Multicriterial Methods used in Expert Systems for Business Decision Making

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Many organizations are in front of most competitive economic environments, where, in order to survive, they must reduce costs all the time and adopt the most intelligent business strategies. In most decision making activities the manager has to decide which variant is the most advantageous, taking into account a multitude of criterions. Expert systems use the expert's knowledge and problem solving skills in a particular subject area throughout an organization, and can propose the optimal variant to be chosen. In this paper we have outlined the role of multicriterial methods in programming expert systems to decide in favor of the most eligible variant between a multitude of possibilities. We also made a case study and designed the prototype of an expert system for choosing the most profitable offer among many, in the prenegotiation stage, for a company, in order to organize the negotiation processes accordingly. In this respect, we tried to highlight the usefulness of multicriterial mathematical methods in three negotiation processes of a Romanian negotiation team with foreign negotiation teams for the acquisition of an equipment.
Keywords: *Business Decision Making, Expert Systems, Multicriterial Methods*

1 Introduction

Today's decisions are complex, combining hard facts with experts' intuition. Rapid business decision-making often requires collaboration across time zones, organizations and cultural norms.

In the field of business decision support, more and more recent research [1] has been concentrating on the human side of the person-technology relation in decision making. It has been shown in many works that business decision making environment is a unity of decision makers' experience, beliefs and perceptions on one side, and decision support tools and techniques – on the other side. The information environment surrounding business activities and decisions is getting increasingly complex due to growing volumes of information of potential relevance to certain business activities [2].

An Expert System (ES) is a knowledge-based computer program containing expert domain knowledge about objects, events, situations and courses of action, which emulates the process of human experts in the particular domain. For long term use, a knowledge base stores rules, facts and other knowledge structures, much as a database stores data. When the ES is used, an inference engine processes the knowledge structures, bringing problem specific information into the system, and makes recommendations to the user based on the information and knowledge structures available [3].

After making a recommendation, users routinely view the decision making logic used by the ES. Since the system remembers its logical chain of reasoning, a user may ask for an explanation of a recommendation and the system will display the factors it considered in providing a particular recommendation. This main attribute, the ability to explain reasoning, enhances user confidence in the recommendation and acceptance of the ES.

Some expert systems are designed to take the place of human experts while others are designed to aid them.

In negociation, as well as in most other circumstances, people must take a decision from a multitude of possible decisions, in order to achieve a certain goal. It is perfectly normal for human reasoning to analyse and to compare the possibilities, in order to adopt that decision which permits the best fulfilment of the desired goal. Although we frequently use the term "optimal decision", in most situations this "optimality" is a very complex concept which can't be defined but by mean of a mathematical model. In our case study we will use three multicriterial methods, implemented in an expert system designed in Exsys Corvid.

Corvid provides an object-oriented structure that makes it easy to build systems using methods and properties of variables, while not requiring the developer to change the way they think and describe their decision-making steps and logic. The result is a very flexible and powerful development environment that can easily be learned. We used Corvid for implementing our application presented in paragraph 3.

2 Multicriterial Methods. Business Decision Making Theoretical Approaches

Mathematical models appeared and were used in the process of decision making in business, particularly in negociation, quite from the necessity to sustain the logical reasoning in negociation and to manage a great number of factors simultaneously.

Furthermore, the applying of these mathematical methods grants the approach of some new qualitative problems, so that it is not at all surprising the fact that in negociation as well there are used more and more mathematical tools, techiques and models.

The process of decision-making is defined by following elements [4]: the decision-maker, the assemblage of decision alternatives, the assemblage of decision criterions, the assemblage of goals.

The decision-maker is the person who must select the most advantageous variant from a multitude of possible ones, variant called the *optimum choice*.

The assemblage of decision alternatives, V, is the assemblage of action possibilities at a given moment.

The assemblage of decision criterions, C, is the assemblage of parameters which defines the process and in respect of which we have in view the comparison of alternatives.

The decision criterions are characterized by a number of levels according to the different alternatives and/or status of unbiased conditions. All these levels can make up decision goals that are possible to achieve, from the point of view of that particular criterion.

Decision models with an assemblage of criterions, called also multicriterial decision models, could be multi-attribute decision models, which are presented below, or multi-objective decision models, which are subject of linear programming [5].

Multi-attribute decision models subsist in the determination of the optimum variant from a finite variant assemblage $V=\{V_1, V_2, ..., V_m\}$, variants that are compared one with another in respect with numerical or non-numerical criterions belonging to a finite assemblage $C=\{C_1, C_2, ..., C_n\}$. Each criterion has a minimum or maximum goal.

For some multi-attribute decision problems, in which the matrix of consequences contains heterogeneous data, numerical or non-numerical, the homogenization of these data is done by the normalization procedure [6], which transforms the matrix of consequences in a matrix $R=(r_{ij})_{i=1,m;\ j=1,n}\}$ with elements in the interval [0,1].

In almost all multi-attribute decision problems there is information regarding the importance of each criterion. This is generally expressed by the vector $P=\{p_1, p_2, ..., p_n\}$ and indicates the level of importance given by the decision-maker to each criterion.

$$r_{ij} = \begin{cases} \dfrac{a_{ij}}{\max\limits_{1\le i\le m} a_{ij}}, & for \max criterions \\ \dfrac{\min\limits_{1\le i\le m} a_{ij}}{a_{ij}}, & for \min criterions \end{cases} \qquad (1)$$

Every multi-attribute decision problem could be expressed by a matrix A, called the matrix of consequences (Table 1), with elements a_{ij} indicating the evaluation (consequence) of variant i, i=1, 2, ..., m (V_i), by criterion j, j=1, 2, ..., n, (C_j).

Table 1. The matrix of consequences

C_i \ V_i	C_1	...	C_n
V_1	a_{11}	...	a_{1n}
...	...	...	...
V_m	a_{m1}	...	a_{mn}
P	p_1	...	p_n

Source: [5]

Multi-attribute decision problems could be classified into three categories [7]: direct methods, indirect methods and methods which use a certain distance for the construction of hierarchies.

Direct methods build a function defined on the assemblage of variants with real values and selects variants for which the function takes the greatest value.

Indirect methods determine a hierarchy on the assemblage of variants based on an algorithm.

Methods which use the distance select a variant which is the closest to the ideal solution.

In our case study we will use a direct method (the method of simple additive weight) and a method which uses the distance (TOPSIS), methods that are presented below:

The method of simple additive weight

The method consists in defining the function f : V→R, given by:

$$f(V_i) = \frac{\sum_{j=1}^{n} p_j r_{ij}}{\sum_{j=1}^{n} p_j}, i = \overline{1,m} \qquad (2)$$

where r_{ij} are the elements of the normalized matrix R, calculated with relation (1) and p_j are the elements of the importance rates vector P, given as last row in Table 1. The optimum variant will be that for which f(V_i) takes the maximum value.

The TOPSIS method

The TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution) is based on the idea that the optimum variant must have the minimum distance to the ideal solution.

The steps of the TOPSIS method are:

- Step 1. We build the normalized matrix R=(r_{ij}), i=1,...,m, j=1,...,n;
- Step 2. We build the weighted normalized matrix V=(v_{ij}), i=1,...,m, j=1,...,n, where

$$v_{ij} = \frac{p_j r_{ij}}{\sum_{j=1}^{n} p_j} \qquad (3)$$

- Step 3. We calculate the ideal solution A and the ideal negative solution B, defined as:

$$A= (a_1, a_2, ..., a_n),$$
$$B= (b_1, b_2, ..., b_n) \qquad (4)$$

where:

$$a_j = \begin{cases} \max\limits_{1\le i\le m} v_{ij}, \ if\ the\ criterion\ C_j\ is\ \max \\ \min\limits_{1\le i\le m} v_{ij}, \ if\ the\ criterion\ C_j\ is\ \min \end{cases} \qquad (5)$$

$$b_j = \begin{cases} \max\limits_{1\le i\le m} v_{ij}, \ if\ the\ criterion\ C_j\ is\ \min \\ \min\limits_{1\le i\le m} v_{ij}, \ if\ the\ criterion\ C_j\ is\ \max \end{cases} \qquad (6)$$

- Step 4. We calculate the distance between the solutions:

$$S_i = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - aj\right)^2}, \ i = 1, 2, \dots, m; \qquad (7)$$

$$T_i = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - b_j\right)^2}, \ i = 1, 2, ..., m; \qquad (8)$$

- Step 5. We calculate the relative nearness from the ideal solution:

$$Ci = \frac{T_i}{S_i + T_i} \qquad (9)$$

- Step 6. We make a classification on the assemblage V according to the descending values of Ci obtained in step 5.

3 Multicriterial Methods. Case Study

The case study in this paper wants to mark out the role of mathematical methods implemented in an expert system for the stage of preparation in an international negotiation process.

For that purpose we tried to highlight the usefulness of multicriterial methods in three business negotiation processes of a same Romanian negotiation team with three other international negotiation teams in order to purchase an industrial equipment.

In order to achieve the chased goal we made a case study at S.C. Chimcomplex S.A., using the two multicriterial methods presented in paragraph 2 (the method of simple additive weight and the TOPSIS method) for selecting, in the stage of prenegotiation, the best offer and for organizing the negotiation processes thereafter. Chimcomplex will have to decide between three offers of three foreign companies, taking into account eight selection criterions:

- C_1 : the account of the good that has to be purchased (million Euro);
- C_2 : requested advance money (%);
- C_3 : time period allowed for the payments (years);
- C_4 : payment staggering (month);
- C_5 : rate of interest (%);
- C_6 : time of delivery of the equipment (month);
- C_7 :guarantee period (years);
- C_8 : offer validity (month).

The following three offers of three foreign companies will be approached further as potential variants of the Romanian company Chimcomplex S.A:

- the offer of Vichem Company, from France – variant 1 (V_1);
- the offer of Michelis Company, from Germany – variant 2 (V_2);
- the offer of Itochu Corporation, from Japan – variant 3 (V_3)

The Romanian company Chimcomplex S.A. confers to each invoked criterion a specific rate of importance on a scale from 1 to 10 (rate 10 for the most important criterion and 1 for the lowest importance criterion). So the importance rates are: For C_1 : 10; for C_2 : 9; for C_3 : 8; for C_4 : 6; for C_5 : 6; for C_6 : 5; for C_7 : 4; for C_8 : 3.

In following table are presented the offers of the three companies according to the criterions invoked by Chimcomplex S.A and the importance rates given by the Romanian negotiation team (Table 2).

Table 2. The characteristics of the variants according to the criterions and the importance rates for each of the criterions

	C_1 Mil.Euro	C_2 %	C_3 years	C_4 Month	C_5 %	C_6 month	C_7 years	C_8 Month
V_1	5	10	7	6	7,5	1	1	2
V_2	4,75	11	6	12	7	2	2	1
V_3	5,25	9	5	5	6,5	1,5	1,5	1,5
P	10	9	8	6	6	5	4	3

For doing all calculations more quickly, we used the expert system generator Corvid, and put all entrance data into an input files, containing the characteristics of each variant in respect to each criterion and the importance rates of the eight criterions.

Further we will apply, using Corvid variables, the two mathematical methods described in paragraph 2 (the method of simple additive weight and the TOPSIS method) for deriving the best variant between the three offers for the Romanian company. Finally we will compare the results obtained with the two methods.

Considering that the matrix in Figure 1 contains heterogeneous data, there will be necessary a normalization procedure. This occurs by minimization for C_1, C_2, C_5, C_6 and by maximization for C_3, C_4, C_7, C_8. For the maximum and minimum criterions we used relation (1) and calculated the elements of the normalized matrix $R=(r_{ij})$ with $i=\overline{1,3}$; $j=\overline{1,8}$, like in Figure1.

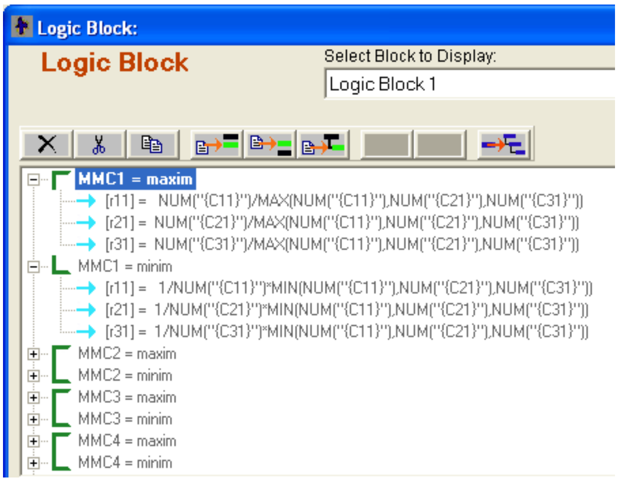

Fig. 1. Determination of the normalized matrix in a Corvid logic block.

Next, for applying the ***simple additive weight method***, we calculate the values for the functions $f(V_i)$ using relation (2), like in Figure 2.

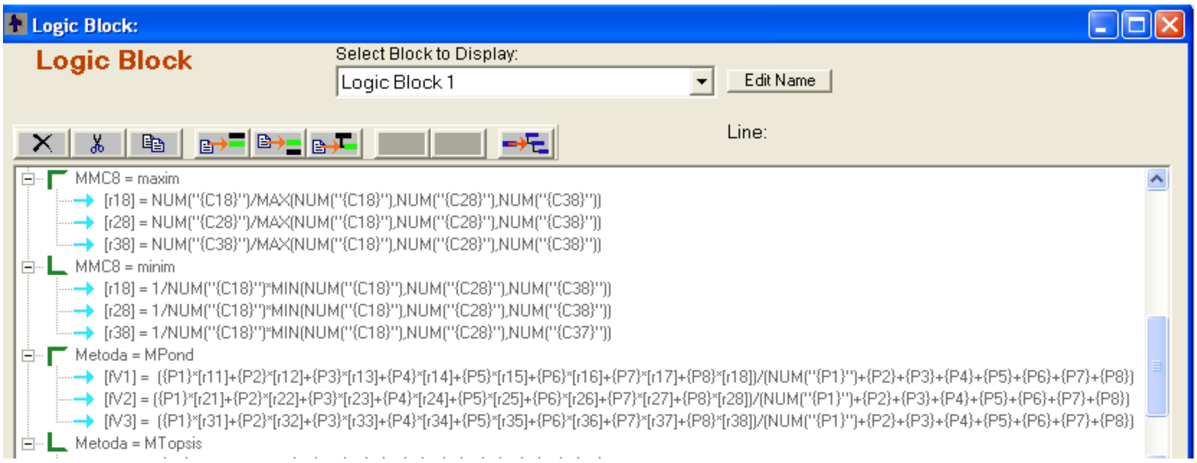

Fig. 2. Determination of fV1, fV2 and fV3 for classifying the variants with the simple additive weight method

We obtain following results:

$\rightarrow fV_1 = 0{,}85882$
$\rightarrow fV_2 = 0{,}85867$
$\rightarrow fV_3 = 0{,}80088$

According to this method, the order of the variants is:
$V_1 \rightarrow V_2 \rightarrow V_3$, like in figure 3.
It is easy to observe that the values for the variants 1 and 2 are very close (they differ only at the forth decimal), so we can conclude that this method is unconvincing, and it can't help much in selecting the optimal variant.
Next we apply the ***TOPSIS method***.
Here we also need the normalized matrix $R=(r_{ij})$, $i=1,\ldots,m$, $j=1,\ldots,n$ and then we build the weighted normalized matrix $V=(v_{ij})$, $i=1,\ldots,m$, $j=1,\ldots,n$, using relation (3). Thereafter we calculate the ideal solution A and the ideal negative solution B, like in Figure 4.

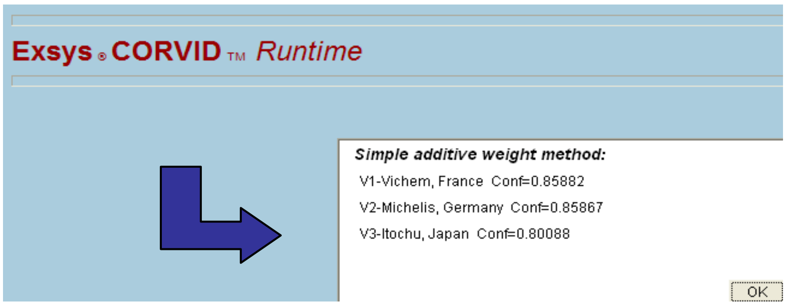

Fig. 3: Results calculated by the Expert System with the simple additive weight method

After calculating the distance between the solution and the ideal solution with relation (7) and the distance between the solution and the ideal negative solution with relation (8), we determine the relative nearness from the ideal solution Ci, with $i=\overline{1,3}$ using relation (9) and we obtain:

$\rightarrow C_1 = 0.407$

$\rightarrow C_2 = 0.706$

$\rightarrow C_3 = 0.323$.

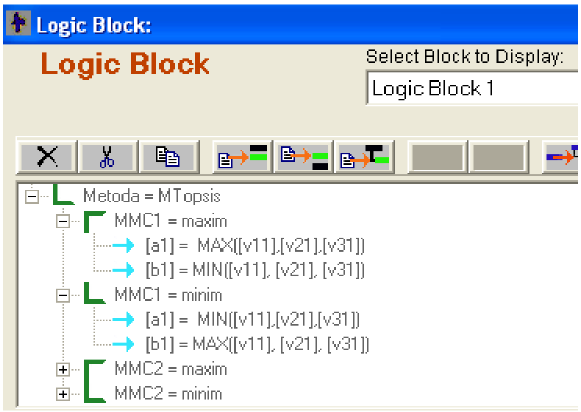

Fig. 4. Part of the logic block calculating the ideal solution A and the ideal negative solution B

We make a classification on the assemblage V according to the descending values of C_i , and we obtain following order of variants: $V_2 \rightarrow V_1 \rightarrow V_3$, like in figure 5, a little different from the simple additive weight method, where the order was $V_1 \rightarrow V_2 \rightarrow V_3$., but the function value for V_1 was very close to that of V_2.

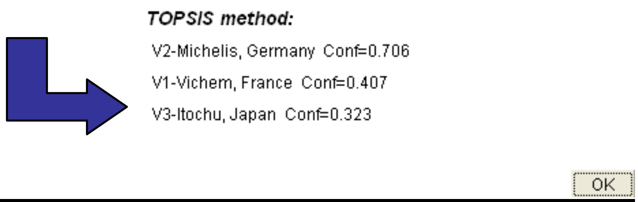

Fig. 5. Results calculated by the Expert System with the TOPSIS method

4 Conclusions

For some business negotiations the stakes are much too high to be lost. That's why it is desired to select and to apply the most efficient strategy which could grant the winning of the negotiation. In this respect it is useful to call on mathematical methods for identifying the best variants for overcoming a deadlock by anticipating the movements of the partner.

Sometimes there are situations in which the negotiators must choose from a multitude of variants, must make a hierarchy and select the optimal offer. In such cases the most appropriate tool are multicriterial methods.

The purpose of this paper was to relieve the usefulness and importance of multicriterial

methods in an expert system used for the preparation stage of an international business negotiation process. Of course, there are also important cultural accents of the negotiators of different countries, which could also be introduced into the expert system program [8].
While applying two different methods. the method of additive weight and the TOPSIS method, the results were nearly the same, so the decision-maker could select the most profitable offer among many in the prenegotiation stage, in order to organize the negotiation processes accordingly. The expert system used the input data as a text file and calculated, using Corvid variables, the functions that indicate the proposed order of variants, accordingly to each of the two different methods.

Acknowledgments
This work was supported by ANCS-CNMP, project number PNII–91-049/2007

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