one.

Two purposes, however, are common among all investors that are:

1- All investors want the "return" to be high.
2- All investors want a secure and stable return. Undoubtedly, there are also purchasers who prefer uncertainty.

Suitable selection among efficient portfolios depends on intention and capability of the investor to tolerate risk. If security is important, the likely return must be sacrificed for uncertainty decrease. In the event that a higher degree of uncertainty is tolerable, a higher level of likely return will be obtained. Analysis of such technique is as below:

First, efficient portfolios must be separated from inefficient ones.

Second, all returns obtained from combining different states of uncertainty must be depicted in lieu of accessible return from the efficient portfolio.

Third, the investor or investment manager must select probable return combination and uncertainty precisely that is proportional to his/her conditions.

Fourth, the portfolio that offers the most appropriate risk and return should be selected (Kahneman, 1997).

Prediction of the analyst about the stock is related to opportunities and threats of the company as well as the status of a specific stock in the market on the basis of general conditions and perspective of the economy, market, nature of new developments in the industry, previous performance, financial structure and other issues (Ramuz, 2006).

Multiple-attribute models

These techniques are used to select an alternative among several alternatives. The decision-maker in such techniques selects, prioritizes and ranks among a limited number of alternatives. Hence, multiple-attribute decision-making (MADM) can be used among *m* alternatives to select the most suitable alternative (Asgharpour, 1999).

TOPSIS method

Yoon and Hwang proposed this technique in 1981. It is one of the compensatory methods in MADM. By compensatory it is meant that exchange among indexes in this model is allowed, i.e. for instance weakness of an index might be compensated by the score of another index (Asgharpour, 2005).

In this technique distance of alternative A_i from the negative optimum point is considered besides its distance from the positive optimum point. It means that the selected alternative must have the least distance from the positive optimum solution and at the same time it has the farthest distance from negative solution **(**Yoon & Hwang, 1995).

VIKOR method

In 1973 Yu proposed harmonic solution based on closeness to the optimum point (Yu, P.L, 1973). Zeleny (1982) suggested utilization of a harmonic function (decision-making function by a specialized group) to determine whether alternatives are near or far from the optimum point.

VIKOR method is one of multiple-choice solution methods for problems with disproportionate and incompatible criterions, so the decision-maker needs a solution close to the optimum solution and all alternatives are evaluated according to the criterions when the decision-maker is not able to identify and mention superiorities of a problem at its beginning and designing time. This method can be regarded as an effective tool for decision-making. It has been used by Tzeng and Opricovic (2002) in sectors such as earthquake engineering and environment. If there are *m* criterions and *n* alternatives in a MADM decision-making problem, the steps of this method are as below in order to select the best alternative.

SAW method

This method was proposed by Mac Crimmon in 1968. Principles of basic subjects were adopted from Ackoff and Churchman in 1954 and Klee in 1971. Simple additive weighted model, i.e. SAW is one of the simplest MADM methods. By calculation of weights of indexes these methods can be used easily. The following steps are essential to use this method.

1- quantification of decision-making matrix
2- linear normalization of values of decision-making matrix
3- multiplication of the normalized matrix by weights of indexes
4- selecting the best alternative (A^*) using the below standard

$A^* = \{A_i \mid \max\} \sum_{j=1}^{n} n_{ij} w_j$

In other words, the alternative that sum of its weighted normalized values ($n_{ij} w_j$) is more than other alternatives will be selected in SAW method (Momeni, 2009).

Research questions

Primary question

How is it possible to determine the optimum portfolio of investment in the stock using a mixed method of MADM decision-making techniques and genetic algorithm?

Secondary questions

1- What are the most important key criterions or factors to select portfolio in Tehran Stock Exchange?
2- What is the importance of each effective standard on portfolio selection?
3- What is the rank of the target companies listed in Tehran Stock Exchange based on the intended criterions?
4- What is the difference among the selected companies in portfolio and unselected stock in terms of four major criterions of profitability, growth, risk and market?
5- How is the efficient border of ten superior selected companies through various models using genetic algorithm?

Methodology

Since the results of this survey are used to select the portfolio the current study is applied. It can be considered in the framework of two kinds of research in terms of method. It is descriptive in the first step in which the criterions and companies are prioritized. So the survey is descriptive-field. But in the second section we are faced with a comparative research, since efficient border of the selected companies are compared. The statistical population under study can be defined at two levels. At one level sixteen investment experts and decision-makers were employed to determine the criterions for portfolio selection and importance of each one. They were directing managers or investment managers of the investment companies who are familiar well with the issues and concepts regarding portfolio selection and management as well as theoretical and scientific topics.

The second level contained industries listed in Tehran Stock Exchange. These industries were identified through reviewing the existing documents in Tehran Stock Exchange. To do this, ten industries which had the highest volume of transactions and the highest market value during the recent five years were identified among various industries in the stock exchange. These industries included the automobile industry, pharmaceutics, real estate, cement, chemicals, parent metals, multidisciplinary companies, metal ores, banks, investment and monetary institutions. Domain of the survey was industries and companies listed in Tehran Stock Exchange during the time period 2008-2012. Various tools and methods were used to collect the required data and information.

Determining priority of the criterions using analytical hierarchy process

Having determined the criterions for portfolio selection, analytical hierarchy process technique was used for paired comparisons of criterions. They will be discussed below.

Table 1- Normalized group-decision matrix of profitability criterions

	Return on equity	Return on assets	Operating profit margin	Net profit margin	Earnings per share
Earnings per share	1.98	0.15	1.12	1.09	1
Net profit margin	2.13	0.13	0.96	1	0.92
Operating profit margin	2.63	0.16	1	1.04	0.89
Return on assets	8.63	1	6.25	7.69	6.67
Return on equity	1	0.12	0.38	0.47	0.51
Sum	16.37	1.56	9.71	11.29	9.98
	ICR = O.O12				

Table 2- Normalized group-decision matrix of growth criterions

	Incomes growth rate	Net profit growth rate	Sustainable growth rate	Earnings per share growth rate
Earnings per share growth rate	0.14	0.48	2.08	1
Sustainable growth rate	0.15	0.43	1	0.48
Net profit growth rate	0.32	1	2.33	2.08
Incomes growth rate	1	3.13	6.67	7.14
Sum	1.61	5.04	12.07	10.71
ICR = O.O25				

Table 3- Normalized group-decision matrix of market criterions

	Ratio of distributed profit	Ratio of market value to book value	Price to earning ratio	Normalized ratio
Ratio of distributed profit	1	2.30	8.62	0.61
Ratio of market value to book value	0.43	1	7.62	0.34
Price to earning ratio	0.12	0.13	1	0.06
Sum	1.55	3.43	17.24	1
Incompatibility rate= 0.049				

Table 4- Normalized group-decision matrix of risk criterions

	Dps / Eps	Market value to book value ratio	Price – Earnings ratio
Dps / Eps	1	2.30	8.62
Market value to book value ratio	0.43	1	7.62
Price – Earnings ratio	0.12	0.13	1
Sum	1.55	3.43	17.24
ICR = O.O49			

	Market risk	Financial Risk	Business risk
Business risk	8.26	6.75	1
Financial risk	3.26	1	0.15
Market risk	1	0.31	0.12
Sum	12.52	8.06	1.27
ICR = O.O95			

Table 5- Normalized group-decision matrix of primary criterions

	Profitability	Growth	Market	Risk	Normalized
Profitability	1	4.23	8.16	5.94	0.64
Growth	0.24	1	2.33	2.26	0.18

Market	0.12	0.43	1	0.58	0.07
Risk	0.17	0.44	1.72	1	0.10
Sum	1.53	6.10	13.21	9.78	1
Incompatibility rate= 0.014					

Table 6- Obtained weights from AHP for the criterions

Table 6

Criterion	Weighted
Earnings per share	0.073
Net profit margin	0.070
Operating profit margin	0.082
Return on assets	0.376
Return on equity	0.042
Earnings per share growth rate	0.023
Sustainable growth rate	0.015
Net profit growth rate	0.035
Incomes growth rate	0.113
Dps / Eps	0.043
Market value to book value ratio	0.024
Price – Earnings ratio	0.004
Business risk	0.076
Financial Risk	0.018
Market Risk	0.007

Ranking of companies using MADM techniques

Having performed the calculations and obtained weights of criterions through analytical hierarchy process, VIKOR, TOPSIS and SAW methods were used to rank the companies based on the obtained criterions and weights.

Portfolio optimization using genetic algorithm

In this section it was intended to select the optimum portfolio using concepts of Marquitz model. Marquitz paid special attention to investment purpose in formulation of his mean-variance model. According to him, the rational investor looks for investment in plans which have higher return and lower risk. He does not investigate the investment risk in standard deviation of that plan; rather he considers the relation among various properties in portfolio and the effect of this relation on total risk.

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Another concept that he proposed was the issue of an efficient portfolio. It means favorable combination of securities in a way that risk of that portfolio is minimized in lieu of a certain return. The rational investor intends to constitute an efficient portfolio, because such portfolios are led to maximization of the expected return at a certain level of risk or minimization of risk at a certain level of return.

Given to above issues it should be stated that many optimization problems such as Marquitz optimization at high volume are mainly hard. Basically a hard problem is the one in which it is not possible to guarantee that an optimum response will be obtained in an acceptable time. But researchers have looked for achieving the optimum response of hard problems in practice and for this reason they use approximate criterions (Stephen and Werner, 2001). Genetic algorithm that was explained completely in previous sections was used in this survey to optimize the selected portfolio.

The efficient border for three portfolios consisted of ten superior shares of SAW, VIKOR and TOPSIS models are depicted in this section which will be compared with each other through sharp standard.

In order to determine the weights of each company in the selected portfolio, monthly return of these companies during the time period April 2008-March 2012 (60 time periods) was used. These two variables were regarded as model inputs by calculation of return values and variance-covariance matrix.

The effective parameters on genetic algorithm were investigated here based on the steps of this algorithm. Number of generation was considered equal to 1000. Also the number of chromosomes (portfolios) was equal to 20 and they were selected based on Roulette wheel. Moreover, probability of occurrence of crossover and mutation were regarded equal to 80% and 3% respectively.

Testing the results of ranking

The obtained results from VIKOR, TOPSIS and SAW methods were compared in two different forms in order to investigate the status of rankings conducted through the above three methods.

A) Comparison based on the efficient border

Efficient border is the geometrical center of all portfolios which have the highest return in lieu of similar risk and also it has the lowest risk in lieu of similar return. If the obtained efficient border from each of the above techniques is higher than the other technique, it is possible to say that this method can show better performances than other portfolios.

Therefore, ten superior shares were selected as optimum portfolio in each of the above techniques and their return was used to depict the efficient border. Genetic algorithm was applied to this end.

The following tables show monthly return and risk of the investment portfolio of ten superior companies of the applied models by genetic algorithm in lieu of different risk-aversion coefficients.

Table 7- Monthly return and risk of the investment portfolio of ten superior companies of LIKOR model by genetic algorithm in lieu of different risk-aversion coefficients

Table 7

Coefficient of risk aversion	Return	σ
0	0.54	2.09
0.1	0.59	2.09
0.2	0.61	2.14
0.3	0.77	2.14
0.4	0.91	2.21
0.5	1.13	2.43
0.6	1.62	3.05
0.7	2.40	4.27
0.8	2.51	4.61
0.9	2.85	6.67
1	4.74	34.66

Table 8- Monthly return and risk of the investment portfolio of ten superior companies of SAW model by genetic algorithm in lieu of different risk-aversion coefficients

Table 8

Coefficient of risk aversion	Return	σ
0	-0.26	2.14
0.1	0.09	2.15
0.2	0.20	2.22
0.3	0.28	2.24
0.4	0.56	2.33
0.5	1.66	3.68
0.6	2.04	4.22
0.7	2.65	5.49
0.8	4.16	9.06
0.9	4.17	9.16
1	4.74	34.66

Table 9- Monthly return and risk of the investment portfolio of ten superior companies of TOPSIS model by genetic algorithm in lieu of different risk-aversion coefficients

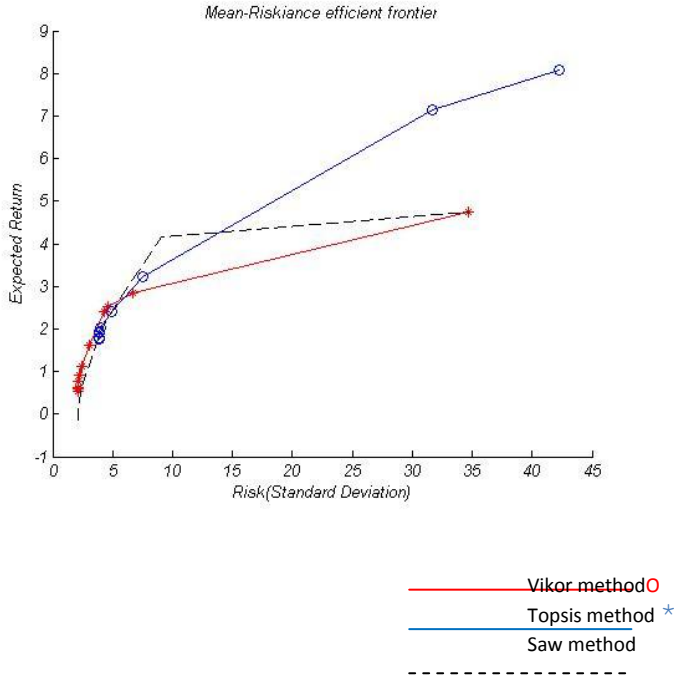
Table9

Coefficient of risk aversion	Return	σ
0	1.75	3.86
0.1	1.76	3.88
0.2	1.78	3.88
0.3	1.80	3.89
0.4	1.90	3.89
0.5	1.95	3.90
0.6	2.02	3.99
0.7	2.40	4.87
0.8	3.22	7.51
0.9	7.13	31.64
1	8.08	42.29

Results of all three methods are illustrated in the below diagram in order to compare the obtained results from these techniques.

Figure 1- Comparing the efficient border of VIKOR, TOPSIS and SAW methods

As this diagram shows, the obtained results from these three models are different in lieu of various values of risk and it can not generally be stated that results of which technique are superior to others.



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B) Comparison of results based on sharp ratio

Another method to compare the results obtained from the above three models is sharp ratio. It shows adjusted excess return based on the selected portfolio with regard to risk-free asset. The below equation is used to calculate the sharp ratio.

$$Sharp\ ratio = \frac{R_p - R_f}{\sigma_p}$$

Equation 1

To calculate the sharp ratio obtained from the above three techniques the tangent of risk-free asset must first be depicted on the efficient border for all three selected portfolios. According to the modern theory of Marquitz portfolio, the tangent which has the highest slope shows the highest sharp ratio and demonstrates the portfolio with a more favorable performance. Portalloc function of MATLAB software and the data presented in section A were used to calculate the slope of tangent for each of the three methods (according to data for the period under study the annual rate of risk-free return was assumed equal to 18%). Sharp ratio obtained from the above three methods is as follows.

Ratio of sharp/VIKOR method	Ratio of sharp/TOPSIS method	Ratio of sharp/SAW method
0.0107	0.0101	0.0116

As the above table shows, SAW method has a better sharp ratio than the other two methods. Therefore, it can be stated that the selected portfolio of SAW method shows a more favorable performance than the other two methods based on the modern portfolio theory.

Interpretation of results

The results were classified to be interpreted better and then the explanations related to each class were represented.

Stock selection criterions

Having studied previous researches extensively to find the effective criterions on financial efficiency of companies and counseling with experts, the applied criterions were divided into four major criterions of profitability, growth, risk and market that totally contain 15 sub-criteria. Opinions of experts were collected in the form of paired comparisons and weight of each standard was calculated through analytical hierarchy process. The results are represented as below.

Table 10- Effective criterions on stocks selection and weight of each one

Criteria	Weighted
Earnings per share	0.073
Net profit margin	0.070
Operatiing profit margin	0.082
Return assets	0.376
Return on equity	0.042
Earnings per share growth rate	0.023
Sustainable growth rate	0.015
The growth rate of net profit	0.035
Earnings growth rate	0.113
Dividend ratio	0.043
Market value to book value ratio	0.024
Price – Earnings ratio	0.004
Business risk	0.076
Financial Risk	0.018
Market Risk	0.007

As it can be observed, inserting experts' opinions in the analytical hierarchy process increases relative importance of criterions in profitability and growth groups than those of the other two groups. This is not improbable, as it was mentioned earlier purpose of each investor is to obtain maximum return with minimum risk (of course many investors consider risk with lower weight in their investment) and criterions of profitability group can be a representative of this. Two criterions of return on assets and return on equity can show the management ability in optimal utilization of resources. But criterions of growth group have a special importance in experts' viewpoint. It seems that capability of continuance of the profitability process that growth criterions can measure it to some extent is a reason for special importance of criterions of the growth group. Market and risk groups are the next important criterions.

Ranking of companies

Evaluation and ranking of 143 companies under study based on the above-mentioned criterions and the obtained weights showed that efficiency of SAW-based approach is more than others and the obtained efficient border is higher than other models given to evaluation of retrospective performance (mean return of five years from 2008 to 2012).

Portfolio optimization

As it was illustrated, solving of Marquitz model in very large dimensions is extremely difficult. Thus, metaheuristic algorithms must be used for solving such problems. Genetics algorithm is highly potent in obtaining the optimum response and given to the efficient border depicted by

this algorithm for various models applied in the current survey, none of the models has special superiority over each other. Considering sharp standard it can be stated that SAW method is better than the other two methods. Therefore based on the modern portfolio theory the selected portfolio of SAW method shows a more favorable performance than the other two methods.

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Appendix

The results of vikor model

	variance covariance matrix									
	Bama	Fayra	Khamhoor	Siman Ghayen	Amlah	Khark	Zahravi	Siman Isfahan	Depars	Detmad
Bama	692.67	-8.49	113.03	-71.28	54.38	63.02	47.45	4.17	-6.81	86.89
Fayra	-8.49	1201.13	-12.43	-67.75	26.44	-23.15	5.81	1.61	27.25	-21.67
Khamhoor	113.03	-12.43	123.17	-15.82	9.42	16.98	5.17	2.80	25.77	18.40
Siman Ghayen	-71.28	-67.75	-15.82	165.00	-0.61	10.17	-14.31	-2.22	4.81	-14.01
Amlah	54.38	26.44	9.42	-0.61	37.47	14.84	5.58	1.24	4.37	16.21
Khark	63.02	-23.15	16.98	10.17	14.84	116.38	10.67	-1.71	2.81	43.68
Zahravi	47.45	5.81	5.17	-14.31	5.58	10.67	46.84	0.61	14.73	21.20
Siman Isfahan	4.17	1.61	2.80	-2.22	1.24	-1.71	0.61	5.76	0.88	1.35
Depars	-6.81	27.25	25.77	4.81	4.37	2.81	14.73	0.88	44.52	16.27
Detmad	86.89	-21.67	18.40	-14.01	16.21	43.68	21.20	1.35	16.27	156.31

The results of topsis model

	variance covariance matrix									
	Fayra	Kroi	Indamin	Zahravi	sarbil	Siman Ghayen	khark	Bama	Bafegh	Hormozgan
Fayra	1201.13	-49.65	-28.76	5.81	21.22	-67.75	-23.15	-8.49	-28.76	-6.43
Kroi	-49.65	348.90	4.40	0.92	12.60	82.50	37.60	181.26	4.40	22.42
Indamin	-28.76	4.40	1788.79	54.21	44.72	63.51	86.58	282.52	1788.79	11.63
Zahravi	5.81	0.92	54.21	46.84	-1.40	-14.31	10.67	47.45	54.21	-0.10
Sarbil	21.22	12.60	44.72	-1.40	115.44	0.62	3.00	19.00	44.72	3.84
Siman Ghayen	-67.75	82.50	63.51	-14.31	0.62	165.00	10.17	-71.28	63.51	1.39

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Khark	-23.15	37.60	86.58	10.67	3.00	10.17	116.38	63.02	86.58	-7.91
Bama	-8.49	181.26	282.52	47.45	19.00	-71.28	63.02	692.67	282.52	0.14
Bafegh	-28.76	4.40	1788.79	54.21	44.72	63.51	86.58	282.52	1788.79	11.63
Hormozgan	-6.43	22.42	11.63	-0.10	3.84	1.39	-7.91	0.14	11.63	47.15

The results of saw model

variance covariance matrix

	Khrikht	kaveh	farabi	Shimiyai fars	goltash	fayra	fsorb	kavian	navard	vasdid
Khrikht	5.95	3.66	-0.22	2.13	0.22	0.08	-3.40	1.70	4.36	3.41
Kaveh	3.66	145.96	5.80	14.70	14.64	-26.83	1.71	-9.05	55.47	-0.06
Farabi	-0.22	5.80	128.65	2.39	-9.48	10.69	2.96	1.61	1.65	5.59
Shimiyai fars	2.13	14.70	2.39	110.55	12.41	-3.38	43.97	5.11	36.69	-10.80
Goltash	0.22	14.64	-9.48	12.41	92.27	-26.77	-0.06	0.49	-3.88	-11.64
Fayra	0.08	-26.83	10.69	-3.38	-26.77	1201.13	-32.01	-2.68	-13.71	13.73
Fsorb	-3.40	1.71	2.96	43.97	-0.06	-32.01	421.61	-16.28	58.60	4.19
Kavian	1.70	-9.05	1.61	5.11	0.49	-2.68	-16.28	22.39	-12.81	-0.85
Navard	4.36	55.47	1.65	36.69	-3.88	-13.71	58.60	-12.81	213.54	-2.68
Vasdid	3.41	-0.06	5.59	-10.80	-11.64	13.73	4.19	-0.85	-2.68	109.04