Expert Systems with Applications 36 (2009) 11966–11980

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

On the selection of equity securities: An expert systems methodology and an application on the Athens Stock Exchange

P. Xidonas *, E. Ergazakis, K. Ergazakis, K. Metaxiotis, D. Askounis, G. Mavrotas, J. Psarras

Management and Decision Support Systems Laboratory, School of Electrical and Computer Engineering, National Technical University of Athens, Heroon Polytechneiou 9, 15780 Athens, Greece
National Technical University of Athens, School of Chemical Engineering, Laboratory of Industrial & Energy Economics 9, Heroon Polytechneiou Str., 15780 Athens, Greece

ARTICLE INFO

Keywords:
Expert systems
Equity selection
Financial analysis

ABSTRACT

In this article we present an expert systems methodology for supporting decisions that concern the selection of equities, on the basis of financial analysis. The proposed methodology is employed for selecting the attractive equities, through the evaluation of the overall corporate performance of the corresponding firms. The crucial importance issue of the industry/sectoral accounting singularities was strongly taken into account. An elaborate review of coherent research studies is also provided. Finally, the validity of the proposed methodology is tested through a large scale application on the Athens Stock Exchange.

1. Introduction

Financial decision making is a very complicated process, where decision makers (DMs) (managers of companies, managers of credit institutions, individual investors, etc.) face, on a daily basis, a large volume of information that should be examined in order to make the final decision concerning the performance or the viability of a firm, the granting or denying of a credit application, the construction and management of a portfolio, the choice of an investment, or the construction of a financial marketing plan. The combination of decision theory with the new knowledge and the powerful tools offered by computer science and information technology, led to the development of new types of decision support methodologies, able to assist DMs and improve the decision-making process. An example of the above effective and fertile combination is the expert systems (ES) technology (Metaxiotis, Ergazakis, Samouilidis, & Psarras, 2004b).

One of the most significant domains of financial decision making which fully complies with the ES approach is the problem of portfolio selection. Portfolio selection involves the construction of a portfolio of equities (or securities from other asset classes) that maximizes the investor's utility. The process leading to the construction of such portfolios constitute of two major phases. In the first phase of the process, DMs, private or institutional investors, have to evaluate and select the equities that are available as investment opportunities. The vast amount of equities traded in international stock markets make this step necessary, in order to focus the analysis on a limited number of the best investment choices. In the second phase of the process, the DMs have to decide on the amount of capital that should be invested in each of the selected stocks, thus constructing a portfolio of the selected equities.

In this article the emphasis is laid on the first stage of the above mentioned process and we focus on the security analysis and evaluation phase. We develop an ES methodology for equity selection exploiting the valuable tool of financial analysis (FA), which is the most appropriate evaluation approach regarding investment decisions within a long-term horizon. FA involves the identification of the strengths and weaknesses of firms, mainly through judgemental procedures concerning the qualitative evaluation and interpretation of financial ratios, as these arise from the accounting statements. Moreover, FA can be viewed as the activity of providing inputs to the portfolio construction phase, since it entails the process of analyzing the singularities of securities and corresponding firms, leading to final selection recommendations. The paper proceeds as follows: In Section 2 we set the problem and we provide an elaborate review and methodological classification of the coherent research studies. In Section 3 we present the proposed methodological framework for the equity selection problem. In Section 4 we present an illustrative application from the Athens Stock Exchange (ASE), along with the corresponding results. Finally, the concluding remarks are given in Section 5.

2. Review and problem setting

2.1. Financial decision making within the ES frame: a brief literature review

According to Klein and Methlie (1995), an ES can be defined as a computer program that represents the knowledge and inference procedures of an expert to solve complicated problems, providing

* Corresponding author. Tel.: +30 210 7723 583.
E-mail addresses: pxid@epu.ntua.gr (P. Xidonas), mavrotas@chemeng.ntua.gr (G. Mavrotas).

0957-4174/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2009.03.066

possible solutions or recommendations. Rada (2008) very accurately stresses that in some cases the term 'expert systems' refers only to knowledge-based systems and in some other also represents, in a broader concept, technologies such as the neural networks or genetic algorithms. These technologies define the, so called, 'evolutionary computation' discipline. This paper exclusively considers the ES technology, within the knowledge or the rule-based frame.

The ES approach is well suited for the study of several financial decision-making problems. The symbolic reasoning of ES enables DMs to draw conclusions, through a process similar to the one used by human experts. Its basic feature is that they utilise an understandable qualitative form of reasoning methodology, which can be further explained to reveal the implementation of this methodology to the data of a specific problem (Metaxiotis, Psarras, & Ergazakis, 2003, 2004a). The diversified nature of the factors (evaluation criteria, objectives and goals) that affect financial decisions, the complexity of the financial, business and economic environments, the subjective nature of many financial decisions, are only some of the features of financial decisions which are in accordance with the ES modelling framework.

A comprehensive bibliography of the applications of artificial intelligence in several business areas can be found in Eom, Lee, and Ayaz (1993), Wong and Monaco (1995a, 1995b) and Turban et al. (2006). A very large number of studies can also be found in the international literature concerning the implementation of ES technology especially in the field of financial management. The contribution of the ES technology in this field is thoroughly presented in O'Leary (1991, 1995), Zopounidis, Doumpos, and Matsatsinis (1997), Nedovic and Devedzic (2002) and Rada (2008). In the exhaustive reviews of Wong and Monaco (1995a, 1995b), a very comprehensive collection of papers is presented, regarding expert systems applications in accounting and finance, on the basis of a very detailed categorization of the corresponding sub-fields (over 35 sub-fields in accounting and finance have been identified and over 40 articles have been classified in the defined categories). Moreover, Siskos and Spyridakos (1999) and Zopounidis and Doumpos (2000) provide an extended theoretical and practical presentation of intelligent multicriteria decision aiding systems within the frame of financial decision making. Table 1 contains a broad collection of articles that have been categorized according to specific domains of financial management. The areas we discern in this article are: (a) portfolio management, (b) accounting, (c) assessment of bankruptcy risk, (d) banking, (e) credit granting, (f) financial analysis, (g) financial planning, (h) investments, (i) bond rating, (j) ES and financial knowledge management, (k) financial marketing, (l) mergers and acquisitions, and (m) project evaluation.

2.2. Equity selection through the corporate performance evaluation scope

It is apparent that researchers in the financial management field have already tried to exploit ES technology, to represent the knowledge of human experts in order to provide recommendations and to support the decision-making process. One of the most prominent areas of the contemporary financial decision making is the area of portfolio management. The portfolio management process is an integrated set of steps undertaken in a consistent manner to create and maintain an appropriate portfolio (combination of assets) to meet clients' stated goals (Maginn, Tuttle, Pinto, & McLeavey, 2007). The three fundamental steps that form the basis for the portfolio management process are: planning, execution and feedback. In the planning step, investment objectives and policies are formulated, capital market expectations are formed and strategic asset allocations are established. In the execution step, the manager constructs the portfolio and integrates investment strategies with capital market expectations to select the specific assets for the portfolio. Finally, in the feedback step, the manager monitors and evaluates the portfolio compared with the plan. Under the same rationale, Spronk and Hallerbach (1997) decompose the investment decision process in the following stages: (a) security analysis to determine the relevant characteristics (or attributes) of the investment opportunities, (b) portfolio analysis to delineate the set of non-dominated or efficient portfolios, (c) portfolio selection to choose the optimal portfolio from the efficient set, and (d) preference analysis.

The portfolio selection problem can be realized as a two phase process (Hurson & Zopounidis, 1995, 1997): (a) evaluation of the available securities to select the ones that best meet the investor's preferences, (b) specification of the amount of capital to be invested in each of the securities selected in the first stage. The proposed methodology concerns the first phase of this process and

Table 1
ES applications in financial management.

Problem domain	Number of articles	Studies
Reviews	13	O'Leary (1991), Eom et al. (1993), O'Leary (1995), Klein and Methlie (1995), Wong and Monaco (1995a), Wong and Monaco (1995b), Durkin (1996), Zopounidis et al. (1997), Siskos and Spyridakos (1999), Zopounidis and Doumpos (2000), Nedovic and Devedzic (2002), Wagner et al. (2002), Turban et al. (2006), Rada (2008)
Portfolio management	10	Pau and Giannoti (1986), Lee and Stohr (1985), Shane et al. (1987), Lee et al. (1989), Suret et al. (1991), Syriopoulos et al. (1992), Tam et al. (1991), Liu and Lee (1997), Lee and Jo (1999), Bao and Yang (2008)
Accounting	10	Michaelsen (1984), Elliot and Kielich (1985), Hansen and Messier (1986), Steinbart (1987), Brown (1991), Behrens and Steinbart (1992), Meservy et al. (1992), McDuffie et al. (1994), Brown and Wensley (1995), Smith and McDuffie (1996)
Assessment of bankruptcy risk	3	Elmer and Borowski (1988), Messier and Hansen (1988), Michalopoulos and Zopounidis (1993)
Banking	2	Chan et al. (1989), Shao (1997)
Credit granting	14	Ben-David and Sterling (1986), Duchessi and Belardo (1987), Shaw and Gentry (1988), Pinson (1989), Hartvigsen (1990), Levine and Pomerol (1989), Nikbakht and Tafti (1989)Butera et al. (1990), Srinivasan and Ruparel (1990), Cronan et al. (1991), Pinson (1992), Sangster (1995), Bryant (2001), Kumra et al. (2006)
Financial analysis	8	Bouwman (1983), Matsatsinis et al. (1996), Matsatsinis et al. (1997), Mui and McCarthy (1987), Sena and Smith (1987), Pacheco et al. (1996), Zopounidis et al. (1996a), Zopounidis et al. (1996b), Shue et al. (2009)
Financial planning	4	Klein (1989), McBride et al. (1989), Dirks et al. (1995), Lee and Nam (1997)
Investments	5	Heuer et al. (1988), Myers (1988), Valentine (1988), Vranes et al. (1996), Poh (2000)
Bond rating	2	Kim and Lee (1995), Shin and Han (1999)
ES and financial knowledge management	3	Wee et al. (1999), Cheng et al. (2009), Shiue et al. (2008)
Financial marketing	4	Borch and Hartvigsen (1991), Kastner et al. (1986), Matsatsinis and Siskos (1995), Mays et al. (1987)
Mergers and acquisitions	1	Hashemi et al. (1998)
Project evaluation	1	Bohanec et al. (1995)

utilizes FA for selecting attractive equities by means of evaluating the overall corporate performance of the corresponding firms (see Edirisinghe & Zhang, 2007; Samaras, Matsatsinis, & Zopounidis, 2008). The evaluation of performance of corporate entities and organizations is an important activity for their management and shareholders as well as for investors and policy makers. Such an evaluation provides the management and shareholders with a tool to assess the strengths and weaknesses of the firm, as well as its competitive advantages over its competitors, thus providing guidance on the choice of the measures that need to be taken to overcome existing problems. Investors are interested in the assessment of corporate performance for guidance to their investment decisions, while policy makers may use such an assessment to identify the existing problems in the business environment and take measures that will ensure a sustainable economic growth and social stability. The performance of a firm or an organization is clearly multidimensional, since it is affected by a variety of factors of different nature, such as: (a) financial factors indicating the financial position of the firm/organization, (b) strategic factors of qualitative nature that define the internal operation of the firm and its relation to the market (organization, management, market trend, etc.), and (c) economic factors that define the economic and business environment.

2.3. Exploiting the ES advantage

The aggregation of all these factors is a subjective process that depends on the DMs' value system and judgement policy. The problem of equity selection is in full accordance with the ES approach. ES is a relatively new approach in supporting DMs to make decisions effectively in complex and ill-structured problem domains. The ES technology originated in techniques from the field of artificial intelligence, aiming to develop computer information systems which represent and exploit the knowledge of human experts on a specific problem domain, to draw conclusions and provide DMs with recommendations. According to the American Heritage Dictionary of the English Language (4th Edition, 2000), an ES is defined as 'a program that uses available information, heuristics, and inference to suggest solutions to problems in a particular discipline'. The main characteristic and basic goal of an ES is its ability to simulate human logic and reasoning, to draw conclusions and to provide corresponding explanations concerning these conclusions (Metaxiotis, Askounis, & Nikolopoulos, 2006). All these issues are of crucial importance for the financial decision-making process, since it involves judgemental procedures that DMs have to follow in order to make the proper decisions (Metaxiotis, 2005). The ES technology is well adapted to this kind of tasks and this is the reason why ES have attracted the interest of many researchers in the financial management field.

The benefits of the ES technology can be summarized as follows (Klein & Methlie, 1995; Turban, Aronson, Liang, & Sharda, 2006; Zopounidis et al., 1997): (a) ES operate and draw estimations and conclusions using the knowledge and experience of human experts. Furthermore, the explanation capability of ES can help DMs to understand better the operation of the system and its assumptions, as well as the inference that the system follows to draw certain conclusions, (b) ES draw conclusion much faster than humans, especially in complex problem domains where a large volume of information and data should be processed and analysed, (c) ES provide the means to handle incomplete information and uncertainty. Uncertainty is a common problem that all DMs face. The ES technology can provide estimations and conclusions in cases where all the necessary information is not available, although these conclusions may not be certain, (d) ES estimations are consistent. Unlike humans, an ES consistently examines and analyses all the available information and data in detail, without overlooking facts or possible solutions, (e) Through the use of ES, the transfer of knowledge is achieved. ES can be used by non-experts to solve complex decision problems, using the knowledge of experts in the problem domain under consideration. Therefore, through the continuous use of ES a non-expert can learn the procedure, the heuristics, and the problem-solving methodology, in general, that an expert would use to solve a specific problem.

The ES technology is based on the domain knowledge of the problem being examined. A problem domain defines the objects, properties, tasks and events within which a human expert works, and also the heuristics that trained professionals have learned to use in order to perform better (Klein & Methlie, 1995). One of the major obstacles of the ES development process is the acquisition of the domain knowledge from the experts and the representation of this knowledge in the most appropriate and applicable form. Acquiring knowledge from the experts is a very difficult and time consuming process, since experts are often inaccessible due to time constraints, they are unenthusiastic, and usually there is a lack of communication between the knowledge engineer and the expert. The problem of finding the proper means for knowledge acquisition and representation in financial analysis, has been already challenged by many scientists in the international literature (Klein & Methlie, 1995). The major part of past work concerning the implementation of ES in different areas of financial decision making focused on the acquisition of domain knowledge either from the experts or through the application of several inductive methods, and the representation of this knowledge in the ES using production rules, networks or frames. The previous works concerning knowledge acquisition can be categorised in two major groups: (a) knowledge acquisition through inductive learning methods (Cronan, Glofferd, & Perry, 1991; Messier & Hansen, 1988; Michalopoulos & Zopounidis, 1993; Ragothaman, Carpenter, & Buttars, 1995; Shaw & Gentry, 1988; Srinivasan & Ruparel, 1990), and (b) knowledge acquisition directly from the experts (Ben-David & Sterling, 1986; Bouwman, 1983; Duchessi & Belardo, 1987; Hartvigsen, 1990; Matsatsinis, 1995; Matsatsinis, Spiridakos, & Zopounidis, 1996; Pinson, 1989, 1992; Sena & Smith, 1987; Srinivasan & Ruparel, 1990; Wooten & Rowley, 1995).

In the case of equity selection through the evaluation of the corporate performance of the corresponding firms, a typical decision involves the examination of several factors, both quantitative and qualitative, which may lead to conflicting decisions. Therefore, the decision process in the problem of equity selection using financial analysis is a complicated one, which makes it difficult for expert financial analysts to express their knowledge and expertise in an applicable form and within a reasonable time frame. The methodology that will be presented aims at resolving all the above constraints and enforcing the limited current research activity as far as the crucial issue of equity portfolio selection within the ES frame is concerned.

3. Proposed methodology

3.1. General description

The aim of the proposed methodology (Xidonas, Ergazakis, Ergazakis, & Psarras, 2008) is the selection of equities which reflect to firms characterized by significant financial strength. The approach developed utilizes FA for this purpose, a highly effective evaluation approach for making rational and non-speculative investment decisions, within a long-term horizon. Within this frame, FA is employed for selecting competitive equities, through the appraisal of the overall corporate performance of the corresponding firms. One of the methodology's main features is that the firms participate in the evaluation process are categorized in classes (eight classes in

total are defined), with respect to their corresponding industry. The ES methodology is then applied separately, in each one of these classes and finally, the partial results are integrated, considering also the major issue of time trend.

The crucial importance issue of the industry/sectoral accounting singularities is strongly taken into account. The methodology employs four specific sets of criteria (financial ratios), specially constructed for the evaluation of the overall corporate performance of the firms under consideration. Each criteria set is related to the specific business activity of each firm and also corresponds to the specific accounting plan each company belongs in. This means that the results the methodology provides have special structure, since there is no uniform evaluation of equities, but specialized evaluations per industry. Therefore, beyond the facility of considering the issue of competition between rival firms, there is the advantage of selecting equities from various business activities and capitalization levels, satisfying in this way the fundamental principle of diversification.

The critical choice of the ES approach for the selection of equities was made because of its remarkable conformity to the nature of the portfolio selection problem. Finally, it has to be mentioned that the proposed methodology was developed in strong cooperation with a panel of experts, financial analysts and portfolio managers. Their contribution was of catalytic impact, in all stages of collaboration (classification of firms, construction of criteria sets, determination of thresholds and validation of results).

A step-by-step description of how the proposed methodology can be applied to the problem of equity selection, is provided below:

Step 1: Apply the ES methodology for each one of the eight defined classes of firms.

Step 2a: Equities which correspond to firms that have been evaluated as firms of 'Very satisfactory' corporate performance are eligible for selection (see Section 3.5 for details of the definition of 'Very satisfactory' corporate performance).

Step 2b: Equities which correspond to firms that have been evaluated as firms of 'Satisfactory' corporate performance are eligible for selection (see Section 3.5 for details of the definition of 'Satisfactory' corporate performance).

Step 2c: Equities which correspond to firms that have been evaluated as firms of 'Medium' corporate performance are eligible for selection (see Section 3.5 for details of the definition of 'Medium' corporate performance).

Step 2d: Equities which correspond to firms that have been evaluated as firms of 'Non-satisfactory' corporate performance are not proposed for selection (see Section 3.5 for details of the definition of 'Non-Satisfactory' corporate performance).

Step 3: Apply *Steps 1–2* for all years of the study period (2004–2006).

Step 4: From each class, select those equities of firms that have been evaluated as firms of 'Very satisfactory' or 'Satisfactory' corporate performance, in at least two out of the three years of the study period. Reject those equities of firms that even once within the study period have been evaluated as firms of 'Non-satisfactory' corporate performance (see Section 3.5 for details).

Step 5: The final set of equities resulted after applying the *Steps 1–4* contains the securities that are proposed for selection.

The logical diagram of the proposed methodology is graphically depicted in Fig. 1. In the following paragraphs, the key-characteristics of the proposed methodology are analyzed.

3.2. Modeling classes of firms

A rather critical issue that the proposed methodology resolves has to do with the fact that provides the flexibility of simultaneously evaluating a significantly large number of firms from a very wide range of business activities.

The methodology's key-characteristic which allows for this convenience is that the firms participate in the evaluation process are categorized in classes, with respect to their corresponding industry. The ASE follows the Industry Classification Benchmark (ICB) standards (www.icbenchmark.com) and in general, this was the pattern adopted for the definition of the classes. As it is shown in Table 2, the proposed methodology categorizes the firms of the ASE in eight classes. This means that the ES methodology is applied, separately, in each one of these classes.

It has to be mentioned that he only deviation from the ICB standards, as far as the definition of the classes, had to do with the fact that the number of firms in some industries was fairly low. The rationale which adopted in this point is the one that suggests the integration and merger of coherent and contextual industries. For example, the industry of 'Telecommunications' (3 firms) was embodied in the highly related industry of 'Technology' (22 firms) in order to constitute the unified Class *c*. Under the same rationale, Class *d* consists of the firms belong to industries of 'Basic materials' (25 firms) and 'Oil and gas' (3 firms).

The reason for defining different classes of firms is related to the need of acquiring fair, objective and representative evaluation results, within the frame of comparing firms with similar characteristics, i.e. firms with relative business activities. Utilizing this approach, the crucial issue of competition between rival firms is strongly taken into account.

3.3. Knowledge acquisition and construction of the criteria sets

As it has already been stressed, the proposed methodology is grounded on a series of interviews with experts. Moreover, the international literature concerning the assessment of corporate performance has also been taken into serious account.

Initially, as far as the involvement of the experts is concerned, the aim was to identify and select the criteria that are the most appropriate to use in the evaluation of corporate performance, under the endmost objective of selecting the most attractive corresponding equities. In a second stage, the emphasis was laid on the determination of the criteria threshold values. The contribution of experts in this phase too was significant. Finally, there was a validation stage where the results were tested with their assistance.

An initial set of financial ratios were chosen from the international literature (Bernstein & Wild, 1999; Courtis, 1978; Edirisinghe & Zhang, 2007; Fridson, Alvarez, & Rubin, 2008; Greig, 1992; Holthausen and Larcker, 1992; Lewellen, 2003; Ou and Penman, 1992; Penman, 1992; Stickney, Brown, & Wahlen, 2006) on the basis of their popularity and their relevance and contribution to the assessment of corporate performance and viability, within the frame of equity portfolio selection. After a series of meetings with the experts, some additional financial ratios where proposed, while some others where considered as not necessary.

With the agreement of all the experts, four sets of financial ratios were constructed, to be used for the assessment of corporate performance (see Tables 3–6). Each criteria set is related to a different type of a generic firm activity. On this basis, the four criteria sets that constructed focus on the evaluation of: (a) industry/commerce firms, (b) financial services firms, (c) banking institutions, and (d) insurance firms. The necessity for obtaining objective and representative evaluation results is the reason for employing different criteria sets, since not all firms follow the same accounting plan (Samaras et al., 2008). Utilizing this approach, the crucial

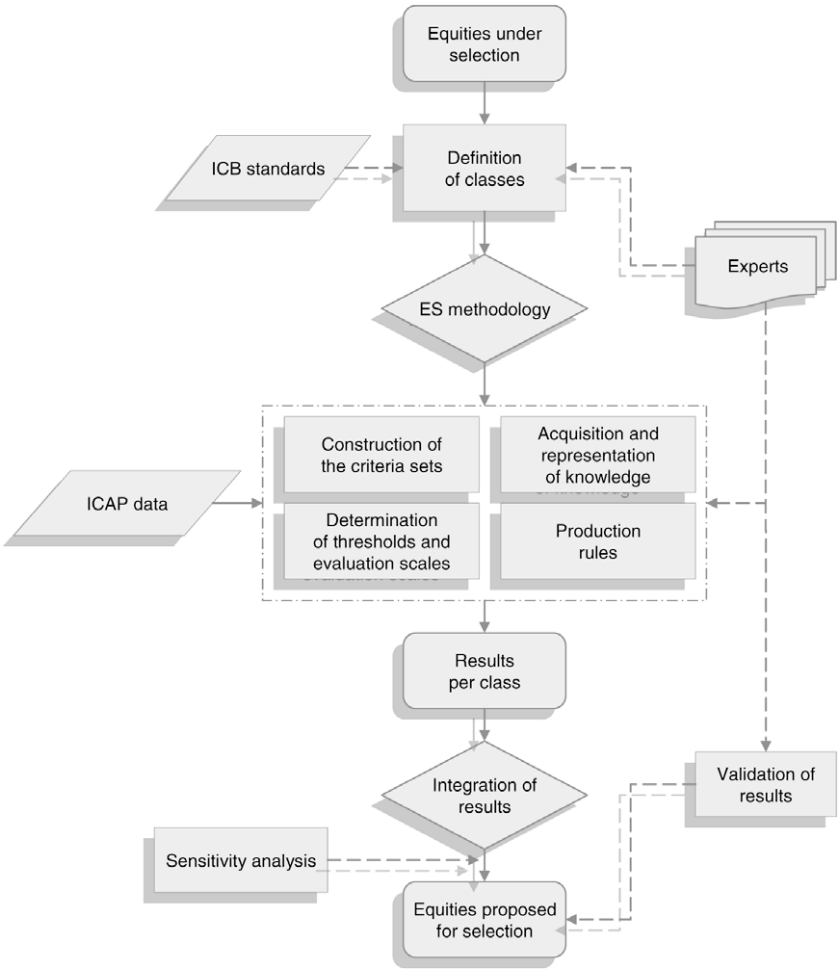

Fig. 1. Logical diagram of the proposed methodology.

Table 2
Definition of classes and distribution of firms per industry/supersector.

Class	Industry	Supersector	Number of companies per supersector	Number of companies per class
a	Consumer goods	Food and beverage	28	64
		Personal and household goods	36	
b	Industrials	Construction and materials	29	54
		Industrial goods and services	25	
c	Technology	Technology	22	25
		Telecommunications	3	
d	Basic materials	Chemicals	9	28
		Basic resources	16	
		Oil and gas	3	
e	Consumer services	Retail	12	49
		Media	11	
		Travel and leisure	14	
		Utilities	4	
		Health care	8	
f	Financials	Financial services	20	20
G	Financials	Banks	14	14
H	Financials	Insurances	5	5

issue of the sectoral accounting singularities is strongly taken into account. The choice of specialized criteria sets is the next safety valve for fair and balanced results, after the initial classification that has been adopted for evaluating firms within the same industry. Finally, it is mentioned that the financial ratios used were categorised in four major groups: profitability ratios, activity ratios, liquidity ratios and solvency/structure ratios. Due to the lack of reliable and objective qualitative data, no qualitative criteria (i.e. quality of management, firm's market position, firm's reputation, organisation, firm's technical structure, etc.) were incorporated in the proposed methodology [see Matsatsinis, Doumpos, and Zopounidis (1997) for an interesting modeling of qualitative criteria as far as the evaluation of a firm's viability is concerned].

In conclusion, according the proposed methodology and with respect to Table 2, the connection between the different classes of firms and the criteria sets has as follows:

- Firms which belong to classes *a*, *b*, *c*, *d* and *e* (consumer goods, industrials, technology, telecommunications, oil/gas, basic materials, consumer services, utilities and health care) are evaluated through the industry/commerce criteria set.
- Firms which belong to class *f* (financial services) are evaluated through the financial services criteria set.
- Firms which belong to class *g* (banks) are evaluated through the banking institutions criteria set.
- Firms which belong to class *h* (insurances) are evaluated through the insurance criteria set.

3.4. Representation of knowledge and production rules

The acquired knowledge is represented through production rules. Rule based representation is one of the widest known and

Table 3
The criteria set for the evaluation of industry/commerce firms.

	Criterion	Definition	Criterion direction	Perspective	Measuring unit
$Cr_{1.1}$	Return on assets	Earnings before interest and taxes divided by total assets	Max	Profitability	%
$Cr_{1.2}$	Return on equity	Net income divided by shareholders equity	Max	Profitability	%
$Cr_{1.3}$	Net profit margin	Net income divided by sales	Max	Profitability	%
$Cr_{1.4}$	Deadline of receivables	(Customers plus accounts receivable) × 365 divided by sales	Min	Activity	Number of days
$Cr_{1.5}$	Deadline of payables	(Suppliers plus accounts payable) × 365 divided by sales	Min	Activity	Number of days
$Cr_{1.6}$	Assets turnover	Sales divided by total assets	Max	Activity	Fraction
$Cr_{1.7}$	Acid liquidity	Current assets minus inventories divided by current liabilities	Max	Liquidity	Fraction
$Cr_{1.8}$	Cash liquidity	Cash plus cash equivalents divided by current liabilities	Max	Liquidity	Fraction
$Cr_{1.9}$	Current liabilities to working capital	Current liabilities divided by currents assets minus current liabilities	Min	Liquidity	Fraction
$Cr_{1.10}$	Solvency ratio	Total liabilities divided by shareholder's equity	Min	Solvency/ structure	Fraction
$Cr_{1.11}$	Leverage ratio	Total assets divided by shareholder's equity	Max	Solvency/ structure	Fraction
$Cr_{1.12}$	Financial expenses coverage	Earnings before interest and taxes divided by interest expenses	Max	Solvency/ structure	Fraction

Table 4
The criteria set for the evaluation of financial services firms.

	Criterion	Definition	Criterion direction	Perspective	Measuring unit
$Cr_{2.1}$	Return on assets	Earnings before interest and taxes divided by total assets	Max	Profitability	%
$Cr_{2.2}$	Return on equity	Net income divided by shareholders equity	Max	Profitability	%
$Cr_{2.3}$	Net profit margin	Net income divided by sales	Max	Profitability	%
$Cr_{2.4}$	Personnel's performance	Earnings before interest and taxes divided by numbers of employees	Max	Profitability	€
$Cr_{2.5}$	Assets turnover	Sales divided by total assets	Max	Activity/liquidity	Fraction
$Cr_{2.6}$	Acid liquidity	Current assets minus inventory divided by current liabilities	Max	Activity/liquidity	Fraction
$Cr_{2.7}$	Solvency ratio	Total liabilities divided by shareholder's equity	Min	Solvency/structure	Fraction
$Cr_{2.8}$	Leverage ratio	Total assets divided by shareholder's equity	Max	Solvency/structure	Fraction

Table 5
The criteria set for the evaluation of banking institutions.

	Criterion	Definition	Criterion direction	Perspective	Measuring unit
$Cr_{3.1}$	Return on assets	Earnings before interest and taxes divided by total assets	Max	Profitability	%
$Cr_{3.2}$	Return on equity	Net income divided by shareholders equity	Max	Profitability	%
$Cr_{3.3}$	Interest-bearing assets/liabilities spread	Average interest-bearing assets return minus average liabilities interest cost	Max	Profitability	Fraction
$Cr_{3.4}$	Net interest margin	Net interest income divided by average total assets	Max	Profitability	%
$Cr_{3.5}$	Efficiency	Total operating expenses divided by operating income	Max	Profitability	%
$Cr_{3.6}$	Personnel's performance	Earnings before interest and taxes divided by numbers of employees	Max	Profitability	€
$Cr_{3.7}$	Equity to total assets	Shareholder's equity divided by total assets	Max	Structure	%
$Cr_{3.8}$	Interest-bearing assets to total assets	Interest-bearing assets divided by total assets	Max	Structure	%
$Cr_{3.9}$	Total loans to deposits	Total loans divided by total deposits	Min	Structure	%
$Cr_{3.10}$	Provisions to total loans	Loan provisions plus other receivable provisions divided by total loans	Min	Structure	%

Table 6
The criteria set for the evaluation of insurance firms.

	Criterion	Definition	Criterion direction	Perspective	Measuring unit
$Cr_{4.1}$	Return on assets	Earnings before interest and taxes divided by total assets	Max	Profitability	%
$Cr_{4.2}$	Return on equity	Net income divided by shareholders equity	Max	Profitability	%
$Cr_{4.3}$	Net profit margin	Net income divided by sales	Max	Profitability	%
$Cr_{4.4}$	Personnel's performance	Earnings before interest and taxes divided by numbers of employees	Max	Profitability	€
$Cr_{4.5}$	Deadline of receivables	(Customers plus accounts receivable) × 365 divided by sales	Min	Activity/liquidity	Number of days
$Cr_{4.6}$	Acid liquidity	Current assets minus inventory divided by current liabilities	Max	Activity/liquidity	Fraction
$Cr_{4.7}$	Solvency ratio	Total liabilities divided by shareholder's equity	Min	Solvency/ structure	Fraction
$Cr_{4.8}$	Insurance provisions to liabilities	Total insurance provisions divided by total liabilities	Min	Solvency/ structure	%

implemented forms for knowledge representation in the development of ES. Production rules have a very simple syntax form, they are easily understandable, while their implementation offers a great degree of flexibility to the ES as they are easy to modify and update. A production rule has the form:

IF *conditions* **THEN** *conclusions*

The conditions part of a production rule may include one simple condition or a number of simple conditions combined with the logical operators **AND**, *OR* and **NOT**. If all the conditions are fulfilled, then the rule is verified and the actions in the conclusion part of the rule are carried out.

Each of the selected criteria was modeled using a three-point scale: very satisfactory, satisfactory and non-satisfactory. The thresholds (cut-off values) for the financial ratios, were determined by the experts, in such a way as to represent their practical implementation. Suggestively, in Table 7 are presented the threshold values of the criteria sets for the evaluation of the Class *a* firms (year 2006). Similar tables have been constructed for the rest of the defined classes of firms during the whole study period. This task was one of the experts' major contributions in the development of the proposed methodology.

Indeed, the methodology's critical success factors were related to the experts' valuable experience in security analysis, along with the potential to have access in a plethora of statistical data, concerning each firm's financial ratios for three consecutive years and the corresponding industry and sectoral average values as well. It is stressed that all the necessary data utilized in the application of the proposed methodology were provided by the ICAP S.A. (www.icap.gr), the largest financial information provider in Greece. The availability of such a detailed and elaborate information, gave the experts assistance of crucial importance in their difficult task to make all the necessary assessments and finally obtain the values of the thresholds.

After the determination of the threshold values for all the criteria sets is completed, detailed hierarchical decision trees are constructed, which clearly represent in a graphical way, the whole decision process described by the experts. The initial level of these hierarchical decision trees at its left side, involves the modeling of

Table 7
Modeling of the criteria set for the evaluation of the Class *a* firms (year 2006).

IF	THEN	is
$Cr_{1.1} > 6.24$	Return on assets	Very satisfactory
$2.09 \leqslant Cr_{1.1} < 6.24$	Return on assets	Satisfactory
$Cr_{1.1} \leqslant 2.09$	Return on assets	Non-satisfactory
$Cr_{1.2} > 10.48$	Return on equity	Very satisfactory
$1.9 \leqslant Cr_{1.2} < 10.48$	Return on equity	Satisfactory
$Cr_{1.2} \leqslant 1.9$	Return on equity	Non-satisfactory
$Cr_{1.3} > 8.49$	Net profit margin	Very satisfactory
$2.45 \leqslant Cr_{1.3} < 8.49$	Net profit margin	Satisfactory
$Cr_{1.3} \leqslant 2.45$	Net profit margin	Non-satisfactory
...	...	...
$Cr_{1.4} < 122$	Deadline of receivables	Very satisfactory
$122 \leqslant Cr_{1.4} < 169$	Deadline of receivables	Satisfactory
$Cr_{1.4} \geqslant 169$	Deadline of receivables	Non-satisfactory
...	...	...
$Cr_{1.12} > 3.6$	Financial expenses coverage	Very satisfactory
$2.3 \leqslant Cr_{1.12} < 3.6$	Financial expenses coverage	Satisfactory
$Cr_{1.12} \leqslant 2.3$	Financial expenses coverage	Non-satisfactory

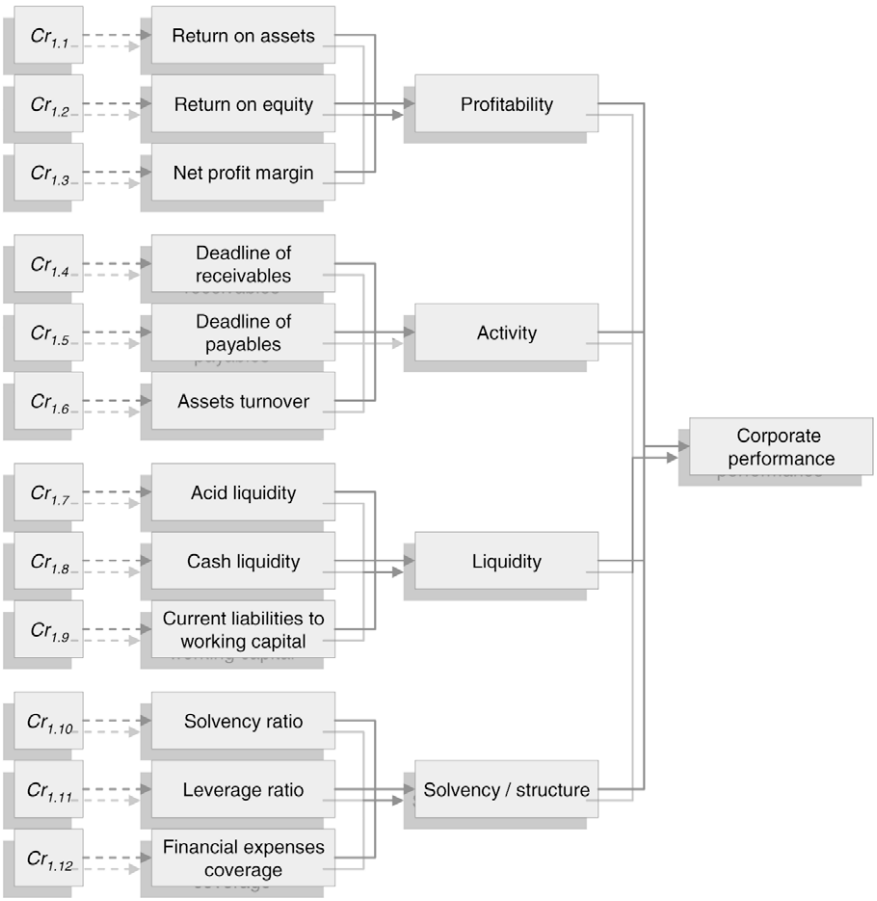

Fig. 2. Decision tree representation of the evaluation process for the industry/commerce firms.

the evaluation criteria, while the final level of the hierarchy to the right side of the decision trees, involves the final decisions drawn as far as the assessment of the firms' overall corporate performance. Fig. 2 suggestively depicts in a decision tree representation, the structure of the evaluation process for the industry/commerce firms.

As it has already been mentioned, each of the selected criteria was modeled using a three-point scale: very satisfactory, satisfactory and non-satisfactory. The same three-point scale was used for the synthesis of the criteria. On the other hand, a four-point scale was utilized for the assessment of the firms' overall corporate performance (synthesis of perspectives): very satisfactory, satisfactory, medium and non-satisfactory. The experts involved in the study, also defined a qualitative interpretation of this scale. The qualitative descriptions that in strategic level interpret the four-point scale are shown in Table 8.

Four types of production rules were constructed in total: (a) production rules for a simple criterion, (b) production rules for the synthesis of criteria, (c) production rules for the assessment of corporate performance (synthesis of perspectives), and (d) production rules for the final selection of equities (*Step 4* of the proposed methodology). An indicative set of rule examples, suggestively for the evaluation of the industry/commerce firms, is presented in Table 9.

On the basis of the proposed methodological framework, a set of 1406 production rules were constructed in total: 289 production

Table 8
Qualitative interpretation of the four-point scale for the overall corporate evaluation.

Corporate performance	Qualitative description
Very satisfactory	Firms involved in this category are characterized by excellent financial strength according to their performances in the criteria of all the examined perspectives (profitability, activity, liquidity, solvency and structure). With respect to their rivals in the corresponding industry, they are placed at the top of the ranking for all the ratios employed. These firms are considered to enjoy the best future prospects and constitute the most powerful and reliable investment opportunities during the specific period of analysis. Equities of these firms can be considered for participation in investment portfolios in a medium-long time horizon
Satisfactory	The firms of this category are characterized by satisfactory financial strength within all the examined perspectives. Relatively to their rivals, they are placed above the industry average values. These firms are considered to enjoy the satisfactory prospects and constitute reliable investment opportunities during the specific period of analysis. Equities of these firms can be considered for participation in investment portfolios in a medium-long time horizon
Medium	This category contains firms that are characterized by medium financial strength. The performance of these firms in the examined criteria is rather moderate. In relation to their competitors, they are placed around the industry average values. These firms are not considered as investment opportunities, at least for the specific period of analysis. Equities of these firms can be considered for participation in investment portfolios, within the frame of the diversification principle
Non-satisfactory	The firms of this category are characterized by extremely poor financial strength within all the examined perspectives (profitability, activity, liquidity, solvency and structure). Relatively to their rivals, they are placed fairly below the industry average values. Equities of these firms do not constitute a rational investment choice for the specific period examined, at least for the medium-long term. In reverse, selection of these equities for participation in portfolios can only be considered within the frame of an aggressive/risky investment policy and only for obtaining short-term profits

Table 9
Production rules of the evaluation process for the industry/commerce firms.

Type a	Type b	Type c	Type d
...	...	...	...
Rule a-01 **if** $Cr_{1.1}$ > *Upper threshold* **then** *Return on assets = Very satisfactory*	*Rule b-02* **if** *Return on assets = Very satisfactory* **and** *Return on equity = Very satisfactory* **and** *Net profit margin = Satisfactory* **then** *Profitability = Very satisfactory*	*Rule c-04* **if** *Profitability = Very satisfactory* **and** *Activity = Very satisfactory* **and** *Liquidity = Satisfactory* **and** *Solvency/structure = Satisfactory* **then** *Corporate performance = Very satisfactory*	*Rule d-04* **if** *Corporate performance*$_{2004}$ *= Very satisfactory* **and** *Corporate performance*$_{2005}$ *= Very satisfactory* **and** *Corporate performance*$_{2006}$ *= Non-satisfactory* **then** *Equity = Is NOT proposed for selection*
...	...	...	...
Rule a-02 **if** $Cr_{1.1} \leqslant$ *Upper threshold* **and** $Cr_{1.1}$ > *Lower threshold* **then** *Return on assets = Satisfactory*	*Rule b-05* **if** *Return on assets = Very satisfactory* **and** *Return on equity = Non-satisfactory* **and** *Net profit margin = Non-satisfactory* **then** *Profitability = Non-satisfactory*	*Rule c-05* **if** *Profitability = Very satisfactory* **and** *Activity = Very satisfactory* **and** *Liquidity = Non-satisfactory* **and** *Solvency/structure = Non-satisfactory* **then** *Corporate performance = Medium*	*Rule d-08* **if** *Corporate performance*$_{2004}$ *= Very satisfactory* **and** *Corporate performance*$_{2005}$ *= Satisfactory* **and** *Corporate performance*$_{2006}$ *= Medium* **then** *Equity = Is proposed for selection*
...	...	...	...
Rule a-03 **if** $Cr_{1.1} \leqslant$ *Lower threshold* **then** *Return on assets = Non-satisfactory*	*Rule b-06* **if** *Return on assets = Very satisfactory* **and** *Return on equity = Satisfactory* **and** *Net profit margin = Non-satisfactory* **then** *Profitability = Satisfactory*	*Rule c-09* **if** *Profitability = Very satisfactory* **and** *Activity = Satisfactory* **and** *Liquidity = Satisfactory* **and** *Solvency/structure = Non-satisfactory* **then** *Corporate performance = Satisfactory*	*Rule d-12* **if** *Corporate performance*$_{2004}$ *= Satisfactory* **and** *Corporate performance*$_{2005}$ *= Satisfactory* **and** *Corporate performance*$_{2006}$ *= Medium* **then** *Equity = Is proposed for selection*
...	...	...	...
	Rule b-08 ***if*** *Return on assets = Satisfactory* ***and*** *Return on equity = Satisfactory* ***and*** *Net profit margin = Non-satisfactory* ***then*** *Profitability = Satisfactory*	*Rule c-12* **if** *Profitability = Satisfactory* **and** *Activity = Satisfactory* **and** *Liquidity = Satisfactory* **and** *Solvency/structure = Non-satisfactory* **then** *Corporate performance = Satisfactory*	*Rule d-15* **if** *Corporate performance*$_{2004}$ *= Satisfactory* **and** *Corporate performance*$_{2005}$ *= Medium* **and** *Corporate performance*$_{2006}$ *= Non-satisfactory* **then** *Equity = Is NOT proposed for selection*
...	...	...	...

Table 10
Distribution of production rules.

Criteria set	Types of production rules				
	Type a	Type b	Type c	Type d	Total
Industry/commerce criteria set	36	108	81	64	289
Financial services criteria set	24	99	27	64	214
Banking institutions criteria set	30	586	9	64	689
Insurance firms criteria set	24	99	27	64	214

rules for the criteria set of the industry/commerce firms, 214 production rules for the criteria set of the financial services firms, 689 production rules for the criteria set of banking institutions and 214 production rules for the criteria set of the insurance firms. Table 10 summarizes the above figures and also provides useful information as far as its distribution to the four defined types of production rules is concerned.

3.5. The expert systems software

The software which was utilized for the implementation of the proposed methodology is the Knowledge Builder® created by the XpertRule Software Ltd. (www.xpertrule.com). The Knowledge Builder® offers a satisfactory graphical and customizable multi-user development environment for medium to large scale knowledge-based applications and components. The acquired knowledge can be represented in tree, rule and case forms and the software is supported by an integrated inference engine. Finally, except the fact that fully customisable objects can be developed, there is also the potential of having flexible and scalable knowledge deployment options (i.e. PC standalone, Ajax thin client web based solutions and COM+ Java Servlet or Java Applet using XML for data exchange).

A complete prototype expert system has been developed, using the typical structural elements of expert systems: database,

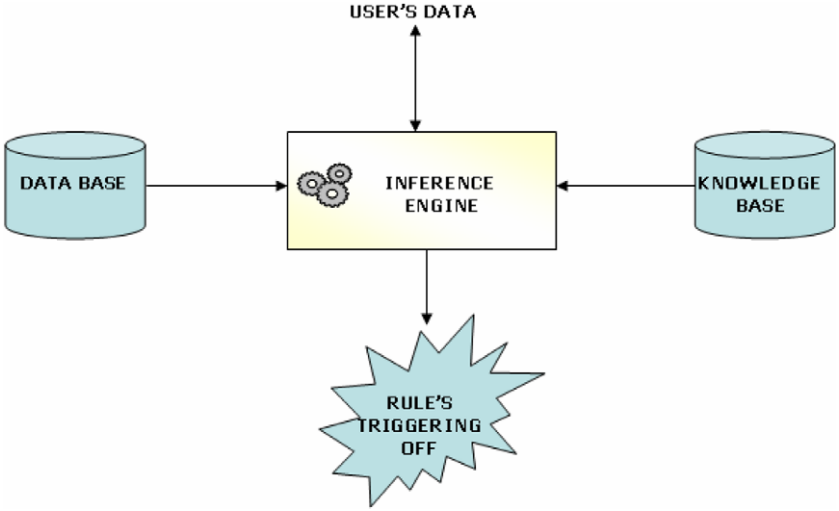

Fig. 3. The process of a rule's triggering off.

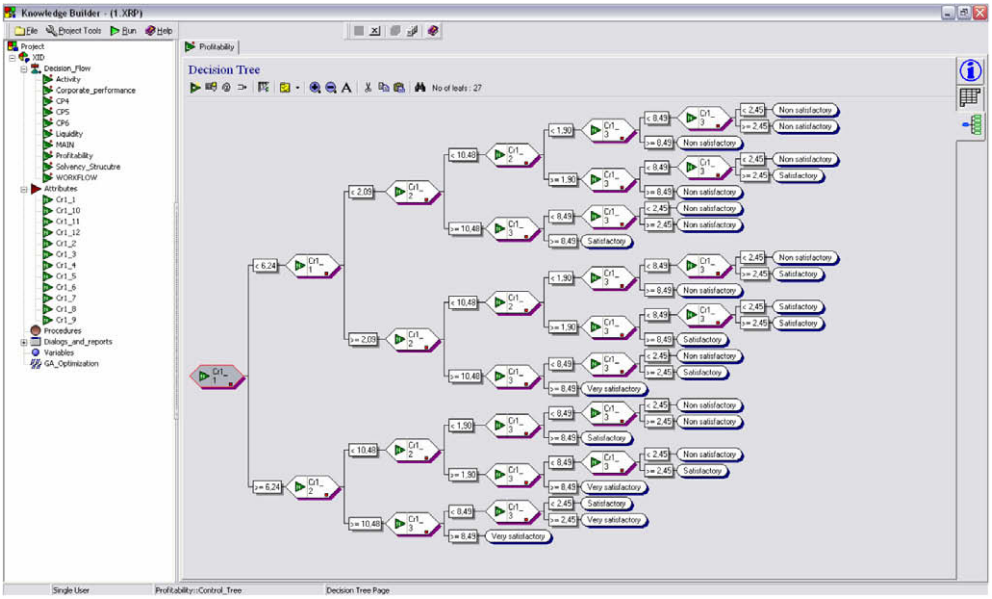

Fig. 4. Decision tree representation for the synthesis of criteria.

knowledge base, inference engine, user interface and the simulation process. These elements are now described:

3.5.1. Database

The system's database contains the following types of data:

- The library of dimensions (i.e. profitability, liquidity, etc.) and criteria.
- Their type (type of measure), their related dimensions and their thresholds (defined based on literature review).
- The necessary data for the calculation of criteria: valuerange, thresholds and mathematic relations for their calculation.

It has to be mentioned that the system's basic philosophy is that, through a process of dialogue with the user, collects basic data for the evaluation of each criterion.

3.5.2. Knowledge base and the inference engine

The system's knowledge base is its most significant part. There are rules containing the knowledge that was modeled so as to evaluate the status of each criterion and accordingly the company's financial performance. In the Knowledge Builder®, the rules are created using decision trees. Their structural units can be any element from the database: calculating processes, variables or even other decision trees (see Fig. 3).

The inference engine integrated in the Knowledge Builder® triggers off the appropriate rules in a dynamic way, depending on the data that user imports in each step and in combination with the data that inference engine receives from the database and the knowledge base. Fig. 1 illustrates the process of triggering off a rule. It is crucial to underline that the inference engine stores automatically in the system's database the list of rules that were triggered off during each simulation. In this way, user knows which

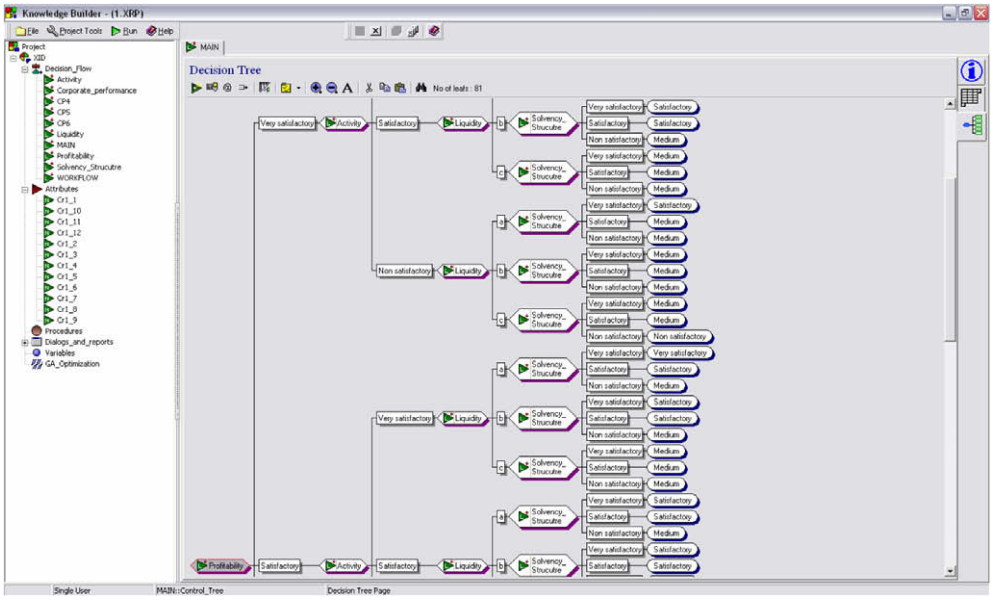

Fig. 5. Decision tree representation for the assessment of corporate performance.

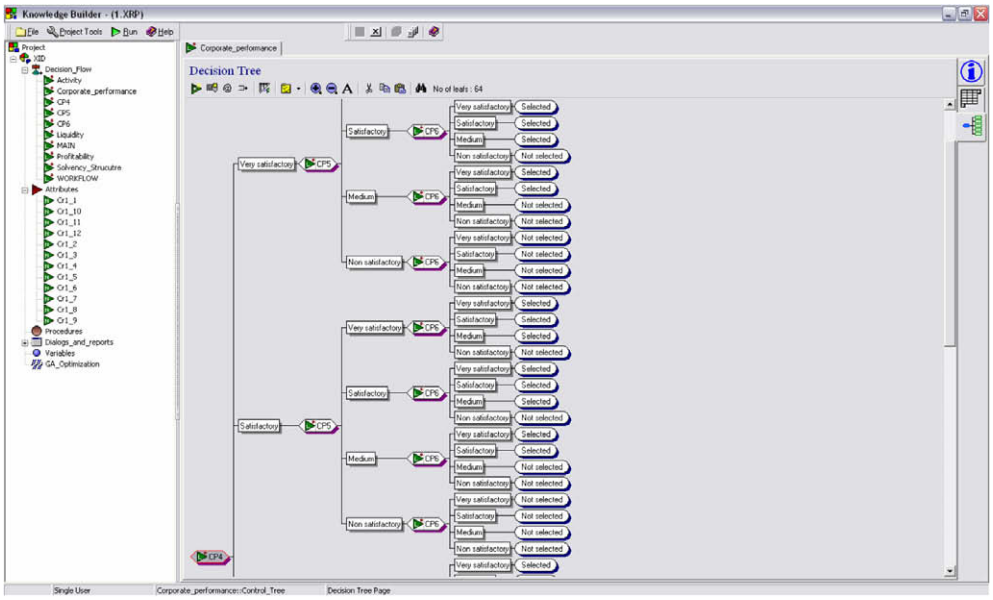

Fig. 6. Decision tree representation for the final selection of equities.

rules were used by the system and the thresholds that were selected for the criterion. This allows user to control the whole process and correct possible errors or wrong choices.

3.5.3. User interface

The user interface is constituted of a variety of dialogues and reports that are categorized in input data, reports and results' presentation forms.

3.5.4. Process of simulation

The process of simulation consists of the following steps:

- Reception: The initial form of the system briefly explains to the user its usefulness and presents the library of criterion.
- Data input: User selects the desired dimension through appropriate forms. Then the introductory form to the particular dimension follows. Afterwards, the user imports the essential data: values of criterion. This procedure is taking place until the assessment of each dimension is completed.
- Presentation of final conclusions: The main conclusions of the simulation regarding the status of each dimension and accordingly the status of the company are presented to the user through a final form.

Moreover, a very important advantage of the system is that it can be easily updated so as to include new dimensions and criteria.

The environment of Knowledge Builder® and three representative phases of the proposed methodology and the corresponding application are shown in Figs. 4–6. In these figures is suggestively depicted in a decision tree representation, the structure of the evaluation process for the evaluation of the Class *a* firms (year 2006). Fig. 4 presents production rules for a simple criterion (return on assets, return on equity and net profit margin) and production rules for the synthesis of criteria (production rules of Type a and

Table 11
Firms and the corresponding industry/supersector.

No	OASIS Code	Name of firm	Industry	Supersector
1	AAAK	Tria Alpha (CR)	Consumer goods	Personal and household goods
2	ALLK	Allatini (CB)	Consumer goods	Food and beverage
3	ALSIN	Alsinco (CR)	Consumer goods	Personal and household goods
4	VARG	Varagis (CR)	Consumer goods	Personal and household goods
5	VARNI	Varvaresos (CB)	Consumer goods	Personal and household goods
6	VELL	Vell Group (CR)	Consumer goods	Personal and household goods
7	**VIVART**	Vivartia (CR)	Consumer goods	Food and beverage
8	VIOKA	Viocarpet (CR)	Consumer goods	Personal and household goods
9	VOX	Fashion Box (CR)	Consumer goods	Personal and household goods
10	GALAX	Galaxidi (CR)	Consumer goods	Food and beverage
...	...	...	...	...
251	**MARFV**	Marfin Bank (CR)	Financials	Banks
252	**PEIR**	Pireaus Bank (CR)	Financials	Banks
253	**PRO**	Proton Bank (CR)	Financials	Banks
254	**TT**	Tahidromiko Tamieutirio (CR)	Financials	Banks
255	AGRAS	Agortiki Asfalistiki (CR)	Financials	Insurances
256	ASASK	Aspis Pronia (CR)	Financials	Insurances
257	**EEGA**	Ethniki Asfalion (CR)	Financials	Insurances
258	EUVRK	Eurobrokers (CR)	Financials	Insurances
259	EUPIK	Europaiki Pisti (CR)	Financials	Insurances

Table 12
Final results.

Class *a*	**7 VIVART**	9 VOX	10 GALAX	11 GRIGO	14 DROME
	17 EEEK	**21 ELMEK**	**25 EFTZI**	26 INFIS	27 KANAK
	28 KARD	29 KATSK	30 KEGO	33 KORRES	36 KRI
	40 MIN	**42 MPELA**	**46 NHR**	**52 SAR**	54 SATOK
	56 SENTR	58 YALKO	**62 FRLK**		
Class *b*	74 VOSYS	75 GEVKA	80 EKTER	83 ELTK	**86 HERAC**
	91 KLEM	92 KLM	94 LYK	97 MEVA	**99 METK**
	104 NIOUS	**106 OLTH**	107 OLP	109 PETRO	**114 TERNA**
	115 TITK	**117 FRIGO**			
Class *c*	119 AGRI	123 BYTE	**129 KOSMO**	**131 KOUES**	**138 PLAIS**
	140 REIN				
Class *d*	145 ALMY	148 DROUK	**152 ELPE**	158 MERKO	**159 MOH**
	161 MYTIL	**162 NEOXH**	**166 SIDE**		
Class *e*	173 AVK	176 ANEK	**177 ARAIG**	178 ASKO	**183 VSTAR**
	186 EYAPS	**189 HLEAT**	190 HYATT	**191 IASO**	**194 INLOT**
	195 KAE	**199 LAMPSA**	205 MOTO	**211 OPAP**	**212 OTOEL**
	214 REV	**216 SPRI**			
Class *f*	221 AIOLK	222 ALTI	223 ANDRO	224 ASTAK	**226 GEK**
	227 GNEF	228 DIAS	**230 EUPRO**	**231 EHAE**	232 INTER
	235 KOUM				
Class *g*	**241 ALFA**	**243 ATE**	**248 ETE**	**249 EUROB**	**250 KYPR**
	252 PEIR				
Class *h*	255 AGRAS	258 EURBK			

Table 13
Evaluation of Vivartia S.A. (year 2006).

	Criterion	Values	Results
$Cr_{1.1}$	Return on assets	6.21%	Satisfactory
$Cr_{1.2}$	Return on equity	4.43%	Satisfactory
$Cr_{1.3}$	Net profit margin	5.23%	Satisfactory
$Cr_{1.4}$	Deadline of receivables	88 days	Very satisfactory
$Cr_{1.5}$	Deadline of payables	121 days	Non-satisfactory
$Cr_{1.6}$	Assets turnover	0.39	Non-satisfactory
$Cr_{1.7}$	Acid liquidity	1.40	Very satisfactory
$Cr_{1.8}$	Cash liquidity	0.51	Very satisfactory
$Cr_{1.9}$	Current liabilities to working capital	1.37	Satisfactory
$Cr_{1.10}$	Solvency ratio	1.18	Satisfactory
$Cr_{1.11}$	Leverage ratio	2.18	Satisfactory
$Cr_{1.12}$	Financial expenses coverage	1.49	Non-satisfactory

b), as far as the profitability is concerned. Fig. 5 presents production rules for the assessment of corporate performance and the synthesis of perspectives (profitability, activity, liquidity, solvency and structure). Finally, Fig. 6 presents production rules for the final selection of equities (integration of the corporate performance results within the examined study period).

4. Application and results

4.1. Field of application

The proposed methodology described in the previous section is applied on data concerning firms whose equities are traded in the ASE. The selection of the ASE is due to the availability of data. Indeed, it was quite difficult to gather complete and reliable financial data concerning other European and non-European stock exchanges. However, it is important to note that the usefulness of the proposed methodology is not affected by the fact that it is applied only to the ASE. The type of data that are employed in this application are also available for the analysts and investors in other countries. Furthermore, no assumptions are made concerning the special characteristics of the stock exchange.

A number of 259 firms (90 firms of high capitalization and 169 firms of medium–low capitalization) were considered for the application of the proposed methodology, covering a broad spectrum of business activities. A number of 62 firms were excluded from the study [securities of special stock exchange characteristics (14), securities under supervision (21), securities under suspension (17) and preferred securities (10)]. The time period of study regards three consecutive years (2004–2006).

Table 3 of Section 3.2 summarizes the distribution of the 259 firms in the corresponding industries and supersectors, while Table 11 provides information relative to the correspondence of each firm with its industry and supersector, as well as the capitalization category of each firm (bold type characters for high capitalization securities and non-bold type characters for medium and low capitalizations stocks).

4.2. Results

With respect to the implementation steps of the proposed methodology described in Section 3.1, in Table 12 are presented the final set of equities that are proposed for selection (Step 7). This set consists of 90 securities (out of the 259 that initially

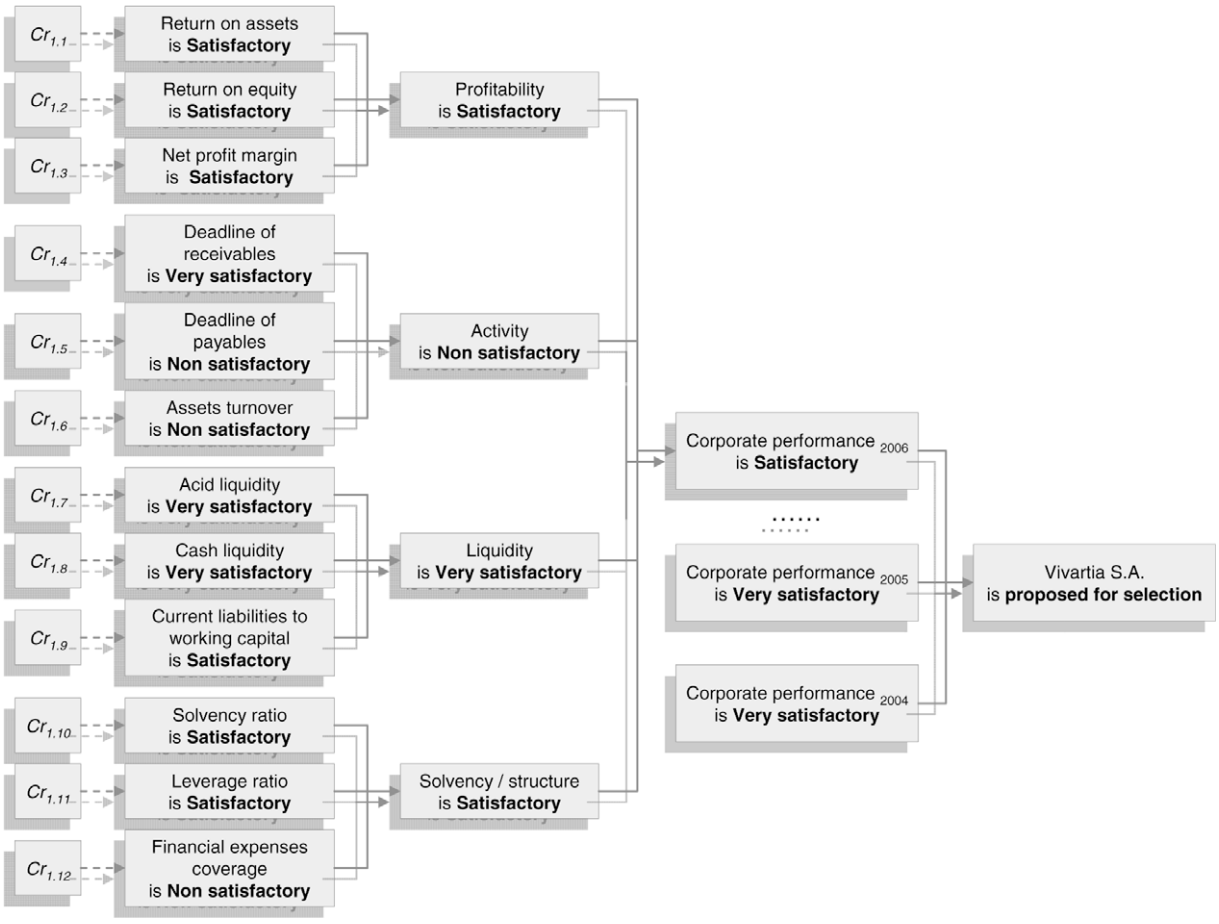

Fig. 7. The decision tree for the representation of the evaluation of Vivartia S.A.

considered), of which 44 are high capitalization equities. Table 12 reveals an important feature of the proposed methodology is now apparent: There is no uniform evaluation of stocks, but specialized evaluation per industry. Therefore, beyond the facility of considering the issue of competition between rival firms, the methodology provides the analyst with the potential of selecting equities from various business activities and capitalization levels, satisfying in this way the fundamental principle of portfolio diversification.

An example of how the ES methodology evaluates the corporate performance of a firm follows: Suppose that the ES is used to evaluate the common registered equity of Vivartia S.A., a high capitalization stock which belongs in the 'Food and beverage' supersector (Consumer goods). Table 13 presents the firm's values in the corresponding criteria set (industry/commerce) for the year 2006. Constructing similar tables for the rest of the two years of the study period and applying the methodology's four types of production rules described in Section 3.4, the decision tree for the representation of the evaluation of the firm is obtained (Fig. 7). According to the decision tree, the equity of Vivartia S.A. is proposed for selection, i.e. to be included in an investment portfolio.

The securities proposed for selection reflect to firms that are characterized by excellent financial strength according to their performances in the criteria of all the examined perspectives (profitability, activity, liquidity, solvency and structure). With respect to their rivals in the corresponding industry, they are placed at the top of the ranking for all the ratios employed. These firms are considered to enjoy the best future prospects and constitute the most powerful and reliable investment opportunities during the specific period of analysis. Equities of these firms can be considered by the rational investor, as prudent options for participation in portfolios, within a medium-long time horizon.

As it has already been mentioned, the proposed methodology contains a final validation stage, where the results were tested with the assistance of experts. Their contribution in this last phase was significant too. They expressed their satisfaction as far the final results are concerned. More precisely, they confirmed that the obtained results were in categorical concurrence with the set of high performance securities, they heuristically manage in their everyday practice. Indeed, among the securities of the final proposed set, they identified almost all the 'winning' equities of the ASE, with respect to the particular time period of the application. Moreover, even in cases of equities of the final proposed set, that were not recognized by experts as, confirmed by the market, direct investment opportunities, both the chances and hints were given for their further study and potential detection of mispriced securities.

The final phase of the methodology had to do with the sensitivity analysis of the obtained results. In the application that has been presented, the sensitivity analysis was conducted with respect to the criteria threshold values. A very large number of different combinations of threshold values examined and the obtained results had no or extremely slight variation compared to the results of the baseline scenario. The generation rationale of the examined combinations had to do with low, random and simultaneous fluctuations on the thresholds of the baseline scenario and in this case too, the experts expressed their satisfaction as far as the stability of the obtained results is concerned.

5. Concluding remarks

It was our purpose in this article to present a straightforward ES approach for the selection of equities. The aim of the proposed methodology is the elicitation of knowledge from professionals in a highly efficient way and the representation in a knowledge base. The methodology developed exploits for this purpose the valuable tool of FA, which is the most appropriate evaluation approach regarding investment decisions within a long-term horizon. Within this frame, the underlying rationale adopted was that FA can be utilized for selecting attractive equities by means of evaluating the overall corporate performance of the corresponding firms.

The special features and contribution of the approach presented are outlined as follows:

- Incorporation in the decision process of several criteria that in a realistic basis represent the way real decisions are supported and strategies are implemented. Moreover, the proposed methodology allows for taken into consideration the analyst's valuable professional experience.
- A significantly large number of firms from a very wide range of business sectors are possible to be simultaneously evaluated. The methodology's key-characteristic which allows for this convenience is that the firms participate in the evaluation process are categorized in classes, with respect to their corresponding industry. The ES methodology is then applied separately, in each one of these classes and finally, the partial results are integrated, considering also the major issue of time trend.
- The crucial importance issue of the industry/sectoral accounting singularities was strongly taken into account. The sortings provided by the methodology are highly reliable and representative, since every sorting has a different structure and is based on a specific criteria set which correspond to the specific accounting plan each company belongs in.
- There is no uniform evaluation of stocks, but specialized evaluations per industry. Therefore, beyond the facility of considering the issue of competition between rival firms, there is the advantage of selecting equities from various business activities and capitalization levels, satisfying in this way the fundamental principle of diversification.
- The methodology developed for the evaluation of the available equities is based on the ES decision technology, a well adapted approach to the nature of the portfolio selection problem.

Further work that may be considered for broadening the proposed methodology can be summarized as follows:

- Embodiment of the methodology in a functional decision support system.
- Expansion of the methodology's focus so as to include additional asset classes.
- Combination of the proposed methodology with inductive learning methods such as rough sets in order to enhance and enrich the acquired knowledge (Pawlak, 1982; Slowinski & Zopounidis, 1995).
- Combination of the current methodology with a continuous optimization technique, for the optimal allocation of the available wealth in the selected securities (portfolio construction).

References

Bao, D., & Yang, Z. (2008). Intelligent stock trading system by turning point confirming and probabilistic reasoning. *Expert Systems with Applications, 34*(1), 620–627.

Behrens, M. L., & Steinbart, P. J. (1992). Integrating expert systems and artificial intelligence in accounting: A description of the academic program at Memphis State University. *Expert Systems with Applications, 4*(2), 219–223.

Ben-David, A., & Sterling, L. (1986). A prototype expert system for credit evaluation. In L. E. Pau (Ed.), *Artificial intelligence in economics and management* (pp. 121–128). Elsevier Science Publishers.

Bernstein, L. A., & Wild, J. J. (1999). *Analysis of financial statements* (5th ed.). New York: McGraw-Hill.

Bohanec, M., Rajkovic, V., Semolic, B., & Pogacnik, A. (1995). Knowledge-based portfolio analysis for project evaluation. *Information and Management, 28*(5), 293–302.

Borch, O. J., & Hartvigsen, G. (1991). Knowledge-based systems for strategic market planning in small firms. *Decision Support Systems, 7*, 145–157.

Bouwman, M. J. (1983). Human diagnostic reasoning by computer: An illustration from financial analysis. *Management Science, 29*(6), 653–672.

Brown, C. E. (1991). Expert systems in public accounting: Current practice and future directions. *Expert Systems with Applications, 3*(1), 3–18.

Brown, C. E., & Wensley, A. (1995). Special issue on expert systems in accounting, auditing, and finance. *Expert Systems with Applications: An International Journal, 9*(4), 433–608.

Bryant, K. (2001). ALEES: An agriculture loan evaluation expert system. *Expert Systems with Applications, 21*(2), 75–85.

Butera, G., Frascari, E., & Iacono, G. (1990). Pamenide: An expert system for assessing the credit of industrial clients. *Interantional Journal of Expert Systems, 3*(1), 73–85.

Chan, Y. Y., Dillion, T. S., Saw, E. G. (1989). Port-man-an expert system of portfolio management in banks. In L. F. Pau (Ed.), *Expert systems in economics, banking and management* (pp. 87–96).

Cheng, H., Lu, Y. C., & Sheu, C. (2009). An ontology-based business intelligence application in a financial knowledge management system. *Expert Systems with Applications, 36*(2P2), 3614–3622.

Courtis, J. K. (1978). Modeling a financial ratios categorical framework. *Journal of Business Finance and Accounting, 5*(4), 371–386.

Cronan, T. P., Glofferd, L. W., & Perry, L. G. (1991). Production system development for expert systems using a recursive partitioning induction approach: An application to mortgage, commercial and consumer lending. *Decision Sciences, 22*, 812–845.

Dirks, S., Kingston, J. K. C., & Haggith, M. (1995). Development of a KBS for personal financial planning guided by pragmatic KADS. *Expert Systems with Applications, 9*(2), 91–101.

Duchessi, P., & Belardo, S. (1987). Lending analysis support system (LASS): An application of a knowledge-based system to support commercial loan analysis. *IEEE Transactions on Systems, Man and Cybernetics, 17*(4), 608–616.

Durkin, J. (1996). Expert systems: A view of the field. *IEEE Expert, 11*(2), 56–63.

Edirisinghe, N. C. P., & Zhang, X. (2007). Generalized DEA model of fundamental analysis and its application to portfolio optimization. *Journal of Banking and Finance, 31*(11), 3311–3335.

Elliot, R. K., & Kielich, J. A. (1985). Expert systems for accountants. *Journal of Accountancy*(September), 126–134.

Elmer, P. I., & Borowski, D. M. (1988). An expert system approach to financial analysis: The case of S and L bankruptcy. *Financial Management, 17*, 66–76.

Eom, S. B., Lee, S. M., & Ayaz, A. (1993). Expert systems applications development research in business: A selected bibliography. *European Journal of Operational Research, 68*, 278–290.

Fridson, M. S., Alvarez, F., & Rubin, M. A. (2008). *Financial statement analysis*. New York: John Wiley & Sons.

Greig, A. C. (1992). Fundamental analysis and subsequent stock returns. *Journal of Accounting and Economics, 15*, 413–442.

Hansen, J. V., & Messier, W. F. Jr., (1986). A knowledge-based expert system for auditing advanced computer systems. *European Journal of Operational Research, 26*, 371–379.

Hartvigsen, G. (1990). KABAL: A knowledge-based system for financial analysis in banking. *Expert Systems for Information Management, 3*(3), 213–231.

Hashemi, R. R., Le Blank, L. A., Rucks, C. T., & Rajaratnam, A. (1998). A hybrid intelligent system for predicting bank holding structures. *European Journal of Operational Research, 109*, 390–402.

Heuer, S., Koch, U., & Cryer, C. (1988). INVEST: An expert system for financial investments. *IEEE Expert, 3*(Summer), 60–68.

Holthausen, R. W., & Larcker, D. F. (1992). The prediction of stock returns using financial statement information. *Journal of Accounting and Economics, 15*, 373–411.

Hurson, C., Zopounidis, C. (1997). *Gestion de portefeuille et analyse multicritere*. Paris: Economica.

Hurson, C., & Zopounidis, C. (1995). On the use of multicriteria decision aid methods to portfolio selection. *Journal of Euro-Asian Management, 1*(2), 69–94.

Kastner, J., Apte, C., Giesmer, J., Hong, S. J., Karnaugh, M., Mays, E., et al. (1986). A knowledge-based consultant for financial marketing. *AI Magazine, 7*, 71–79.

Kim, B. O., & Lee, S. M. (1995). A bond rating expert system for industrial companies. *Expert Systems with Applications, 9*(1), 63–70.

Klein, M. (1989). FINSIM EXPERT: A KB/DSS for financial analysis and planning. *Engineering Costs and Production Economics, 17*(1–4), 359–367.

Klein, M., & Methlie, L. B. (1995). *Knowledge-based decision support systems with applications in business* (2nd ed.). New York: John Wiley and Sons.

Kumra, R., Stein, R., & Assersohn, I. (2006). Assessing a knowledge based approach to commercial loan underwriting. *Expert Systems with Applications, 30*(3), 507–518.

Lee, J. B., Stohr, E. A. (1985). Representing knowledge for portfolio management decision making. Working paper 101, Center for Research Information Systems, New York University.

Lee, J. K., & Jo, G. S. (1999). Expert system for predicting stock market timing using a candlestick chart. *Expert Systems with Applications, 16*, 357–364.

Lee, J. K., Kim, H. S., & Chu, S. C. (1989). Intelligent stock portfolio management system. *Expert Systems, 6*(2), 74–85.

Lee, J. K., & Nam, S. Z. (1997). An object-oriented optimal savings system: HYPER-SAVINGS. *International Journal of Intelligent Systems in Accounting, Finance and Management, 6*, 303–320.

Levine, P., & Pomerol, J.-Ch. (1989). Knowledge representation by schemata in financial expert systems. *Theory and Decision, 27*, 147–161.

Lewellen, J. (2003). Predicting returns with financial ratios. MIT Sloan School of Management, MIT LFE Working Paper No.LFE-1054-03.

Liu, N. K., & Lee, K. K. (1997). An intelligent business advisor system for stock investment. *Expert Systems, 14*(3), 129–139.

Maginn, J. L., Tuttle, D. L., Pinto, D. E., & McLeavey, D. W. (2007). *Managing investment portfolios* (3rd ed.). New York: John Wiley and Sons.

Matsatsinis, N. E. (1995). An intelligent support system for marketing decisions: Support methodology and integrated architecture. Doctoral dissertation. Technical University of Crete (in Greek).

Matsatsinis, N. F., Siskos, Y. (1995). MARKEX: An intelligent decision support system for product development decisions. In *EURO XIV conference*, Jerusalem, 1995.

Matsatsinis, N. E., Doumpos, M., & Zopounidis, C. (1997). Knowledge acquisition and representation for expert systems in the field of financial analysis. *Expert Systems with Applications, 12*(2), 47–262.

Matsatsinis, N. E., Spiridakos, A., & Zopounidis, C. (1996). Towards an expert system for the evaluation of the financial status of small firms. In Y. Siskos, C. Zopounidis, & K. Pappis (Eds.), *Management of small firms* (pp. 101–109). Cretan University Editions (in Greek).

Mays, E., Apte, C., Giesmer, J., & Kasmer, J. (1987). Organizing knowledge in a complex financial domain. *IEEE Expert, 2*, 61–70.

McBride, R. D., O'Leary, D. E., & Widmeyer, G. R. (1989). A knowledge-based system for cash management with management science expertise. *Annals of Operations Research, 21*, 301–316.

McDuffie, R. S., Smith, L. M., & Flory, S. M. (1994). Validation of an accounting expert system for business combinations. *Expert Systems with Applications, 7*(2), 175–183.

Meservy, R. D., Denna, E. L., & Hansen, J. V. (1992). Application of artificial intelligence to accounting, tax, and audit services: Research at Brigham Young University. *Expert Systems with Applications, 4*(2), 213–218.

Messier, W. F., & Hansen, J. V. (1988). Inducing rules for expert system development: An example using default and bankruptcy data. *Management Science, 34*(12), 1403–1415.

Metaxiotis, K. (2005). Leveraging expert systems technology to improve service industry. *European Business Review, 17*(3), 232–241.

Metaxiotis, K., Askounis, D., & Nikolopoulos, K. (2006). Identifying the characteristics of successful expert systems: An empirical evaluation. *International Journal of Information Technology and Management, 5*(1), 21–36.

Metaxiotis, K., Askounis, D., & Psarras, J. (2004a). Expert systems technology in production planning & scheduling. In Prof. Emeritus Cornelius T. Leondes (Ed.), *Intelligent knowledge-based systems: business and technology of the new millennium*. USA: Kluwer Academic Publishers.

Metaxiotis, K., Ergazakis, K., Samouilidis, J.-E., & Psarras, J. (2004b). Decision support through knowledge management: the role of the artificial intelligence. *International Journal of Computer Applications in Technology, 19*(2), 101–106.

Metaxiotis, K., Psarras, J., & Ergazakis, K. (2003). Production scheduling in ERP systems: An AI-based approach to face the gap. *Business Process Management Journal, 9*(2), 221–247.

Michaelsen, R. H. (1984). An expert system for tax planning. *Expert Systems, 1*, 149–167.

Michalopoulos, M., Zopounidis, C. (1993). An expert system for the assessment of bankruptcy risk. In B. Papathanassiou, K. Paparrizos, (Eds.), *Proceedings of 2nd Balkan conference on operational research* (pp. 151–163).

Mui, G., & McCarthy, W. E. (1987). Applying AI techniques to the familiarization phase of financial decision making. *IEEE Expert, 1987*(Fall), 33–41.

Myers, S. C. (1988). Notes on an expert system for capital budgeting. *Financial Management, 17*(3), 23–31.

Nedovic, L., & Devedzic, V. (2002). Expert systems in finance: A crosssection of the field. *Expert System with Applications, 23*, 49–66.

Nikbakht, E., & Tafti, M. H. A. (1989). Application of expert systems in evaluation of credit card borrowers. *Managerial Finance, 15*(5), 19–27.

O'Leary, D. E. (1991). Artificial intelligence and expert systems in accounting databases: Survey and extensions. *Expert Systems with Applications, 3*(1), 143–152.

O'Leary, D. E. (1995). AI in accounting, finance and management. *International Journal of Intelligent Systems in Accounting, Finance and Management, 4*, 149–153.

Ou, J. A., & Penman, S. H. (1992). Financial statement analysis and the prediction of stock returns. *Journal of Accounting and Economics, 11*, 295–329.

Pacheco, R., Martins, A., Barcia, R. M., Khator, S. (1996). A hybrid intelligent system applied to financial statement analysis. In *Proceedings of 5th international conference on fuzzy systems (FUZZ-96-IEEE)*, New Orleans (pp. 1007–1012).

Pau, I., & Giannoti, G. (1986). *Technical analysis of future markets*. Prentice-Hall.

Pawlak, Z. (1982). Rough sets. *International Journal of Information and Computer Sciences, 11*, 341–356.

Penman, S. H. (1992). Return to fundamentals. *Journal of Accounting, Auditing and Finance, 7*(4), 465–482.

Pinson, S. (1989). Credit risk assessment and meta-judgement. *Theory and Decision, 27*, 117–133.

Pinson, S. (1992). A multi-expert architecture for credit risk assessment: The CREDEX system. In D. E. O'Leary & P. R. Watkins (Eds.), *Expert systems in finance* (pp. 37–64). Elsevier Science Publishers.

Poh, K. L. (2000). An intelligent decision support system for investment analysis. *Knowledge and Information Systems, 2*, 340–358.
Rada, R. (2008). Expert systems and evolutionary computing for financial investing: A review. *Expert Systems with Applications, 34*(4), 2232–2240.
Ragothaman, S., Carpenter, J., & Buttars, T. (1995). Using rule induction for knowledge acquisition: An expert systems approach to evaluating material errors and irregularities. *Expert Systems with Applications, 9*(4), 483–490.
Samaras, G. D., Matsatsinis, N. F., & Zopounidis, C. (2008). A multicriteria DSS for stock evaluation using fundamental analysis. *European Journal of Operational Research, 187*(3), 1380–1401.
Sangster, A. (1995). The bank of Scotlands COMPASS – The future of bank lending? *Expert Systems with Applications, 9*(4), 457–468.
Sena, J. A., & Smith, L. M. (1987). A sample expert system for financial statement analysis. *Journal of Accounting and EDP, 3*, 15–22.
Shane, B., Fry, M., & Toro, R. (1987). The design of an investment portfolio selection decision support system using two expert systems and a consulting system. *Journal of Management Information Systems, 3*, 79–92.
Shao, Y. P. (1997). The infusion of expert systems in banking: An exploratory study. *Expert Systems with Applications, 12*(4), 429–440.
Shaw, M., & Gentry, J. A. (1988). Using an expert system with inductive learning to evaluate business loans. *Financial Management, 17*, 45–56.
Shin, K. S., & Han, I. (1999). Case based reasoning supported by genetic algorithms for corporate bond rating. *Expert Systems with Applications, 16*, 85–95.
Shiue, W., Li, S. T., & Chen, K. J. (2008). A frame knowledge system for managing financial decision knowledge. *Expert Systems with Applications, 35*(3), 1068–1079.
Shue, L. Y., Chen, C. W., & Shiue, W. (2009). The development of an ontology-based expert system for corporate financial rating. *Expert Systems with Applications, 36*(2p1), 2130–2142.
Siskos, Y., & Spyridakos, A. (1999). Intelligent multicriteria decision support: Overview and perspectives. *European Journal of Operational Research, 113*, 236–246.
Slowinski, R., & Zopounidis, C. (1995). Application of the rough set approach to evaluation of bankruptcy risk. *International Journal of Intelligent Systems in Accounting, Finance and Management, 4*, 27–41.
Smith, L. M., & McDuffie, R. S. (1996). Using an expert system to teach accounting for business combinations. *Expert System with Applications, 10*(2), 181–191.
Spronk, J., & Hallerbach, W. G. (1997). Financial modelling: Where to go? With an illustration for portfolio management. *European Journal of Operational Research, 99*(1), 113–127.
Srinivasan, V., & Ruparel, B. (1990). CGX: An expert support system for credit granting. *European Journal of Operational Research, 45*, 293–308.
Steinbart, P. (1987). The construction of a rule based system as a method for studying materiality judgements. *Accounting Review, 62*, 97–116.
Stickney, C. P., Brown, P., & Wahlen, J. M. (2006). *Financial reporting, financial statement analysis, and valuation: A strategic perspective* (6th ed.). South-Western College Publishing.
Suret, J. M., Cormier, E., & Roy, J. (1991). Un systme expert de choix d' actions. *FINECO, 1*, 39–60.
Syriopoulos, C., Doukidis, G., Karakoulas, G., Liakopoulou, T., & Skevophilax, E. (1992). An advisor expert system for investments in stock market. *Bulletin of Union of Greek Banks, 3rd Quarter*, 78–83 (in Greek).
Tam, K. Y., Kiang, M. Y., & Chi, R. T. H. (1991). Inducing stock screening rules for portfolio construction. *Journal of the Operational Research Society, 42*(9), 747–757.
Turban, E., Aronson, J. E., Liang, T. P., & Sharda, R. (2006). *Decision support and business intelligence systems* (8th ed.). New Jersey: Prentice Hall International.
Valentine, J. L. (1988). Applying expert systems to investment. *Financial Analysts Journal, 1988*(November–December), 48–53.
Vranes, S., Stanojevic, M., Stevanovic, V., & Lucin, M. (1996). INVEX: Investment advisor expert system. *Expert Systems, 13*(2), 105–119.
Wagner, W. P., Otto, J., & Chung, Q. B. (2002). Knowledge acquisition for expert systems in accounting and financial problem domains. *Knowledge-Based Systems, 15*, 439–447.
Wee, L. K. A., Tong, L. C., & Tan, C. L. (1999). A generic information extraction architecture for financial applications. *Expert Systems with Applications, 16*(4), 343–356.
Wong, B., & Monaco, J. A. (1995a). Expert system applications in business: A review and analysis of the literature (1977–1993). *Information and Management, 29*(3), 141–152.
Wong, B., & Monaco, J. A. (1995b). A bibliography of expert system applications for business (1984–1992). *European Journal of Operational Research, 85*(2), 416–432.
Wooten, T. C., & Rowley, T. H. (1995). Using anthropological interview strategies to enhance knowledge acquisition. *Expert Systems with Applications, 9*(4), 469–482.
Xidonas, P., Ergazakis, K., Ergazakis, M., Psarras, J. (2008). An expert systems methodology for equity selection using financial analysis. In *43rd meeting of the European working group on financial modeling*, London, United Kingdom, September 4–6, 2008.
Zopounidis, C., & Doumpos, M. (2000). *Intelligent decision aiding systems based on multiple criteria for financial engineering*. Dordrecht: Kluwer Academic Publishers.
Zopounidis, C., Doumpos, M., & Matsatsinis, N. F. (1996b). Application of the FINEVA multicriteria knowledge-based decision support system to the assessment of corporate failure risk. *Foundations of Computing and Decision Sciences, 21*(4), 233–251.
Zopounidis, C., Doumpos, M., & Matsatsinis, N. F. (1997). On the use of knowledge-based decision support systems in financial management: A survey. *Decision Support Systems, 20*, 259–277.
Zopounidis, C., Matsatsinis, N. F., & Doumpos, M. (1996a). Developing a multicriteria knowledge-based decision support system for the assessment of corporate performance and viability: The FINEVA system. *Fuzzy Economic Review, 1/2*, 35–53.