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ScienceDirect
European Journal of Operational Research 187 (2008) 1380–1401
EUROPEAN JOURNAL OF OPERATIONAL RESEARCH
www.elsevier.com/locate/ejor

A multicriteria DSS for stock evaluation using fundamental analysis

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Available online 9 November 2006

Abstract

The paper describes a multicriteria decision support system which aims at presenting an evaluation of the Athens Stock Exchange (ASE) stocks, on the basis of fundamental analysis. The system evaluates the stocks based on the method of fundamental analysis ratios, which is the most appropriate evaluation approach regarding investment decisions within a long term horizon. In addition to quantitative data deriving from fundamental analysis, the system uses qualitative data as well, in order to improve the reliability of the evaluation. The system introduced in this paper, utilises multicriteria analysis methodologies in order to rank the stocks by placing the best stock first and the worst last. Stock evaluation considers the specific characteristics of the potential investor, as well as his attitude towards undertaken risk. The final output of the system is four stock rankings which respond to four different criteria groups, depending on the type of accounting plan each listed company belongs to. The system incorporates a large volume of relevant information and operates in 'real world conditions' since its data are constantly updated. Finally, the system is intended for both institutional and private investors.

Keywords: Multiple criteria analysis; Decision support systems; Stock evaluation

1. Introduction

Stock evaluation constitutes one of the most important parts of the portfolio management (PM) process. The field of professional portfolio management is an extremely competitive environment; therefore there is an imperative need for the creation of technologically advanced management tools which will be developed in order to reinforce the arsenal of both professional managers and private investors. During the development process of various management tools, special effort has been made to ensure that the operation of those tools will cover the overall spectrum of problems faced by professional managers as well as private investors. A methodological base which deals with the multi-attribute nature of the portfolio management problems,

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doi:10.1016/j.ejor.2006.09.020

and particularly stock evaluation, is the multicriteria decision aid (MCDA), which provides a range of methodological tools for dealing with the stock evaluation problem. Applying MCDA to stock evaluation, and PM generally, presents certain advantages, the most important of which refer to incorporating the investor experience and policy preferences in the decision-making process, as well as the system–investor interaction, in order to achieve the best possible compromise solution. In addition, MCDA offers the possibility of considering qualitative criteria. Based on MCDA methodological approach, the article aims at presenting a Multicriteria Decision Support System for Stock Evaluation Using Fundamental Analysis, which will offer the possibility of selecting the stocks which will be included in the portfolio being composed. The system described in this paper, constitutes part of an Intelligent Multicriteria DSS for an integrated portfolio management (Samaras and Matsatsinis, 2003).

Section 2 introduces the theoretical background of stock evaluation and multicriteria DSS. Section 3 outlines the current state and the essential points of a survey in multicriteria DSS when applied in stock evaluation and portfolio management. Section 4 presents the proposed multicriteria DSS. Section 5 presents an application of the system to the ASE. Section 6 presents the concluding comments on the proposed multicriteria DSS.

2. Theoretical background

2.1. Stock evaluation and portfolio management

Stock evaluation is a complex multi-attribute problem that can be dealt with successfully only as a combination of scientific methodology, on the one hand, and personal experience of the field professionals, on the other. Thus, all advanced tools will be utilised in order to ensure the integration of the know-how that derives from considerable research activity, with the experience that results from the long-time involvement of professionals in the field of portfolio management. The proposed tool is fundamental analysis.

A fundamental portfolio theory was developed by Markowitz (1952), who proposed the well-known model of *mean-variance.* The model determines a set of effective portfolios, in which the anticipated return is related to the undertaken risk, while the *multiattribute utility theory* allows the selection of one portfolio out of this set. Then, *equilibrium models* were developed; these models are: (a) capital asset pricing model (CAPM) (Sharpe, 1964), which is further development of the *mean-variance* model and the multiattribute utility theory, under performance conditions towards risk (beta) and (b) arbitrage pricing theory (APT) (Ross, 1976), where the stock return common component is expressed, now, through a number of effect factors, each of which is related to a sensitivity index (beta).

Another model category is the *evaluation models* in which the stock price is predicted on the basis of financial and stock-exchange variables, as well as data from the current financial conjuncture. The proposed stock evaluation approach belongs in this category of models. Finally, the *market efficiency theory* was developed, which has offered considerable applications in the topic of portfolio management. According to this theory, there is such competition among the investors that the stock prices should represent directly the volume of right information in the stock evaluation, in such a way that the market cannot be beaten. Therefore, the most appropriate policy is the policy following the market as long as there is a good dispersion in our portfolio.

2.2. Multicriteria decision support systems

Decision support systems (DSSs) are interactive computer systems that use models and data to identify and solve low-structure problems, in order to support decision-makers in the decision making process (Turban and Aronson, 2001). A system can be identified as DSS if, among others, comprises a model base, support interactively a decision-making process, and is possibly based on a preferential reasoning.

A large category of "classic" DSSs includes *Multicriteria DSS*, which are based on multicriteria decision making (MCDM). The most important multicriteria analysis methods are the following:

(a) *Multi attribute utility theory* (*MAUT*) (Keeney and Raiffa, 1976; Keeney, 1992).
(b) *Multiobjective mathematical programming* (Colson and De Bruyn, 1989; Lee and Chesser, 1980).

(c) *Outranking methods*, represented by the ELECTRE methods family (Roy, 1968, 1978; Roy and Bertier, 1971; Yu, 1992; Vincke, 1992).
(d) *Preference disaggregation approach based on ordinal regression*, represented by the UTA (UTility Additive) methods family (Jacquet-Lagrèze and Siskos, 1982), UTASTAR (Siskos and Yannacopoulos, 1985), UTA II (Siskos, 1980), UTADIS and its variations (Devaud et al., 1980; Zopounidis and Doumpos, 1999), Quasi-UTA (Beuthe et al., 2000). It is worth mentioning two studies: one about UTA methods and the systems based on them (Jacquet-Lagrèze and Siskos, 2001) and a comparative study between UTA methods and the outranking theory (Siskos et al., 2004).

Some interactive multicriteria DSSs are: ADELAIS (Siskos and Despotis, 1989), MINORA (Siskos et al., 1993), MARKEX (Matsatsinis and Siskos, 1999), UTA+ (Kostkowski and Slowinski, 1996), FINCLAS (Zopounidis and Doumpos, 1998), MUSA (Grigoroudis and Siskos, 2002), MIIDAS (Siskos et al., 1999), PREFDIS (Zopounidis and Doumpos, 2000a).

3. Multicriteria DSSs in stock evaluation and portfolio management

Multicriteria DSSs constitute an important category of DSSs with considerable applications in the portfolio management field. Multicriteria decision analysis provides the methodological framework, required to accommodate the multicriteria nature of the portfolio management problem. In addition, it leads to the development of realistic models which, besides the two basic criteria of return and risk, also consider other equally important criteria that derive from fundamental and technical analysis, as well as the investor's profile that represents his goals, preferences and policies.

A survey (Matsatsinis et al., 2002), describes the most important elements in the current state in the field of Multicriteria DSSs in stock evaluation and portfolio management. Hurson and Zopounidis (1997), examine two types of problems: stock evaluation and portfolio composition. Stocks are ranked according to Minora (Siskos and Yannacopoulos, 1985; Siskos et al., 1993) method of preference analysis, while they are classified into categories according to Electre Tri (Yu, 1992) outranking method. Portfolio composition is attained by Adelais (Siskos and Despotis, 1989) multiple objectives interactive linear programming method. Spronk and Hallerbach (1997) proposed a system for supporting individual financial decision-making. The system is based on multicriteria analysis. The general framework for portfolio management is decision oriented. It is a very general framework in the sense that it can accommodate any type of investor. The framework is also very specific because it gives room to different settings of the portfolio management problem. Another paper is the *portfolio selection using* Adelais (Zopounidis et al., 1998), which was developed and applied to a set of fifty-two stocks of the Athens Stock Exchange, for the two-year period of 1989–1990. Investor (Zopounidis and Doumpos, 2000b), is a multicriteria DSS which deals with the problem of portfolio selection and composition. Finally, Multicriteria DSS for a Global Stock Evaluation (Samaras et al., 2003), is a DSS that uses multicriteria analysis methods in order to rank the ASE stocks, placing the best stock first and the worst last. The ranking procedure follows an integrated approach based on three main considerations: fundamental analysis, technical analysis and stock-exchange analysis. Thus, the potential investor is offered the opportunity to choose from the most "attractive stocks" the ones he will include in his portfolio being constructed.

An important category of multicriteria DSSs is the Intelligent Multicriteria DSSs.They are systems which utilise multicriteria methodologies, on the one hand, and on the other hand at least one AI technology. Fineva (Zopounidis et al., 1996) system constitutes an intelligent multicriteria DSS that combines multivariable statistical analysis, multicriteria analysis and Expert System (ES) technology. The aim of the system is to evaluate the ASE stocks, using fundamental analysis. Invex (Vranes et al., 1996) is an investment program selection system. Its main characteristic is the combination of five different techniques: heuristics, expert system, fuzzy logic, an investor's-behaviour-risk model and the multicriteria method Promethe II. Intelligent Investor (Samaras and Matsatsinis, 2003) is an intelligent multicriteria DSS which aims at offering an overall consideration of the portfolio management problem. The system incorporates all the advanced portfolio management tools, such as fundamental analysis, technical analysis, market psychology, and uses both multicriteria analysis methods and rule-based expert systems technology. The system is intended for both institutional and private investors and has been applied in the Athens Stock Exchange. Finally, a review of studies relevant to portfolio management, is presented in an article by Steuer and Na (2003).

It is observed that there are two basic categories of systems:

(a) The systems that are proposed by the universities and the research sectors. These systems are based on scientific methods, more or less promoted that are clearly worded. These systems have the disadvantage that they do not really exist; they constitute only part of a research proposal.
(b) The systems that are proposed by the market. These systems present the reverse image of the previous ones. They are installed and operate completely, but they are not based on scientific methods.

It is obvious that it lacks a system that can combine the advantages of the aforementioned systems. Thus, it becomes necessary to develop a Decision Support System that can support the procedure of stock evaluation and that will have the following characteristics:

- It will cover the operation of evaluation-ranking of stocks, that constitutes one of the basic operations of portfolio selection.
- It will have a high level of interaction, increasing and enhancing the role of the decision-investor to the procedure of decision making.
- It will have specialized investment proposals, in order to satisfy, each time, the user, based on his profile.
- It could be installed and operate under real world conditions, in order to respond to the real and current needs of the users-investors.

We will try to incorporate all these desirable characteristics to the proposed system, which is described to the following section.

4. The proposed system

The proposed system aims at evaluating stocks, in order to single out the ones which are eligible to be included in the portfolio being constructed. For stock evaluation, the system is based on the UTA* multicriteria method (Siskos and Yannacopoulos, 1985). This method offers the possibility of ranking the stocks by starting with the best one towards the worst. Ranking criteria are fundamental analysis ratios and qualitative criteria from the Athens Stock Exchange. The undertaken risk is also incorporated in the ranking process. Thus, the stock evaluation is adapted to the investor's preferences. The eligible stocks to be included in the portfolio are picked out from the top of every ranking list.

The basic goals of developing the system are:

- The support of the decision-investor to the procedures of ill-structured decision making problems, such as the evaluation-ranking of stocks/companies.
- The largest transparency to all the stages of the decision making procedure.
- High level of interaction between the decision maker and the system.
- The system is useful and constitutes an operating system of communication, that eases and encourages the interaction of the decision maker and the system.
- The completed formulation of the preferences of the decision maker and the absolute specialization of his preference profile.
- The incorporation of a huge volume of "active information" in order for the system to be always updated and to support valuable decisions.
- The processing of the above information with the use of valuable and scientific documented models.
- Architecture that gives the possibility of incorporation of any environment of work and development.

The system is intended to provide support for investment decisions regarding ASE stocks. However, it is fully parameterised and can be used in other stock exchanges, too, provided it is equipped with the respective databases.

The set of stocks to be invested in will be selected from the above ranking lists and will be adapted to the investor's attitude towards risk.

4.1. Fundamental analysis evaluation

Fundamental analysis (FA) is the study of sector and company conditions to determine the value of a stock. Fundamental analysis constitutes the basic necessary analysis method of the overall evaluation of a company. The strong and weak points of the company hidden behind the accounting figures are also pinpointed by FA. Fundamental analysis aims to determine the financial health of the company, by useful "*ratios*", based on the company's financial statements. FA is one of the most effective analysis methods since it provides a *dynamic analysis* of the company's financial situation and evaluate with precision the advantages and disadvantages of the company. The outlook of the stock is determined by the above analysis, given that the stock is a picture of the company for shareholders and potential investors, in order to predict the future course of stock prices. Fundamental Analysis requires a series of financial statements (Annual Balance Sheets and Annual Results) of the last five years, as well as, qualitative information regarding all listed companies. This information will be converted to *Financial* and *Qualitative Ratios*. Fundamental analysis infers the "*position*"of the company, which represents the *"real value"* of the stock. Afterwards, the "real value" is compared to the *"market value"* of the stock, in order for the stock to be rated as "overvalued" or "undervalued". The estimate of each *stock position* may change every time new data from the company accounting figures enter the respective database. The updating of the database is conducted on a year, semester or quarter basis, depending on the availability of the data (Conso, 1981; Depallens, 1980; Gualino and Remilleret, 1979; Vizzanova, 1981; Giese, 1981).

The ASE provides the Annual Balances, Annual Results, as well as Quarterly Accounting Statements of all the companies listed on the ASE. These data constitute the *Functional Balance*, which in turn will form the basis for the financial analysis of an enterprise. These financial statements are made out according to the Accounting Plan (AP) to which each company belongs. There are four Accounting Plans in Greece:

- Commerce/industry AP;
- Banks AP;
- Insurance companies AP;
- Investment companies AP.

Further information on Investment Companies is also drawn from the *Price Bulletin*, which is issued monthly by AGII (Association of Greek Institutional Investor). A database of the *FA ratios,* for every AP category is created based on this information. The system output (Fig. 1) is a *based on FA ranking list*, for every AP category.

4.2. Multicriteria methodological background

The ranking carried out by the four subsystems is based on the multicriteria ranking method UTASTAR (Siskos and Yannacopoulos, 1985), which is an improved version of the UTA (Jacquet-Lagrèze and Siskos, 1982) method, according to which, the problem of ordinal regression is the following: Having a weak-order preference structure ($>$, $\sim$), with "$>$" the strict preference and "$\sim$" the indifference on a set of alternative actions, the additive utility functions, based on multiple criteria, are adjusted in such a way that the resulting preference structure would be as consistent as possible with initial structure.

4.2.1. Reference set – initial preference structure

Reference set is the set of referential alternative actions $A=\{a,b,c,\ldots,k\}$, which can be ranked by the decision-maker in order of preference, according to the relations P and I (preference structure).

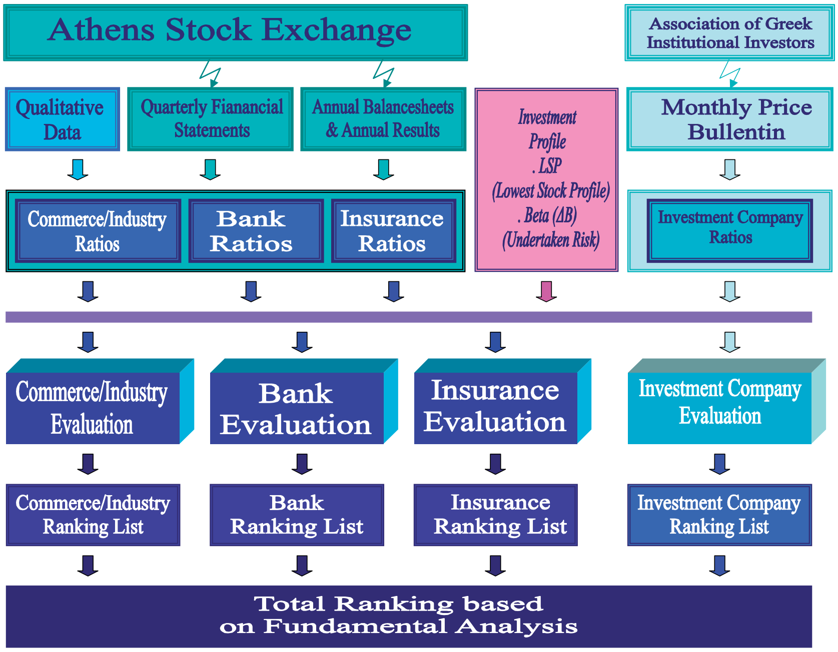


Fig. 1. Methodological frame of the proposed multicriteria DSS.

4.2.2. Criteria

Criteria $g_1, g_2, \ldots, g_n$, can be either quantitative or qualitative and are defined as real monotone functions: $g_i : A \rightarrow [g_{i^*}, g_i^*] \subset R$, where g_{i^*} is the least desirable value, and g_i^* is the most desirable value for the criterion g_i. If $g_i(a)$ is the estimate of alternative a, regarding criterion g_i, then vector $g(a) = \{g_1(a), g_2(a), \ldots, g_n(a)\}$, represents the *profile* of decision a.

4.2.3. Utility function

The utility function, under certainty, is a real function defined as follows:$u : \Pi[g_{i^*}, g_i^*] \rightarrow R$, for which the following attributes are true:

$$APb \Longleftrightarrow u[g(a)] > u[g(b)], \tag{1}$$

$$AIb \Longleftrightarrow u[g(a)] = u[g(b)] \quad \forall a, b \in A. \tag{2}$$

4.2.4. Criteria aggregation model

Given the initial preference structure of the alternative actions in the reference set, by the decision-maker, UTA method is designed to estimate a system of utility functions, according to the additive model: $U(g) = u(g_1) + u(g_2) + \cdots + u(g_n)$ subject to the set of regularisation constraints:

$$u_i(g_{i^*}) = 0, u_i(g_i) \geqslant 0, \quad i = 1, 2, \ldots, n, \tag{3}$$

$$u_1(g_1^*) + u_2(g_2^*) + \cdots + u(_n(g_n^*) = 1. \tag{4}$$

In the initial version of UTA method there is a unique error function $\sigma : A \rightarrow [0, 1]$, where σ(a) is the amount of utility that must be added in the estimated utility $U[g(a)]$ of the alternative a, in order to make it possible for this action, to regain its rank in the weak-order However, this error function is not sufficient to completely minimise the dispersion of points all around the monotone curve (under- and over-estimation errors). In UTA*, a double positive error function is used, which allows to better stabilize the position of the points around the curve. Thus, the global utility function of an alternative action will have the following form: $U[g(a)] + \sigma^+(a) \;\; - \sigma^-(a)$, where $\sigma^+(a)$ and $\sigma^-(a)$, represent the over-estimation and under-estimation errors of alternative a, respectively.

4.2.5. UTA algorithm phases*

UTA* algorithm includes two phases.

In the first phase, there is an estimation of the optimal marginal utilities and the global utility of every alternative action a that belongs to A, according to the additive utility model. The first phase comprises the following stages:

In the first stage the global utility of every alternative action α, is calculated in relation with the marginal utilities:

$$U[g(a)] = \sum_{i=1}^{n} u_i[g_i(a)] \tag{5}$$

and then in relation with variables $w_{ij,}$which are defined as follows:

$$w_{ij} = u_i(g_i^{j+1} - g_i^j) \geqslant 0, \quad \forall i\kappa\alpha\iota j. \tag{6}$$

The marginal utilities $u[g(a)]$ which are expressed with variables w_{ij}, are defined by the following relations:

$$u_i(g_i^1) = 0, \quad \text{for } j = 1, \tag{7}$$

$$\text{and} \quad u_i(g_i^j) = \sum_{k=1}^{j-1} wik, \quad \text{when } j > 1. \tag{8}$$

Symbol g_i^j is interpreted as follows: index i denotes the criterion the evaluation refers to, while index j denotes the point in the space $[g_{i^*}, g_i^*]$. Supposing that the best and worst values of every criterion are finite, we divide the space $[g_{i^*}, g_i^*]$in $\alpha_i - 1$ equal intervals having the form $[g_i^j, g_i^{j+1}]$,where $j = 1, \ldots, (\alpha_i - 1)$and $g_{i^*} = g_i^1, g_i^* = g_i^{ai}$.The value of parameter α_i is determined by the decision-maker, who states this way the number of points that are estimated for every marginal function u_i. Points g_i^j are calculated by the following relation:

$$g_i^j = g_{i^*} + \frac{j-1}{ai-1}(g_{i^*} - g_i^*). \tag{9}$$

In the next stage, a double error function, for every alternative, is introduced having the following form: $\sigma(a) = \sigma^+(a) - \sigma^-(a)$, while, for every pair of consecutive alternatives (a_j,a_{j+1}) of the initial structure, a relation with the following form is defined:

$$\Delta(a_j, a_{j+1}) = U[g(a_j)] - U[g(a_{j+1})] + \sigma^+(a_j) - \sigma^-(a_j) - \sigma^+(a_{j+1}) + \sigma^-(a_{j+1}). \tag{10}$$

Then, for the estimation of marginal utilities in the first phase, and the stability analysis of the global optimum in the second phase, linear programming formulation is used, aiming at finding the optimal utility functions that minimise a global error function

$$\text{Min} \quad F = \sum_{j=1}^{k} [\sigma^+(a_j) + \sigma^-(a_j)] \tag{11}$$

$$\text{Under the set of constraints :} \quad \Delta(a_j, a_{j+1}) \geqslant \delta, \quad \text{if } a_j P a_{j+1}, \tag{12}$$

$$\text{and} \quad \Delta(a_j, a_{j+1}) = \delta, \quad \text{if } a_j I a_{j+1}, \tag{13}$$

$$\sum_{i=1}^{n} \sum_{j=1}^{ai-1} w_{ij} = 1, \tag{14}$$

$$\sigma^+(a_j), \quad \sigma^-(a_j) \geqslant 0, \; j \in [k], \tag{15}$$

$$\forall a_j \in A, \quad \forall i = 1, 2, \ldots, n \quad \text{and} \quad j = 1, 2, \ldots, \alpha_i - 1, \tag{16}$$

where δ a small positive number.

The error function F expresses the over-estimations or under-estimations of the alternative actions over the weak-order. Its minimum value is the criterion for the control of the consistency degree between additive model and initial preference structure. The optimum value is $F^* = 0$.

The consistency degree is also controlled by the index τ of Kendall, where its value in range $[-1, 1]$ expresses the distance between the two above rankings. The optimum value is $\tau = 1$.

In the second phase, there is a sensibility analysis of the global optimum. In case of non-uniqueness, the optimal solutions that maximise the criteria weight are determined.

4.3. Stock ranking system methodology

The stock ranking methodology is described, by five steps, in the following diagram (Fig. 2). It is noted that the procedure that is described below, takes place separately for each category of the accounting plan: Commerce/Industry, Banks, Insurance Company, Investment Company.

Step 1: Initial ranking. The system uses criteria which are fundamental analysis ratios as well as qualitative indices (Fig. 3).

The initial ranking of the companies follows the following procedure:

(a) *Reference set definition*. The reference set consists in the determination of the subset R of the initial set A of the companies that should be ranked. The subset R includes the companies that the decision maker-investor knows well and can point out their evaluation. Moreover, the alternatives (companies) of the reference set are selected in such way, that they represent the set of all the alternatives.

(b) *Decision-maker preference structure.* The decision maker-investor points out the ranking of the alternatives (companies), from the best to the worst, based on his preference profile.

(c) *Solving of the UTA* model.* The ranking of the decision maker (DR: decision-maker ranking) is inserted into the UTA* model, which, based on the ranking the selected criteria, tries to determine the ‘‘crisis policy’’ of the decision maker. The output of this procedure is a proposed ranking of the model (MR: model ranking) that expresses the way that the model decodes the above data. The ranking of the model takes place in decreasing series of the alternatives.

(d) *Over-estimation and under-estimation errors Minimization*. The over-estimation and under-estimation errors, between the ranking of the decision maker and the ranking of the model, are defined.

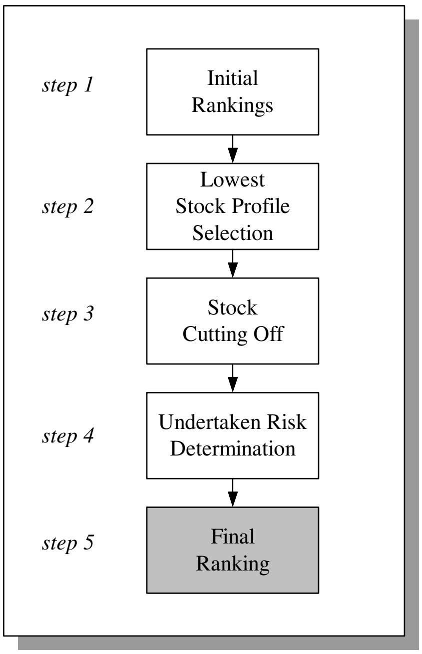


Fig. 2. Stock ranking methodology.

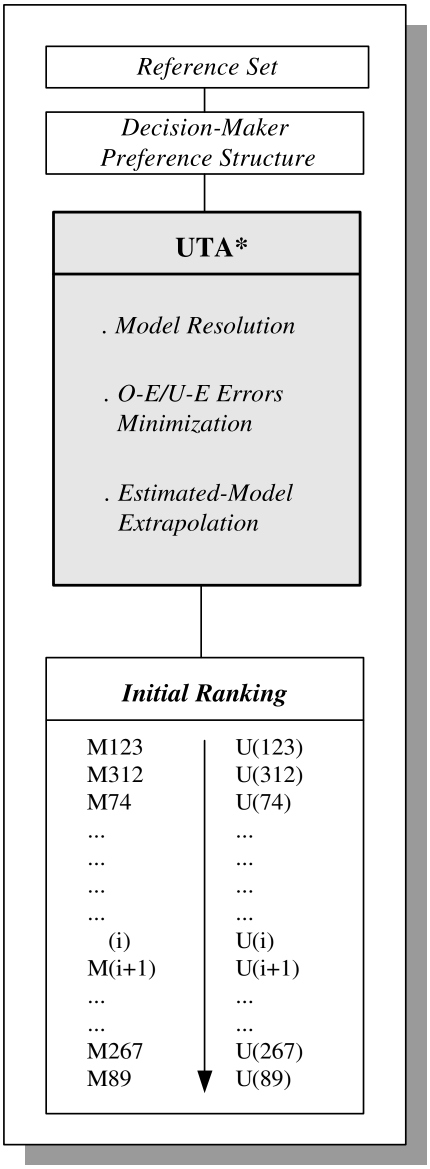


Fig. 3. Initial ranking.

Then, based on an interactive operation between the decision maker and the model, a minimization effort of these errors takes place. The minimization of the above errors minimization is succeeded through the following feedbacks:

- *Feedback a:* The decision maker does not accept the suggestions of the model for over-estimation or under-estimation error of the alternatives. Thus, he goes back to the reconsideration of the criteria modeling.
- *Feedback b:* The decision maker accepts the suggestions of the model, related to the inconsistencies and proceeds to a new ranking of the alternatives that were previously wrongly evaluated. Thus, he changes his judgment policy.
- *Feedback c:* This feedback refers to the trade-offs analysis and takes place when there is no great deviation among the preferences of the decision maker and the estimated preference model. The decision maker accepts the estimated preference model and proceeds to the modification of the

marginal utility function in a way that it will lead to inconsistencies elimination. It should be noted that the trade-off includes a high degree of complexity due to their interactive character and also the uncertainty of the consequences on the preference model that will be produced from the decision maker's reactions.

The procedure ends when we reach a satisfying approach between the two rankings with high correlation degree.

(e) *Estimated-model extrapolation.* Since the estimated model has been approved, an expansion of the model takes place and the utilities of all the alternatives of set A are calculated.

The symbolism, for ex. M123 → U123 means that the firm with code *M*123 and estimated utility *U*123,is ranked at the top of the list, as it has large utility.

Step 2: Lowest stock profile (LSP) selection. The lowest stock profile describes the lowest standards that a stock should meet in order to be considered worth investing and to be included in the stock portfolio. Using LSP, the set of remaining stocks, i.e. the eligible ones to be included in the portfolio, is fully adapted to the potential investor's preferential profile. The LSP is calculated as follows: for every criterion *i*, is given a value a_i^π which is equal to the least desirable criterion value. Thus, for every value a_i^π of the criterion i there is a corresponding utility u_i^π (Fig. 4).

The LSP derives from an additive utility function:

$$U^\pi = \sum_{i=1}^{n} p_i u_i^\pi, \tag{17}$$

where p_i is the weight of criterion g_i.

The LSP can be defined by the user–investor, who will be able to choose between: *strict*, *regular* and *lenient LSP*, or to determine his own specific LSP.

Step 3: Stock cutting-off. All the stocks that are below the LSP in the ranking will be cut off from the stock list as ''rejected'', as shown in ''Fig. 5''. Cutting off will take place at the point where

$$U(i) > U^\pi >= U(i+1). \tag{18}$$

The remaining part of the ranking list, after cutting off, includes only the ''acceptable'' stocks, i.e. the stocks that are eligible to be included in the portfolio being formed.

Step 4: Undertaken risk definition. The *beta* derives from the investor's profile and represents part of the risk the investor is willing to undertake. Here, beta is not considered as a simple evaluation criterion but as an investment choice. Let the specific investor choose a beta $\mathbf{b}_c$, which can be expressed in the form

$$b_l < b_c < b_h, \tag{19}$$

where b_l is the lowest limit and b_h is the highest limit of undertaken beta. The middle of this space is calculated as

$$b_m = (b_h - b_l)/2 \tag{20}$$

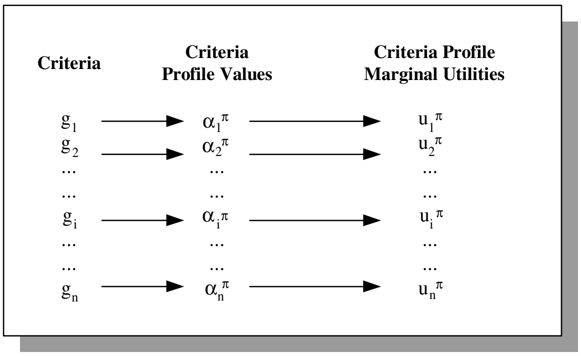


Fig. 4. Lowest stock profile selection.

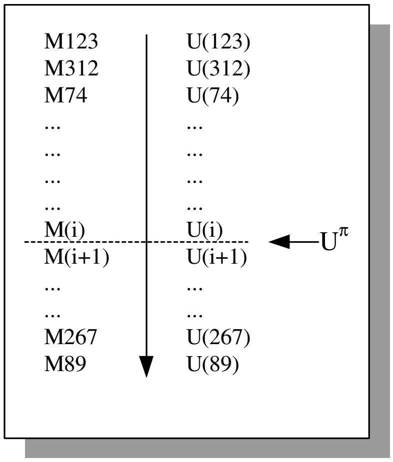


Fig. 5. Stock cutting-off.

so, the undertaken beta is

$$b_u = b_l + b_m \tag{21}$$

based on *undertaken beta* (b_u) and beta of stock i $(b_i)^*$, we can calculate the absolute value of the difference:

$$\Delta b_i = |b_u - b_i|, \tag{22}$$

Δb_i participates *as a criterion* in the final ranking. The scale for Δb_i of every stock is continuous. The most desirable value is the lowest value of Δb_i and the least desirable value is the highest value of Δb_i. Based on the (Capital Asset Pricing Model) (Sharpe, 1964) the return of a stock i is split into two parts: the part of the return referring to the market and the part of the return referring to specific characteristics of the stock. Similarly, the risk that is connected to a stock, is split into two parts: the market risk (systematic risk) and the non-systematic risk. A basic characteristic of this model is based on the fact that the special component of the risk of a portfolio decreases, when the number of stocks, that are incorporated into the portfolio (variance) increases. So, this component is "diversified". On the contrary, the market risk examines the changes of the return that exist to the financial market. These changes are applied similarly to all the stocks. Thus, the participation of each stock to the risk cannot be reduced and this risk is called "systematic risk".

Based on the CAPM model, the return of a stock is given as follows:

$$R_i = R_{\mathrm{f}} + b_i(R_{\mathrm{M}} - R_{\mathrm{f}}). \tag{23}$$

R_i: the return of the stock
R_{f}: the return of the risk-free stock
R_{M}: the return of the market
b_i: beta

The beta b_i calculates the systematic risk which is connected to a stock. The beta coefficient is equal to the ratio of covariance between the return of the stock and the return of the market (σ_{im}) to the variance of the market return (σ_m^2):

$$b_i = \sigma_{im}/\sigma_m^2. \tag{24}$$

The beta coefficient is also called "coefficient of aggressiveness" since its value allows the classification of stocks or portfolios into three categories:

- *''Aggressive''* stocks or portfolios that multiply the changes of the market. They have beta value larger than 1.
- *''Defensive''* stocks or portfolios that submultiply the changes of the market. They have beta value less than 1.
- *''Indifferent''* stocks or portfolios that change as the market changes. They have beta value equal or near 1.

In order to minimize a part of risk, we could minimize beta that is connected to the systematic risk. Moreover, beta allows the portfolio manager to adjust his investment strategy according to his forecasts for the market. When his forecast for the market is increasing, the manager could create a portfolio with beta value larger than 1. He will proceed in reverse, if his forecast is decreasing. If his forecast is uncertain, then he will create a portfolio with beta value equal or near 1. So, beta is a basic and fundamental variable for the portfolio manager as well as for role to the portfolio selection and analysis. Finally, in case of investment choice, we do not minimize beta, but the difference between the desired value of beta and the stock beta.

Step 5: Final ranking. The final ranking comprises only the stocks that remained after the cutting off (step 3). The stocks do not appear by decreasing series of utility but by increasing code of stock number. This ranking is based on two criteria (Fig. 6):

- 1st *Criterion:* Criterion value is the utility of every stock as it was defined in the remaining part of the ranking list (step 3). The criterion value scale is continuous and ascending, as the most desirable value is the highest utility value, and the least desirable is the lowest utility value
- 2nd *Criterion:* Criterion value for every stock is value Δb_i, as it was defined in the above step 4. The criterion value scale is continuous and descending, since the most desirable value is the lowest value, and the least desirable is the highest value of Δb_i.

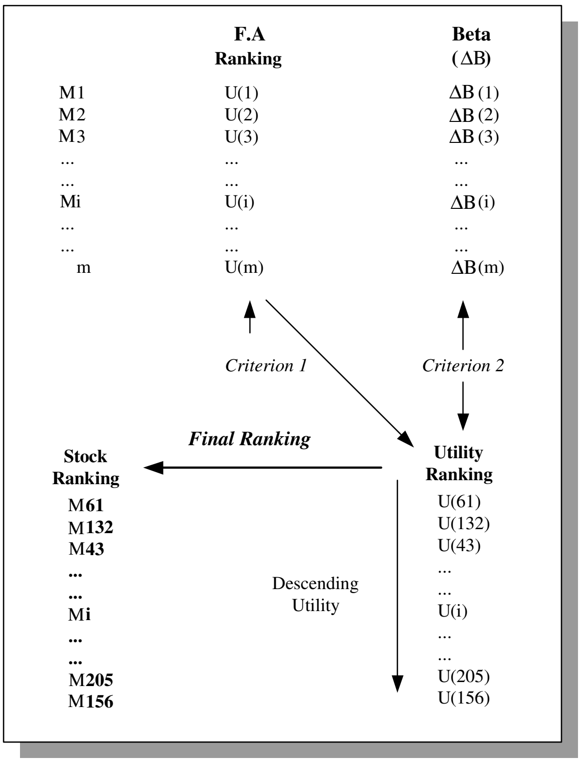


Fig. 6. Final ranking.

The resulting final ranking includes only the "acceptable" stocks, which have been ranked in such a way that they incorporate the investor's attitude towards risk. The eligible stocks to be included in the portfolio will be obtained from the top of this final ranking list.

4.4. Stock ranking and accounting plans

It has already been mentioned that stock ranking is carried out on the basis of their distinction according to four accounting plans. For every accounting plan there is a different evaluation structure, with different criteria sets in every case.

4.4.1. Commerce/industry stock ranking

Commercial/industrial stocks are ranked after four initial rankings are carried out, at the following levels:

- *Financial structure.* Ratios-criteria used are:
  - A15(+): Cumulative depreciation/fixed assets;
  - B12(+): Equity/liabilities;
  - G14(+): Working capital/requirements for working capital;
  - G15(+) : Working capital/current assets;
  - D11(+): Current assets/current liabilities;
  - D12(+): (Current assets-inventory)/current liabilities;
  - E14(−): Liabilities/(liabilities + equity).

The sign in the parenthesis denotes the type of criterion scale: (+) for increasing scale and (−) for declining scale.

- *Management performance*
  - Z11(+): Sales/total assets;
  - Z12(+): Sales/equity;
  - Z14(−): Inventory * 365/cost of goods sold;
  - Z17(−): Interest expenses/sales;
  - Z18(−): Operating expenses/sales;
  - Z19(+): Deadline of suppliers–deadline of customers.
- *Profitability*
  - H11(+): Gross profit * 100/total assets;
  - H12(+) : Pretax profit * 100/total assets;
  - H13(+): Profit after taxes * 100/equity;
  - H15(+): Gross profit * 100/sales;
  - H16(+): Operating profit * 100/sales;
  - H17(+): Pretax profit * 100/sales.
- *Self-financing policy*
  - F13(+): Self-liquidation * 100/sales;
  - F15(+): Self-liquidation/long-term liabilities;
  - F16(+): Self-liquidation/investments.

Then, stocks are ranked at *Fundamental Analysis* level, using the utilities of the four previous initial rankings, as well as qualitative criteria. Finally, the *Commerce/Industry Stock Final Ranking List* (Fig. 7) is formed with the use of *Fundamental Analysis* ranking utilities as criteria, along with the undertaken risk determined by the investor.

4.4.2. Bank stock ranking

Bank stocks are ranked with the use of the following ranking criteria. The sign in the parenthesis denotes the type of criterion scale: (+) for increasing scale and (−) for declining scale.

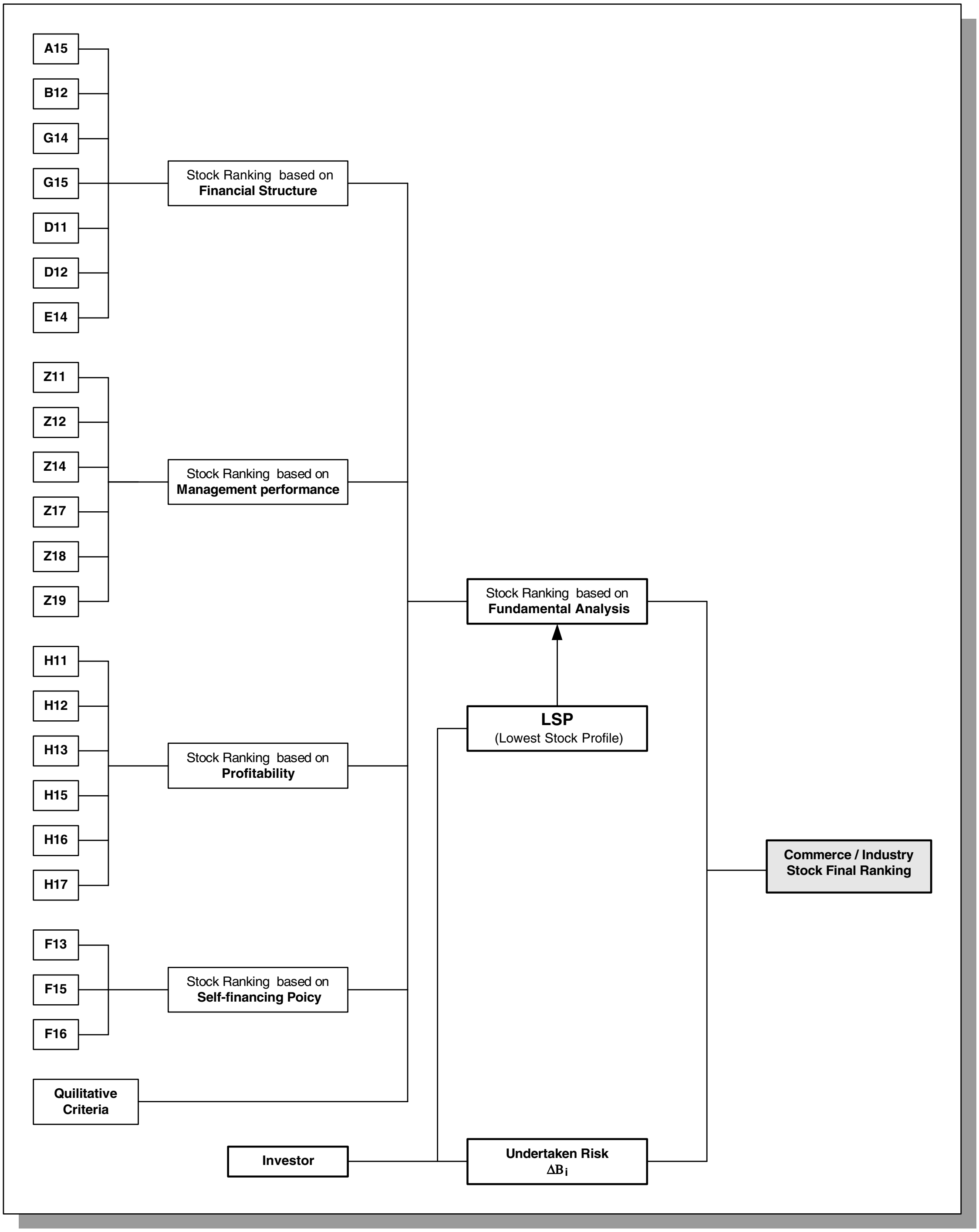


Fig. 7. Commerce/industry stock final ranking.

- A 21(+): Cash and cash equivalents/current deposits;
- A 22(+): Cash and cash equivalents/deposits;
- G 25(−): Liabilities/equity;
- E 21(+): Operating income/assets;

- E 22(−): Operating expenses/assets;
- Z 28(−): (Interest of long term deposits + savings)/(Long term deposits + savings);
- Z 29(+): Profit after taxes/equity.

In addition to the above quantitative criteria, qualitative criteria are also considered for Bank stock evaluation. On the basis of these criteria, Bank stocks are ranked at *Fundamental Analysis*level. Finally, the *Bank Stock Final Ranking List* (Fig. 8) is formed with the use of *Fundamental Analysis* ranking utilities as criteria, along with the undertaken risk determined by the investor.

4.4.3. Insurance stock ranking

Insurance stocks are ranked with the use of the following ranking criteria. The sign in the parenthesis denotes the type of criterion scale: (+) for increasing scale and (−) for declining scale:

- A 31(+): Gross profit * 100/total assets;
- A 32(+): Operating profit * 100/total assets;
- A 33(+): Profit after taxes * 100/equity;
- B 31(+): Gross profit * 100/sales;
- B 32(+): Operating profit * 100/sales;
- B 33(+): Pretax profit * 100/sales.

In addition to the above quantitative criteria, qualitative criteria are also considered for Insurance stock evaluation. On the basis of these criteria, Insurance company stocks are ranked at Fundamental Analysis level. Finally, the Insurance Stock Final Ranking List (Fig. 9) is formed with the use of Fundamental Analysis ranking utilities as criteria, along with the undertaken risk determined by the investor.

4.4.4. Investment stock ranking

Investment stocks constitute a special case and are ranked with the use of the following indices as ranking criteria. The sign in the parenthesis denotes the type of criterion scale: (+) for increasing scale and (−) for declining scale:

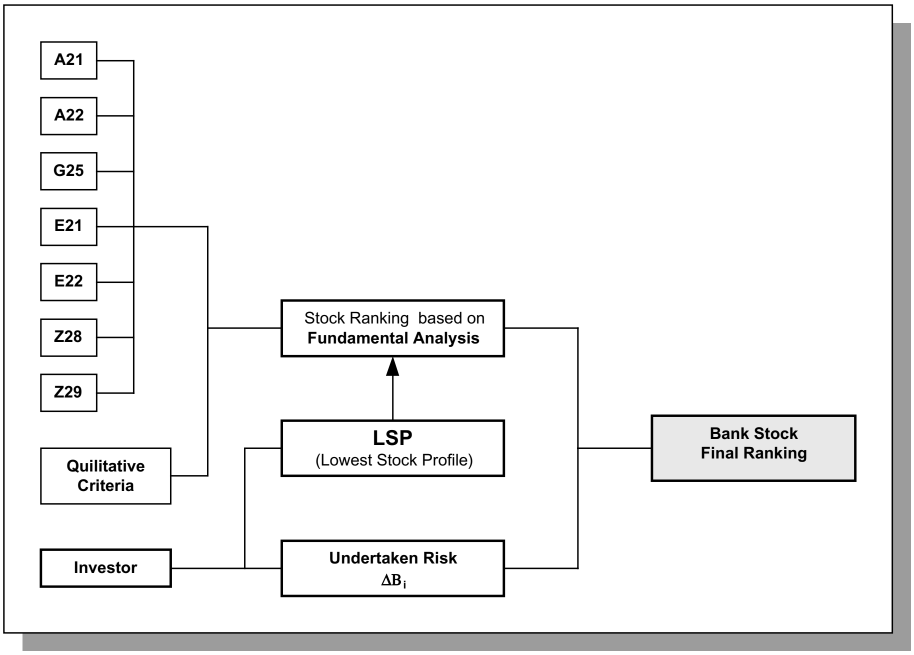


Fig. 8. Bank stock final ranking.

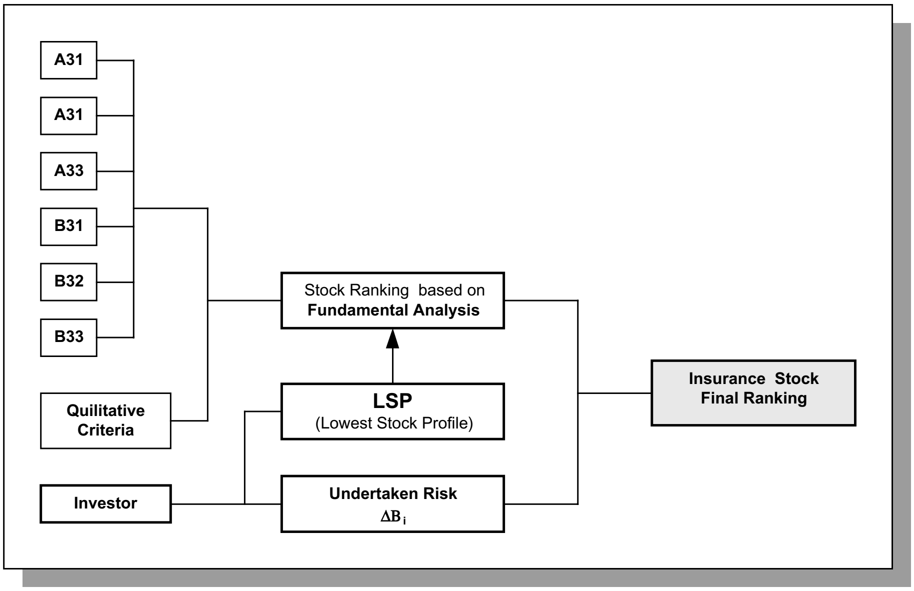


Fig. 9. Insurance stock final ranking.

- A 41(+): Net asset value performance;
- A 42(−): Premium/discount;
- A 43(+): Net asset value change.

In addition to the above quantitative criteria, qualitative criteria are also considered for Investment stock evaluation. On the basis of these criteria, Investment stocks are ranked at Fundamental Analysislevel. Finally, the Investment Stock Final Ranking *List* (Fig. 10) is formed with the use of Fundamental Analysis ranking utilities as criteria, along with the undertaken risk determined by the investor.

4.4.5. Qualitative data

It has already been mentioned that in addition to financial-quantitative data, there are also qualitative data which play an important role to the quality evaluation of a company and consequently the company stocks. The multicriteria analysis methods that are used can handle such qualitative data. Qualitative data, which are used as qualitative indices in the above rankings, depending on the case, are the following:

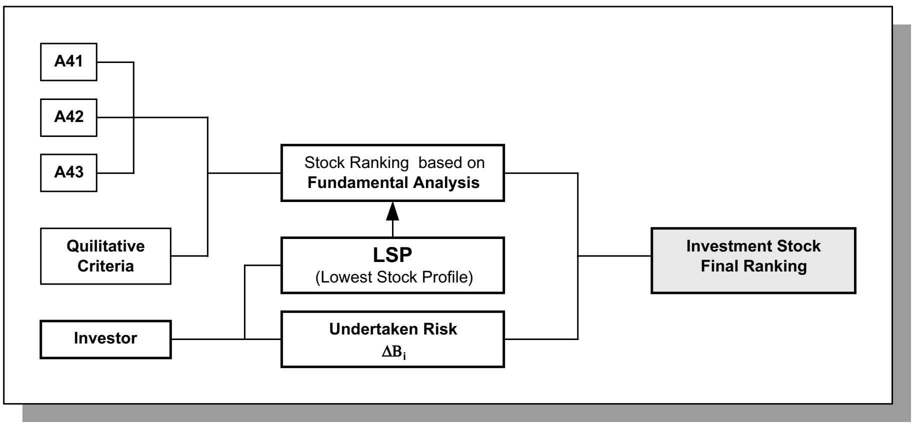


Fig. 10. Investment stock final ranking.

- Managers' experience;
- Firm position in the market;
- Technological structure of the firm;
- Organization–personnel;
- Special competitive advantages of the firm;
- Flexibility of the firm towards the tendency of the market.

The above qualitative criteria are monotonous and increasing and the performances are evaluated based on a ten grade. The qualitative data, for the definition of the above performances, are taken from the periodical statements of ASE. The output is a qualitative evaluation of the firms, which, combined with the basic analysis, provides us with the final evaluation-ranking of the firms that are entered to the ASE.

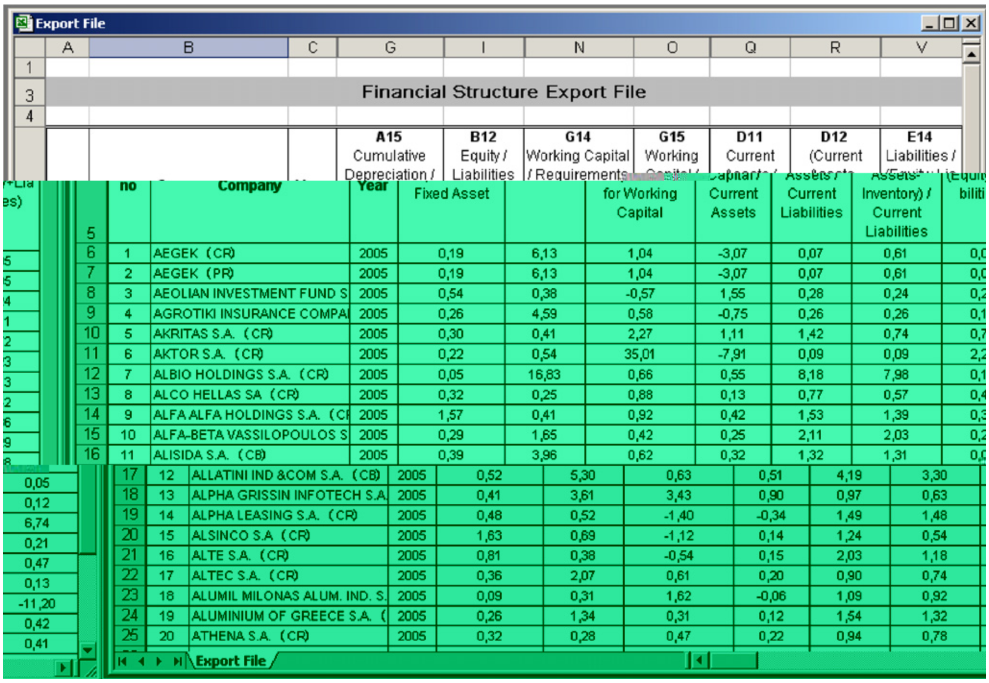
5. Application to the ASE

In this section, some of the basic operations of stock ranking, applied at the system of ASE, are presented.

5.1. Export files

In order for the system to be able to proceed to the multicriteria rankings, it is necessary to determine the reference set for each ranking. Thus, the system generates *Export Files* to *MS-Excel*, that could represent the basis for the determination of the reference sets from the decision maker-manager of the system or the investor. Such a file is presented below (Fig. 11).

In this file we can see the companies in alphabetical order, the evaluation year and the performances of each company to all the selected criteria for the specific accounting plan.


Export File

Financial Structure Export File

no	Company	Year	A15 Cumulative Depreciation / Fixed Asset	B12 Equity / Liabilities	G14 Working Capital / Requirements for Working Capital	G15 Working Capital / Current Assets	D11 Current Assets / Current Liabilities	D12 (Current Assets − Inventory) / Current Liabilities
1	AEGEK (CR)	2005	0,19	6,13	1,04	-3,07	0,07	0,61
2	AEGEK (PR)	2005	0,19	6,13	1,04	-3,07	0,07	0,61
3	AEOLIAN INVESTMENT FUND S	2005	0,54	0,38	-0,57	1,55	0,28	0,24
4	AGROTIKI INSURANCE COMPA	2005	0,26	4,59	0,58	-0,75	0,26	0,26
5	AKRITAS S.A. (CR)	2005	0,30	0,41	2,27	1,11	1,42	0,74
6	AKTOR S.A. (CR)	2005	0,22	0,54	35,01	-7,91	0,09	0,09
7	ALBIO HOLDINGS S.A. (CR)	2005	0,05	16,83	0,66	0,55	8,18	7,98
8	ALCO HELLAS SA (CR)	2005	0,32	0,25	0,88	0,13	0,77	0,57
9	ALFA ALFA HOLDINGS S.A. (C	2005	1,57	0,41	0,92	0,42	1,53	1,39
10	ALFA-BETA VASSILOPOULOS S	2005	0,29	1,65	0,42	0,25	2,11	2,03
11	ALISIDA S.A. (CB)	2005	0,39	3,96	0,62	0,32	1,32	1,31
12	ALLATINI IND &COM S.A. (CB)	2005	0,52	5,30	0,63	0,51	4,19	3,30
13	ALPHA GRISSIN INFOTECH S.A	2005	0,41	3,61	3,43	0,90	0,97	0,63
14	ALPHA LEASING S.A. (CR)	2005	0,48	0,52	-1,40	-0,34	1,49	1,48
15	ALSINCO S.A (CR)	2005	1,63	0,69	-1,12	0,14	1,24	0,54
16	ALTE S.A. (CR)	2005	0,81	0,38	-0,54	0,15	2,03	1,18
17	ALTEC S.A. (CR)	2005	0,36	2,07	0,61	0,20	0,90	0,74
18	ALUMIL MILONAS ALUM. IND. S.	2005	0,09	0,31	1,62	-0,06	1,09	0,92
19	ALUMINIUM OF GREECE S.A. (	2005	0,26	1,34	0,31	0,12	1,54	1,32
20	ATHENA S.A. (CR)	2005	0,32	0,28	0,47	0,22	0,94	0,78

Fig. 11. Financial structure export file (commerce/industry).

5.2. Reference set and LSP

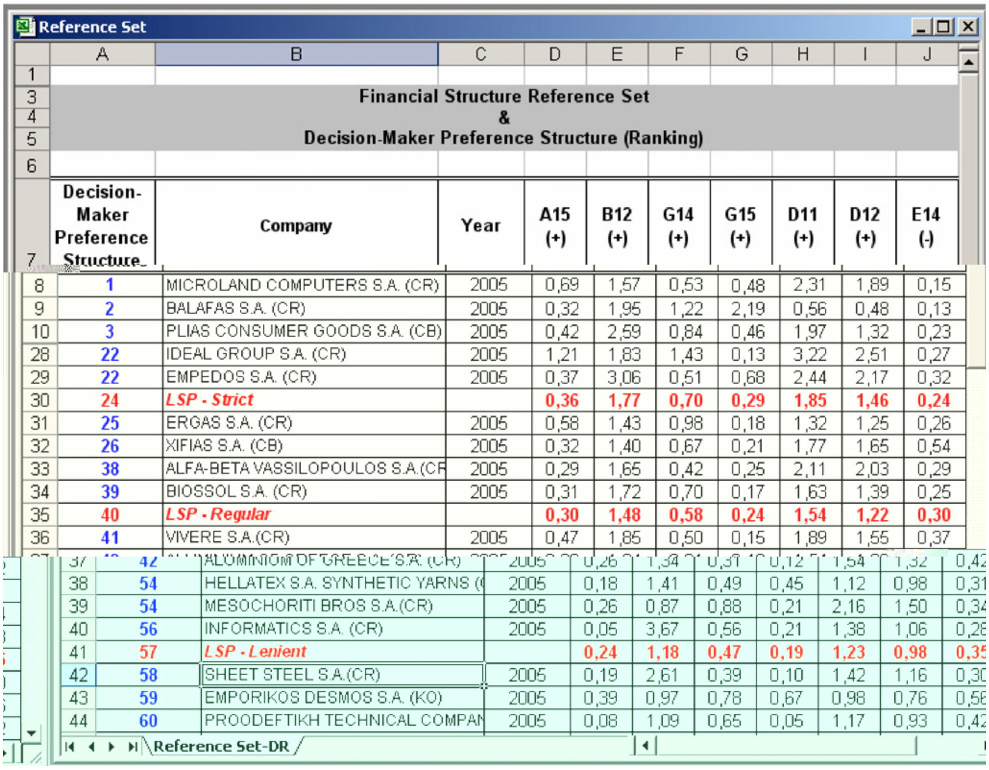
Based on the *export files*, the decision maker, with the aid of specialists (financial analysts), determines the necessary reference sets for each accounting plan: *Commerce/Industry, Banks, Insurance Company, Investment Company*. The decision maker denotes his preferences, giving a preordering (ranking from the best to the worst), for a set of stocks/companies, for which he can express his opinion. Such a reference set, with the ranking/classification criteria, the defined preordering and the corresponding *LSP (strict, regular* and *lenient)* is presented below (Fig. 12).

Except from the companies/stocks, the above reference set incorporates three "fictitious stocks" that constitute the *Lowest Stock Profile (LSP)*. Based on the LSP there will be a categorization of all the classified stocks. The definition of LSP takes place for each criterion as follows:

- *LSP regular:* It is the average rate of the values of the corresponding criterion for all the stocks that should be classified.
- *LSP Strict:* It is defined based on the criterion values that have better performance than the average rate.
- LSP lenient: It is defined based on the criterion values that have worst performance than the average rate.

So, depending on the investment profile of the investor, we will select the cutoff point of the "acceptable" for investment stocks.

- The balanced-indifferent investor will select stocks that are above the *LSP-Regular.*
- The conservative-demanding investor will select stocks, with more demanding specifications, above the *LSP Strict.*
- The dangerous-slack investor will select stocks, with less demanding specifications, above the *LSP Lenient.*



Reference Set

Financial Structure Reference Set & Decision-Maker Preference Structure (Ranking)

Row	Decision-Maker Preference Structure	Company	Year	A15 (+)	B12 (+)	G14 (+)	G15 (+)	D11 (+)	D12 (+)	E14 (-)
8	1	MICROLAND COMPUTERS S.A. (CR)	2005	0,69	1,57	0,53	0,48	2,31	1,89	0,15
9	2	BALAFAS S.A. (CR)	2005	0,32	1,95	1,22	2,19	0,56	0,48	0,13
10	3	PLIAS CONSUMER GOODS S.A. (CB)	2005	0,42	2,59	0,84	0,46	1,97	1,32	0,23
28	22	IDEAL GROUP S.A. (CR)	2005	1,21	1,83	1,43	0,13	3,22	2,51	0,27
29	22	EMPEDOS S.A. (CR)	2005	0,37	3,06	0,51	0,68	2,44	2,17	0,32
30	24	*LSP - Strict*		0,36	1,77	0,70	0,29	1,85	1,46	0,24
31	25	ERGAS S.A. (CR)	2005	0,58	1,43	0,98	0,18	1,32	1,25	0,26
32	26	XIFIAS S.A. (CB)	2005	0,32	1,40	0,67	0,21	1,77	1,65	0,54
33	38	ALFA-BETA VASSILOPOULOS S.A.(CR	2005	0,29	1,65	0,42	0,25	2,11	2,03	0,29
34	39	BIOSSOL S.A. (CR)	2005	0,31	1,72	0,70	0,17	1,63	1,39	0,25
35	40	*LSP - Regular*		0,30	1,48	0,58	0,24	1,54	1,22	0,30
36	41	VIVERE S.A.(CR)	2005	0,47	1,85	0,50	0,15	1,89	1,55	0,37
37	42	ALUMINIUM OF GREECE S.A. (CR)	2005	0,26	1,34	0,31	0,12	1,54	1,32	0,42
38	54	HELLATEX S.A. SYNTHETIC YARNS (	2005	0,18	1,41	0,49	0,45	1,12	0,98	0,31
39	54	MESOCHORITI BROS S.A.(CR)	2005	0,26	0,87	0,88	0,21	2,16	1,50	0,34
40	56	INFORMATICS S.A. (CR)	2005	0,05	3,67	0,56	0,21	1,38	1,06	0,28
41	57	*LSP - Lenient*		0,24	1,18	0,47	0,19	1,23	0,98	0,35
42	58	SHEET STEEL S.A.(CR)	2005	0,19	2,61	0,39	0,10	1,42	1,16	0,30
43	59	EMPORIKOS DESMOS S.A. (KO)	2005	0,39	0,97	0,78	0,67	0,98	0,76	0,56
44	60	PROODEFTIKH TECHNICAL COMPAN	2005	0,08	1,09	0,65	0,05	1,17	0,93	0,42

Reference Set-DR

Fig. 12. Financial structure reference set (commerce/industry).

This reference set is inserted into the UTA∗ model and it will constitute the "leader" for the determination of the model classification.

5.3. Solving of the model

The system proceeds to the solving of the model as it arises by the UTA∗ model. The reference set appears, after the solving, in the screen that is presented below (Fig. 13).

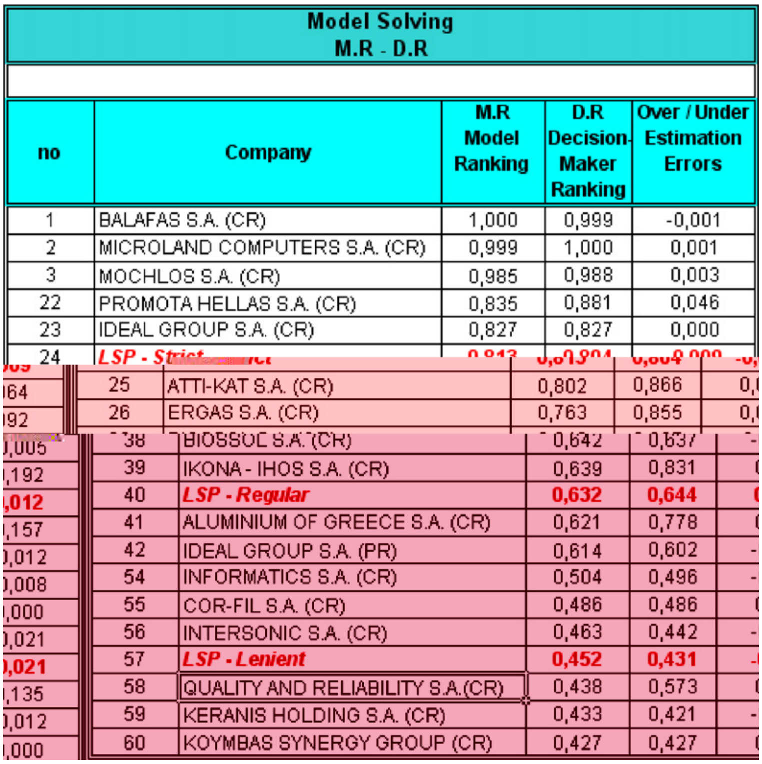
In this screen, we can see the stocks/companies of the reference set, as well as the three LSP, with the corresponding decision-maker ranking (DR) (4th column) and model ranking (MR) (3rd column). In the last column of the screen, we can see the over-estimation and under-estimation errors between the MR and DR. In order to reduce these errors, the decision maker has three alternatives:

- Accept the ranking of the model and change his preordering.
- Accept the estimated preference model and proceed to the modification of the marginal utility function in a way that it will lead to inconsistencies elimination (trade-offs analysis).
- Insist on his preordering, by forcing the system to make the necessary arrangements (criteria weights, etc.).

After few feedbacks and interactions, between the decision maker and the system, a satisfying convergence between the MR and DR is succeeded. The model knows that the decision maker wishes a classification and it is ready for model extrapolation.

5.4. Estimated-model extrapolation and final ranking

This is the last phase of the classification of companies/stocks, during which the system proceeds to the extrapolation of the estimated model to the set of the companies/stocks that are at *ASE* (Fig. 14).



Model Solving
M.R - D.R

no	Company	M.R Model Ranking	D.R Decision-Maker Ranking	Over / Under Estimation Errors
1	BALAFAS S.A. (CR)	1,000	0,999	-0,001
2	MICROLAND COMPUTERS S.A. (CR)	0,999	1,000	0,001
3	MOCHLOS S.A. (CR)	0,985	0,988	0,003
22	PROMOTA HELLAS S.A. (CR)	0,835	0,881	0,046
23	IDEAL GROUP S.A. (CR)	0,827	0,827	0,000
24	LSP - Strict	0,813	0,804	
25	ATTI-KAT S.A. (CR)	0,802	0,866	
26	ERGAS S.A. (CR)	0,763	0,855	
38	BIOSSOL S.A. (CR)	0,642	0,637	
39	IKONA - IHOS S.A. (CR)	0,639	0,831	
40	LSP - Regular	0,632	0,644	
41	ALUMINIUM OF GREECE S.A. (CR)	0,621	0,778	
42	IDEAL GROUP S.A. (PR)	0,614	0,602	
54	INFORMATICS S.A. (CR)	0,504	0,496	
55	COR-FIL S.A. (CR)	0,486	0,486	
56	INTERSONIC S.A. (CR)	0,463	0,442	
57	LSP - Lenient	0,452	0,431	
58	QUALITY AND RELIABILITY S.A.(CR)	0,438	0,573	
59	KERANIS HOLDING S.A. (CR)	0,433	0,421	
60	KOYMBAS SYNERGY GROUP (CR)	0,427	0,427	

Fig. 13. Model solving and comparison MR–DR (commerce/industry).

Fig. 14. Stock final ranking (commerce/industry).

In the screen, we can see all the inserted companies/stocks of the corresponding accounting plan, with the utility value that is raised by the solving of the model (3rd column) and the classification order (4th column). For the companies/stocks that participate at the reference set, we can also have the preordering (last column). In this screen, the classified companies/stocks appear in colored zones:

- *Green zone:* Includes the companies/stocks that are above the *LSP-Strict*. These companies/stocks satisfy the specification of a conservative investor, who wants to be strict with the performance of the companies.
- *Green* + *Yellow zone:* Includes the companies/stocks that are above the *LSP-Regular*. These companies/stocks satisfy the specifications of a balanced investor, who is satisfied with the average rate of the companies' performances.
- *Green* + *Yellow* + *Red zone:* Includes the companies/stocks that are above the *LSP-Lenient*. These companies correspond to an investor, who is likely to include in his portfolio companies/stocks with performance lower than the average ones, when they are good from the technical and financial point of analysis. This case concerns investors who want to invest in short term.

6. Concluding comments

The proposed system, by incorporating a huge volume of financial-quantitative and qualitative data, is a ''live'' system that operates in ''real world'' conditions, since its data are updated on a monthly basis through multiple sources. The final system output is a fundamental analysis evaluation of the ASE stocks, in the form of a ranking list, starting from the best towards the worst stock. The system is intended to support investment decisions and it addresses both institutional and private investors.

The special features – advantages of the system are outlined as follows:

- The proposed system is a Multicriteria DSS since it uses multicriteria analysis methodologies.
- The rankings provided by the system are highly reliable, since every ranking has a different structure and is based on specific indices- criteria which correspond to the specific accounting plan each company belongs in.
- There is no uniform ranking of stocks, but specialized rankings for every single stock sector. Therefore, there is the advantage of selecting stocks from various sectors, which would not be possible if the ranking were uniform.
- The system can also provide a uniform ranking, by assembling all the sector rankings.
- It deals with risk (beta) in a unique way. Beta is no longer a simple criterion in the fundamental analysis, but it constitutes an investment choice and incorporates the investor's attitude towards risk.
- The system provides the lowest stock profile (LSP) determination, by the investor, and therefore considers important views of the investor's preferential profile.
- The system, using all this information, can offer individualized stock evaluations, which fully respond to the potential investor's requirements and preferences.
- The proposed system can operate either autonomously or as part of an integrated system that incorporates all portfolio management operations. It presents a rather high automation level (refers to the performance of hard and time-consuming data procedures), as well as a high level of participation and interaction as far as the decision-maker is concerned, within the decision-making process.

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