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AN EXPERT SYSTEM FOR RANKING COMPANIES AND INVESTMENTS: WOOD INDUSTRY CASE*

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Abstract: Wood industry is a very important part of both the Greek Rural and industrial sector. The discovery of the differentiation in the level of growth and in the quality of financial management between the Greek wood companies can provide very important aid in the design of an effective rural development policy.

The evaluation and ranking of Greek wood companies based on actual financial data is a very complicated task and it requires expertise knowledge and skills. On the other hand a computer expert system can perform validation and evaluation in an efficient way and can substitute human experts. An expert system was designed and developed towards this direction. It uses multicriteria analysis for each one of the wood companies based on actual financial data and it applies fundamental principles of fuzzy logic in order to calculate the expected intervals of flows for the following years.

Keywords: Multicriteria analysis, computer expert systems, wood industries, fuzzy logic.

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1. INTRODUCTION

The systematic and organized processing of wood by the utilization of contemporary means and the application of basic technological rules to the production line has a long history in Greece. The two most important time-periods for the development of Greece's wood industry are the periods 1938-1940 and 1965-1970. Especially from 1965 to 1970 the rapid technological development (in means and in production methods) the development of new wood products and the development of the international commerce, resulted in historic changes in wood industry [13].

On the other hand Greece had not developed any kind of serious policy, regarding the size and the structure of the units, the adequacy of raw materials and the consuming requirements. Consequently, this evolution took place without any programming and without any design. The lack of raw materials, the large cost of production, the small demand of the market, the development of many micro units (most of them were family business) and the intense competition, have resulted in the reorganization of the brunch in a vertical way. The results were the development of bigger units and the redistribution of land-planning [13].

The wood companies with more than 10 employees (130 establishments) participate with 1.2% to the gross value of production, with 1.7% to the employment and with 0.5% to the exportation of the aggregation of manufacture [5].

The eight main wood industries of Greece were chosen to be evaluated, based on financial data. The financial data were provided by ICAP at our request.

The aim of this paper is to describe the development of an expert system that takes into account financial data that affect the function of eight Wood Processing Companies (W.P.C) in order to evaluate and rank them. The expert system uses multicriteria analysis and fuzzy logic in order to carry out the evaluation and the ranking of the eight W.P.C. The project was designed to evaluate the W.P.C. for a period of ten years, from 1991 to 2000. The validation and the ranking of the eight W.P.C. is carried out in the following way:

- First the financial data are processed and eight annual indexes of pure numbers are created.
- Each index is assigned a weight (equal or uneven weights might be used).
- The Expert System uses multicreteria analysis in order to output the net annual flow for each one of the eight W.P.C. The net flow is the difference between the outgoing flow and the incoming flow.
- The Expert system ranks annually the eight W.P.C. according to the value of their net flow.
- Eight Fuzzy Expected intervals are produced by the Expert System. They are the intervals in which the values of the net flows of the eight W.P.C. are expected to be included in the following year 2001.

2. THE MULTICRITERIA ANALYSIS METHODOLOGY

The PROMETHEE II methods are part of the theory of relevance superiority [2]. They use six types of general tests with the corresponding test's functions in order to determine the superiority between two alternative solutions. In this case the aim is the determination of the superiority of one W.P.C. X_i over a W.P.C. X_j. The type of general level test criterion was selected to be used in this project, with the corresponding criterion function, because it has an indifferent region, for the determination of the superiority [3]. This type of general criterion is the most appropriate to be used in this case, due to the fact that it does not apply a strict choice. Only pairs of W.P.C. are tested in the form (v_i, v_j) $i = 1, 2, ..., 8$, in order to determine which one v_i or v_j has the superiority according to the financial indexes. The function $H(d)$ is used to express the superiority:

Equation 2.1. Level criterion function that uses preference functions. The value of variable d is the difference between the financial indexes of each pair of W.P.C. (v_i, v_j) for the criterion under evaluation.

$$H(d) = \begin{cases} P(v_i, v_j), \text{ superiority of W.P.C. } v_i \text{ if } d \geq 0 \\ P(v_j, v_i), \text{ superiority of W.P.C. } v_j \text{ if } d \geq 0 \end{cases} \quad (2.1.)$$

Where $P(v_i, v_j)$, $P(v_j, v_i)$ are the functions of preference.

Equation 2.2. The level criterion function. It should be mentioned that p and q are parameters that usually have a fixed value.

$$H(d) = \begin{cases} 0 & \text{if} \quad |d| \leq q \\ 1/2 & \text{if} \quad q < |d| \leq p \\ 1 & \text{if} \quad P \leq |d| \end{cases} \quad (2.2.)$$

When it is examined which of two the W.P.C. (v_i, v_j) is the superior, the superiority function $H(d)$ is applied according to the price of d (positive or negative) for each criterion. The q and p parameters are partly estimated in this project and they do not have a fixed value. The estimation of p and q is performed in the following way.

- First of all the annual performances of the eight W.P.C. is calculated for each criterion.
- If there exists a W.P.C. with a very high value of performance that is clearly much higher than the performance of the other seven W.P.C. it is excluded for the criterion under testing. This is done in order to avoid problems that might be caused in the calculation of p and q.

- Afterwards, all of the differences d are calculated, for each pair of W.P.C. (under examination) for each criterion. If the preference function takes into account $|d|$ (the absolute value of d) only the positive values of d are considered.
- Afterwards the range E between the maximum and the minimum values of d is calculated using equation 2.3.

Equation 2.3. Calculation of the range

$$E = d_{\max} - d_{\min} \tag{2.3.}$$

- Finally q, p are estimated using the following equations 2.4. and 2.5.

Equation 2.4. Calculation of p

$$q = d_{\min} + \lambda * E \tag{2.4.}$$

Equation 2.5. Calculation of q

$$p = d_{\min} + \mu * E \tag{2.5.}$$

The coefficients λ and μ are considered to be threshold values that will be used for the estimation of p and q respectively. The parameters λ and μ can be assigned specific values, depending on the type of the problem and on the degree of sensitivity of the superiority control. In this case λ has been assigned the value of 0.2 and μ the value of 0.4. In this way the q, p were calculated for each criterion and for each year [10].

The multicriteria indicator of preference $\Pi\ (v_i,v_j)$ which is a weighted mean, of the preference functions $\Pi\ (v_i,v_j)$ with weights defined by the researcher, expresses the superiority of the U.R.C v_i against U.R.C. v_j after all the criteria are tested. The values of Π are calculated using the following equation 2.6 [4].

Equation 2.6. Calculation of the multicriteria indicator

$$\Pi\ (v_i,v_j) = \frac{\sum_{t=1}^{k} w_t * Pt(v_t,v_j)}{\sum_{t=1}^{k} w_t} \tag{2.6.}$$

It should be mentioned that k is defined to be the number of criteria $(k=8)$ and $P_t(v_i,v_j)$ the preference functions for the k criterions. The multicriteria preference indicator $\Pi\ (v_i,v_j)$ takes values between 0 and 1. When two W.P.C. (v_i,v_j) are compared to each other each one is assigned two values of flows the outgoing flow and the incoming flow.

The outgoing flow is calculated that by the following equation 2.7 [1].

Equation 2.7. Calculation of the outgoing flow

$$\varphi^{+}(v_i) = \sum_{v_j \in A} \Pi(v_i, v_j) \tag{2.7.}$$

In both cases A is defined to be the number of the alternative solutions W.P.C. v_j. (Which in this case are seven). The outgoing flow expresses the total superiority of the W.P.C. v_i against all the other W.P.C. v_j for all the criterions. The incoming flow is determined by the following equation 2.8 [1].

Equation 2.8. Calculation of the incoming flow

$$\varphi^{-}(v_i) = \sum_{v_j \in A} \Pi(v_i, v_j) \tag{2.8.}$$

The incoming flow expresses the total superiority of all the other W.P.C. against W.P.C. v_i for the criteria. The net flow for each W.P.C. v_i is estimated by the following formula: $\varphi(v_i) = \varphi^{+}(v_i) - \varphi^{-}(v_i)$.

The net flow is the number that is used for the comparison between the W.P.C. in order to obtain the final ranking. Each W.P.C. that has a higher net flow is considered to be superior in the final ranking.

The superiority of W.P.C. v_i over the W.P.C. v_j can be expressed using the following expression:

$V_j P v_j$ (v_i is superior to v_j) or $v_i \to v_j$, when $\varphi(v_i) > \varphi(v_j)$

When $\varphi(v_i) = \varphi(v_j)$ the superiority relation is written as follows: $v_i \, \mathrm{I} \, v_j$ (This means that the relation between v_i, v_j is neutral).

3. DESCRIPTION OF THE INFERENCE ENGINE

The expert system was designed to be rule-based and it consists of facts, rules and object-frames. It was designed and constructed to have a main rule set and local rule sets within the object frames [7].

The most important part of an Expert System is the Inference Engine, which is the mechanism that leads to the goal. The Inference engine strategy that was applied was backward-chaining with opportunistic forward, which means that it was designed to be a goal driven expert system, to use Forward Chaining only for the phase of Data Gathering in order to make it faster. It starts from the goal and it evaluates only the necessary rules in order to reach the final conclusion [11].

Knowledge about real world objects is stored in the object frames that contain various types of slots. Each slot describes the properties and the characteristics of the associated object [7].

4. INPUT DATA

The data that were used as input to the expert system come from balance sheets of the W.P.C. for the period 1991 - 2000. According to these balance sheets, the financial indexes were calculated. These indexes express the efficiency and the performance of the management of the W.P.C. These indexes were used (in past research projects) for the evaluation of investments, using multicriteria analysis [6].

The weights of the financial indexes that were used in the analysis are the following:

$$w_i = 0.125 \ \ (i = 1,...,8) \ \ \text{with} \ \ \sum_{i=1}^{7} w_i = 1$$

Table 4.1: Financial indexes used for the determination of the initial input data

x_1 = Reserves*360/Sales
x_2 = Receivable*360/Sales
x_3 = Gross Profit/Sales
x_4 = Profit before taxes/Equity capital
x_5 = Sales/Total Assets
x_6 = Current liabilities*360/Cost of Sales

5. RESULTS OF THE ANALYSIS

Initially the expert system performed the calculation of the annual net flows of the eight most important Greek W.P.C. from 1991 to 2000. The calculation of the net flows was performed according to the financing indexes that were mentioned in table 1. Afterwards, all of the W.P.C. have been ranked in proportion to their annual net flows and for the entire period of 1991 -2000. These rankings can be seen clearly in the following tables 5.1. and 5.2.

Table 5.1: Annual evaluations of the eight W.P.C. according to their net flows from 1991 to 2000.

	91	92	93	94	95	96	97	98	99	00
ABX	1.559	-0.16	-0.48	-1.47	-0.80	-2.80	-1.79	-1.46	0.19	-0.166
AKRITAS	1.49	-0.16	3.506	0.818	0.478	2.138	3.166	3.838	2.16	1.162
DRITSA	0.978	1.162	-0.85	-2.51	3.49	1.158	-0.84	0.470	1.80	-0.166
KARAMPELA	-1.40	-0.16	-0.17	-0.83	-3.15	-4.16	-3.15	-3.15	-3.82	-0.166
KOYNDOYRI	-1.60	-0.16	-5.16	0.146	0.47	2.462	1.798	2.470	1.31	-0.166
MOYRIKIS	0.109	-0.16	-0.13	-1.15	-0.47	-0.81	-1.15	-1.17	-0.65	-0.166
SELMAN	0.324	-0.16	1.16	1.854	0.51	3.182	0.518	-1.16	2.01	-0.166
XYLEMBORIKI	-1.48	-0.16	2.146	3.158	-0.51	-1.15	1.474	0.178	-3	-0.166

The average net flows from 1991 to 2000 of all the eight W.P.C. that were used in the project are selected and presented in table 5.2.

Table 5.2: The average net flows from 1991 to 2000 for the W.P.C. and their ranking

W.P.C.	Average value 1991-2000	Ranking according to the average value
ABEX	7.411/8 = 0.92	3
AKRITAS	18.59/8 = 2.32	1
DRITSA	4.674/8 = 0.584	4
KARAMPELA	–20.193/8 = –2.524	8
KOYNTOYRI	1.555/8 = 0.194	5
MOYRIKIS	–5.789/8 = –0.723	7
SELMAN	8.232/8 = 1.029	2
XYLEMPORIKI	0.468/8 = 0.0585	6

The ranking of each W.P.C. and the average ranking for each one, for the total period 1991-2000 is shown in table 5.3. In this table it is clearly shown that Akritas has been characterized 4 out of 10 times as the first company. The position of Akritas Company has become very strong after 1997 and it is obvious that it is very strong up to now.

Dritsa company was first twice, but the last years after 1996 its position has dropped significantly. There are four W.P.C. that were first in the past years, but recently they are not so strong.

Table 5.3: Annual position for each one of the eight W.P.C. in the rankings of the period 1991-2000 and the average position of each U.R.C. in the same rankings. Rankings of the companies of wood

W.P.C	91	92	93	94	95	96	97	98	99	00	Average
ABEX	1	2	6	7	7	7	7	2	5	2	3
AKRITAS	2	2	1	3	3	3	1	3	1	1	1
DRITSA	3	1	7	8	1	4	5	4	3	2	4
KARAMPELA	6	2	5	5	8	8	8	5	8	2	8
KOYNTOYRI	8	2	8	4	4	2	2	1	4	2	5
MOYRIKIS	5	2	4	6	5	5	6	6	6	2	7
SELMAN	4	2	3	2	2	1	4	8	2	2	2
XYLEMBORIKI	7	2	2	1	6	6	3	7	7	2	6

6. THE CONCEPT AND THE USE OF FUZZY EXPECTED INTERVALS

6.1. General

One of the main features of the expert system is the calculation of the Fuzzy Expected Interval (F.E.I) for each one of the Wood companies of Greece. This means that it can produce a narrow characteristic interval of values. The flow of the company is expected to fall into this interval for the following years.

For example the F.E.I. could be (1.200, 1.480). This would mean that total flow for the company would fall between 1.200 and 1.480 in most of the cases. In this way the F.E.I can be used to forecast the future flow of each W.P.C. of Greece. Thus, a classification of all W.P.C. of the country, according to their expected flow, can be achieved. It is important that the system manages to produce an interval that is as narrow as possible.

The central idea is that statistically and practically there is no interest in forecasting the exact number of the future flow, but rather in finding the general tendency and its direction. The main point is to know if the flow will increase from 1.200 to 1.900, or if it will drop to 0.600 and not to estimate the precise number concerning the past flows of the W.P.C. [14]

This means that data can be grouped in an imprecise way (using various keywords) and thus Fuzzy Logic can be applied [12].

For example if the past data of net flows are 0.980, 1.010, 1.090 and 9.99 for four years, they can be grouped in the following way:

On four occasions the net flow was almost 1.000.

In this way the data can be grouped imprecisely.

There are four types of sentences that can be used during classification of the data.

	Keywords	Lower Bound	Upper Bound
1st type	almost	$x-20\%$	$x-1$
2nd type	more or less	$x-20\%$	$x+20\%$
3rd type	over	$x+1$	$x+20\%$
4rth type	much more than	$2x$	$+\infty$

In a hypothetical situation using this approach, the net flows can be classified imprecisely into groups in the following way.

5 times the flow was almost 0.600
8 times the flow was more or less 0.850
3 times the flow was over 1.100
2 times the flow was much more than 1.500

This is very flexible way of classifying existing data.

Fuzzy logic was introduced by Zadeh in 1965. All the theorems that are used in the following section were described by Kandel and Byatt [8].

6.2. Functions used in the first two steps of the calculation of the F.E.I.

After the classification, the first two steps that should be followed according to Kandel [9] are:

A. The first step is to input data from the imprecise classification, into the characteristic function $C(X)$ and find all C' s [9].

The characteristic function $C(X)$ is described by the following
Equation 6.2.1.

$$C(X)=\begin{cases}0 & \text{IF} \quad X\le 0\\ \dfrac{X}{100} & \text{IF} \quad X\le 100\\ 1 & \text{otherwise}\end{cases} \tag{6.2.1.}$$

where the number 100 is used as the maximum number of flow that was ever calculated according to the data existing so far. (It is the most extreme case according to the designers' judgment). This function is used for the forecast of the total flow.

B. The second step, 9 is to find all μ's, which are the candidate Fuzzy Expected Intervals. The μ's are intervals of the form [LB, UB] and they can be calculated from the following equations 6.2.2. and 6.2.3.

Equation 6.2.2. This equation is used to find the upper bound of every interval μ_i.

$$\underset{j}{UB}=\frac{\sum_{i=j}^{n}\max(pi_1,pi_2)}{\sum_{i=j}^{n}\max(pi_1,pi_2)+\sum_{i=1}^{j-1}\min(pi_1,pi_2)} \tag{6.2.2.}$$

Where pi_1 is the lowest bound of group i and pi_2 is the upper bound of group i.

Equation 6.2.3. This equation is used to find the lower bound of every interval μ_i.

$$\underset{j}{LB}=\frac{\sum_{i=j}^{n}\min(pi_1,pi_2)}{\sum_{i=j}^{n}\min(pi_1,pi_2)+\sum_{i=1}^{j-1}\max(pi_1,pi_2)} \tag{6.2.3.}$$

Where pi_1 is the lowest bound of group i and pi_2 is the upper bound of group i.

6.3. Fuzzy set theorems applied in the third and fourth steps

C. The third task is to find the minimum interval of each line using Theorems 6.3.1., 6.3.2. and 6.3.3. according to Kandel [9]. Theorems 6.3.1. to 6.3.6. are used to compare pairs of intervals of values and to determine which interval is larger and which is smaller.

Theorem 6.3.1. *is the following:*

$$\max(S,R)=\begin{cases}R & \text{if} \quad r_m > s_1\\ S & \text{if} \quad s_n > r_1\end{cases} \tag{3.1}$$

Where $S=\{S_1,\dots,S_n\}$ $R=\{r_1,\dots,r_m\}$ *and* $R\cap S=\varnothing$

Theorem 6.3.2. *is the following:*

$$\max(S,R)=\begin{cases} R & \text{if} \quad r_m > s_n \\ S & \text{if} \quad s_n > r_m \end{cases} \tag{6.3.2.}$$

Where $R=\{r_1,...,r_m\}$ $S=\{S_1,...,S_n\}$ $R,S \neq \varphi,\ S \notin R,\ R \notin S$.

Theorem 6.3.3. *is the following:*
If $R=\{r_1,...,r_m\}$ $S=\{S_1,...,S_n\}$ *and* $R \subseteq S$ *then*

$$\min(S,R)=[S_1,...,r_m] \tag{6.3.3.}$$

D. The final task is to find the maximum interval over the minima using the Thorems 6.3.4., 6.3.5., and 6.3.6. according to Kandel [9].

Theorem 6.3.4. *is the following:*
If $R=\{r_1,...,r_m\}$ $S=\{S_1,...,S_n\}$ *and* $R \cap S = \varnothing$ (6.3.4.)
Then $\max(S,R)=R$ *if* $r_1 > S_n$ *and* $\max(S,R)=S$ *if* $S_1 > r_m$

Theorem 6.3.5. *is the following:*
If $R=\{r_1,...,r_m\}$ $S=\{S_1,...,S_n\}$ *and* $R\,S \neq \varphi,\ S \notin R,\ R \notin S$ (6.3.5.)
Then $\max(S,R)=R$ *if* $r_m > S_n$ *and* $\max(S,R)=S$ *if* $S_n > r_m$

Theorem 6.3.6. *is the following:*
If $R=\{r_1,...,r_m\}$ $S=\{S_1,...,S_n\}$ *and* $R \subseteq S$ (6.3.6.)
Then $\max(S,R)=[r_1,...,S_n]$

The maximum interval found is the Preliminary Fuzzy Expected Interval. The maximum number of flow (which in this case is 100) should be multiplied to the bounds of the Preliminary Fuzzy Expected in order to produce the real fuzzy expected interval. This interval could indicate the expected situation for the specific W.P.C. It is obvious that the narrower this interval is, the more useful it is. To achieve a narrower interval, for example, [1.500-1.700] for the net flow of the following year, the classification of the groups of frequencies should be successful.

7. DISCUSSION OF THE W.P.C.'S EXPECTED INTERVALS OF VALUES

Actually the testing was done for the eight W.P.C. of Greece. The initial knowledge base of the system included financial data for the eight W.P.C. from 1991 to 2000.

It is estimated that the values of the net flows of these W.P.C. will fall inside these intervals for the following year 2001.

Table7.1: F.E.I.'s for the eight W.P.C. for 2001.

W.P.C.	F.E.I. for 2001
ABEX	(0.3, 0.32)
AKRITAS	(2.09, 2.18)
DRITSA	(0.66, 1.15)
KARAMPELA	(0, 0.01)
KOYNTOYRI	(1.4, 1.4)
MOYRIKIS	(0.01, 0.02)
SELMAN	(0.53, 0.62)
XYLEMPORIKI	(1.4, 1.4)

According to the F.E.I. that were produced by the computer expert system, Akritas is going to be first for 2001, with a significant difference from Koundouri and Xylemboriki that are classified as second. Selman is going to be in the third position and Abex in the fourth position.

The expert system will be used and tested again with future data. This means that the task of the evaluation of the W.P.C. will continue and the system's credibility will also be evaluated.

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