DECISIONS IN NEGOTIATIONS USING EXPERT SYSTEMS AND MATHEMATICAL METHODS

CORNELIA MUNTEAN, ILEANA HAUER, ANTOANETA BUTUZA *

ABSTRACT: *The goal of this paper is at the very instant to highlight the role and the importance of mathematical multi-attribute methods, implemented in expert systems, in the preparing of international negotiation processes. We used Exsys Corvid as an expert system generator to implement a prototype of an expert system with three mathematical methods: the method of simple additive weight, the diameter method and the TOPSIS method. The applying of these methods in the exposed case study permitted the preparation and deployment of the negotiation in such a manner that the goals expected by the negotiator should be fulfilled.*

KEY WORDS: *business decision making; negotiation preparing process; expert systems; mathematical methods; simple additive weight method; diameter method; TOPSIS method.*

JEL CLASSIFICATION: *C02; M19.*

1. INTRODUCTION

Some negotiations have far too high stakes to be lost. That's the reason why it is so important to choose and apply the most effective strategy, which should warrant the winning of the negotiation. In this respect one can invoke mathematical models for obtaining a better vision upon the negotiation process and also for identifying the most efficient variant to overcome a deadlock through anticipation of the partner's movements (Vasiliu, 2003).

A basic tool of mathematical models is the game theory (Neamtu & Opris, 2008), which could be very useful in identifying settlements of negotiations due to the

* *Assist. Prof., Ph.D., West University of Timisoara, Romania, cornelia.muntean@feaa.uvt.ro*
Assist. Prof., Ph.D., West University of Timisoara, Romania, ileana.hauer@feaa.uvt.ro
Lecturer, Ph.D., West University of Timisoara, Romania, antoaneta.butuza@feaa.uvt.ro

fact that it allows designing a model of analyzing the situations where the decisions of a negotiator could affect the benefits of the other/s.

But there are also situations when the negotiators must select from a multitude of variants, make a hierarchy and choose the optimal one. In these situations the most suitable mathematical tools are multi-criteria methods.

The purpose of this paper is just to relieve the usefulness and importance of multicriterial methods. This is highlighted by a case study on a Romanian company by programming a prototype of an expert system used for the preparation stage of an international business negotiation process. While applying three different mathematical methods, the results were nearly the same, so the decision-maker could select the most profitable offer among many in the pre-negotiation stage, in order to organize the negotiation processes accordingly.

2. MATHEMATICAL MULTI-CRITERIA METHODS USED IN PREPARING THE NEGOTIATION PROCESS

2.1. Multi-criteria decisions

Multi-criteria decision problems are those which arise when the selection of an alternative or of an action plan go through, given that the decider must consider withal several goals. These goals are frequently of different nature and could be in contradiction with each other.

A decision is the compendium of some activities with open eyes of selecting the direction of an action and engagement in that, which usually involves the allocation of some resources. This decision appears following some information and knowledge and belongs to a person or to a group of people who has the necessary authority and who answer for the efficient using of the resources in some given situations. The most important characteristic of a decision is the possibility of choosing between alternatives.

Most situations in real life presume the existence of some multi-criteria decisions. The decision itself consists in a selection, “a good choice” from a number of available solutions. Every solution is an alternative. In context of multi-criteria decisions, the selection goes through the evaluation of each possible variant. The criterions will be compulsory quantifiable, even if comes through only by a nominal scale (of type yes/no), and their result must be calculated for each alternative, individually. The results of these criterions are the minimal necessary information for comparing de available variants and, accordingly, they facilitate the selection of one of these, of the most suitable one.

The complexity of problems which require to make a decision taking into account several criterions which are to be accomplished, derives from the fact that, whether the state of certainty or the state of uncertainty is involved, the results of a decisional variant must include more sometimes incomparable attributes, and to measure these for comparison is difficult. Practically it is impossible to achieve the maximum levels desired separately, for each of the criterions, at the same time.

The decisions must be the result of a thinking process, preceded by an information and a thoroughgoing analysis of all the problem presumptions, of the influence elements, considering the concrete conditions in which each enterprise conducts its activities.

For choosing the best decision there must exist the following elements:

- an economic objective or a well established goal which could be quantified;
- a great amount of information which should reflect as well as possible the economical phenomena and processes that actually occur, with influences on adopting a decision;
- a well done investigation and data processing machine, to allow the achievement of a reasonable selection process.

Commonly, the results of a criterion in the case of a decision process appears in a table (called decisional matrix or decisional table), delimited by several columns and lines. The lines of a table represent the alternatives and the columns the criterions. A value that resides at the intersection of a line and a column in a table represents the result of a criterion – a calculated or evaluated characteristic of an alternative regarding a criterion. The decisional matrix is the central structure for MCDM (Multiple criteria decision making), because it contains the necessary data for comparing the alternatives of the decision.

The process of decision-making is defined by following elements (adapted from Gheorghiță, 2001): 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 lot 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 impartial conditions.

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

2.2. Mathematical multi-attribute decision models

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]:

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

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.

Every multi-attribute decision problem could be expressed by a matrix A, called the matrix of consequences, 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). The data could be stored in **table 1,** where $P=\{p_1, p_2, ..., p_n\}$ indicates the level of importance given by the decision-maker to each criterion.

Table 1. The matrix of consequences

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

Source: Andrasiu, et. al., 1986

Multi-attribute decision problems could be classified into three categories: direct methods, indirect methods and methods which use a certain distance for the construction of hierarchies (Neamțu, 2008)

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

2.3. The method of simple additive weight

The method consists in defining the function $f : V \rightarrow R$, given by:

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

The optimum variant will be that for which $f(V_i)$ takes the maximum value. The method uses the normalized matrix.

2.4. The diameter method

The diameter method has the advantage that in the hierarchy of variants it takes into consideration the homogeneity or heterogeneity of the data in respect to the different criteria. A variant will be homogeneous if it takes close values for all criteria and will be heterogeneous if it takes very big values for some criteria and very small values for others, with the presumption that all criteria are alike (minimum or maximum).

We can build the matrix:

$$L = \begin{pmatrix} & C_1 & C_2 & \dots & C_n \\ 1 & L_{11} & L_{12} & \dots & L_{1n} \\ \dots & \dots & \dots & \dots & \dots \\ m & L_{m1} & L_{m2} & \dots & L_{mn} \end{pmatrix} \quad (3)$$

in which the column j, j=1,n contains the variants corresponding to the ordering of the elements of the assemblage $\{a_{1j}, a_{2j}, \dots, a_{mj}\}$ in ascending (descending) order if the criterion C_j is a maximum (minimum).

If $a_{i1j}, a_{i2j}, \dots, a_{imj}$, i=1,m, j=1,n is the ordering of the assemblage $\{a_{1j}, a_{2j}, \dots, a_{mj}\}$, j=1,n, then $L_{1j}=V_{i1}, L_{2j}=V_{i2}, \dots, L_{mj}=V_{im}$.

For i=1..m and j=1..n are defined the following functions:

- The estimate function:

$$A:V \to R,\ A(V_i) = \sum_{j=1}^{n} \left[m - loc(V_i, C_j)\right] p_j / \sum_{j=1}^{n} p_j \quad (4)$$

- The diameter function:

$$d:V \to N\ \ d(V_i) = \max_j [loc(V_i, C_j)] - \min_j [loc(V_i, C_j)] \quad (5)$$

where

$$loc : V \times C \to \{1, 2, \dots, m\}\ \ loc(V_i,C_i)=k,\ k = \overline{1,m} \Leftrightarrow V_i = L_{kj} \quad (6)$$

- The aggregation function:

$$Aggr : V \to R, \qquad Aggr(V_i) = \frac{A(V_i) + m - d(Vi)}{2} \quad (7)$$

The hierarchy of variants is given by the descending values of the aggregation function (Aggr).

2.5. 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

$$v_{ij} = \frac{p_j r_{ij}}{\sum_{j=1}^{n} p_j} \tag{8}$$

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

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

where:

$$a_j = \begin{cases} \max\limits_{1\le i\le m} v_{ij}, \textit{ if the criterion } C_j \textit{ is } \max \\ \min\limits_{1\le i\le m} v_{ij}, \textit{ if the criterion } C_j \textit{ is } \min \end{cases} \tag{9}$$

$$b_j = \begin{cases} \max\limits_{1\le i\le m} v_{ij}, \textit{ if the criterion } C_j \textit{ is } \min \\ \min\limits_{1\le i\le m} v_{ij}, \textit{ if the criterion } C_j \textit{ is } \max \end{cases} \tag{10}$$

Step 4. We calculate the distance between the solutions:

$$S_i = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - aj\right)^2}\ , i = 1, 2, \dots ,m; \tag{11}$$

$$T_i = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - b_j\right)^2}\ , i = 1, 2, ... , m; \tag{12}$$

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

$$Ci = \frac{T_i}{S_i + T_i} \tag{13}$$

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

3. 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. An Expert System (Andone I., Mockler R., 2001) 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.

Exsys Corvid (www.exsys.com) provides an object-oriented structure that makes it easy to build expert 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 (Muntean, Butuza, Dobrican 2002). The result is a very flexible and powerful development environment that can easily be learned. We used Corvid for implementing our application.

We considered the Romanian textile company IASITEX S.A. and used the three multi-attribute methods presented in paragraph 2 (the method of simple additive weight, the diameter method, the TOPSIS method) for selecting, in the stage of pre-negotiation, of the best offer and for organizing the negotiation processes thereafter. After an initial stage of commercial tender, Iasitex S.A. will have to decide between two offers of two foreign companies, taking into account six 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 : guarantee period (years);
- C_6 : offer validity (month).

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

- the offer of VAKONA GmbH, from Germany – variant 1 (V_1);
- the offer of Hashima Co., Ltd., from Japan – variant 2 (V_2)

In following table are presented the offers of the two companies according to the criteria invoked by Iasitex S.A.

Table 2. The characteristics of the variants according to the criteria

	C_1 Mil.Euro	C_2 %	C_3 years	C_4 month	C_5 years	C_6 month
V_1	10	10	3	12	2	1
V_2	8	15	2	6	3	2

The Romanian company Iasitex S.A. confers to each invoked criterion a specific rate of importance on a scale from 0 to 1: For C_1 :0.3; for C_2 : 0.2; for C_3 : 0.1; for C_4 : 0.1; for C_5 :0.2; for C_6 : 0.1.

For doing all calculations more quickly, we used the expert system generator Corvid (Muntean & Muntean 2010, pp.199-205), and put all entrance data into two input files, the first one used as a metablock, containing the characteristics of each variant in respect to each criterion (figure 1), and the other as a simple data file, containing the importance rates of the six criteria (figure 2).

	A	B	C	D	E	F	G
1	V	C1	C2	C3	C4	C5	C6
2	V1	10	10	3	12	2	1
3	V2	8	15	2	6	3	2

Figure 1. The content of the input text file, used further as a metablock

	A	B	C	D	E	F
1	P1	P2	P3	P4	P5	P6
2	0.3	0.2	0.1	0.1	0.2	0.1

Figure 2. The content of the simple input file, containing the importance rates

Further we will apply, using Corvid variables, the three mathematical methods described in paragraph 2 (the method of simple additive weight, the diameter method and the TOPSIS method) for deriving the best variant between the two remaining offers for the Romanian company. Finally we will compare the results obtained with each of the three methods. Considering that the matrix in figure 1 contains heterogeneous data, there will be necessary a normalization procedure and we will obtain a normalized matrix $R=(r_{ij})$ with $i=\overline{1,2}$ $j=\overline{1,6}$.

For the Romanian company every criterion must be optimized, and this occurs by minimization for C_1, C_2, and by maximization for C_3, C_4, C_5, C_6. For the maximum and minimum criteria we used relation (1) and calculated de elements of the normalized matrix R. The obtained normalized matrix is:

$$R=\begin{pmatrix} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 \\ 0.8 & 1 & 1 & 1 & 0.67 & 0.5 \\ 1 & 0.67 & 0.67 & 0.5 & 1 & 1 \end{pmatrix} \tag{14}$$

4. RESULTS, DISCUSSIONS AND CONCLUSIONS

Applying the first method, the ***simple additive weight method***, we obtain following values for the functions $f(V_i)$ using relation (2): $f(V_1) = 0,82$ and $f(V_2) = 0,85$. According to this method, the order of the variants is: $V_2 \rightarrow V_1$ (figure 3).

Next we apply the ***diameter method***. We calculate with Corvid variables the aggregation functions $Aggr(V_i)$, with $i=\overline{1,3}$ using (7). We obtain: $Aggr(V_1) = 0,7$ and

$Aggr(V_2) =$ 0,8. So, applying this method the variants order is the same: $V_2 \rightarrow V_1$. (figure 4)

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

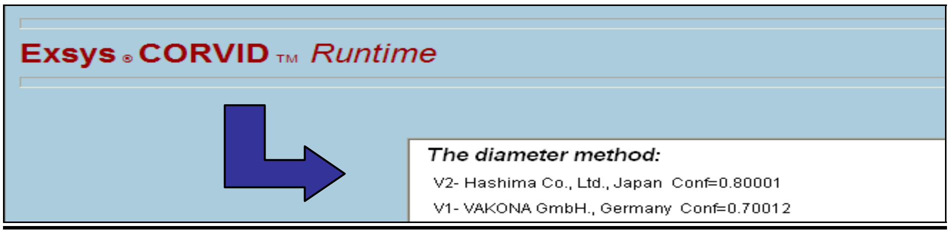

Figure 4. Results calculated by the Expert System with the diameter method

Finally, we apply the ***TOPSIS method***. After calculating the relative nearness from the ideal solution Ci, with $i=\overline{1,3}$ using relation (13), we obtain:

$\rightarrow C_1 = 0{,}44$

$\rightarrow C_2 = 0{,}56$

We make a classification on the assemblage V according to the descending values of C_i, and we obtain following order of variants: $V_2 \rightarrow V_1$ (fig.5), the same as with the other two methods.

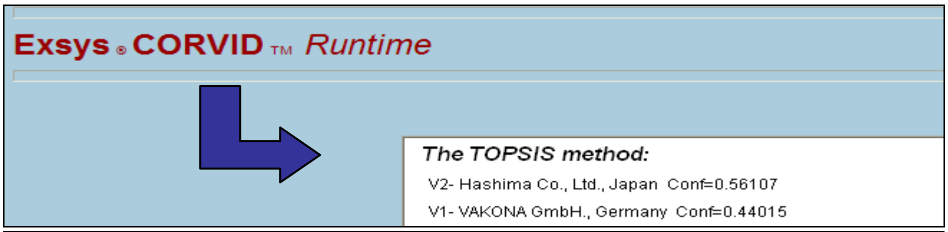

Figure 5. Results calculated by the Expert System with the TOPSIS method

As a conclusion, this paper presented a short overview of three mathematical multi-criteria methods that were implemented in an expert system for deciding in a negotiation problem. The expert system used in a quick and easy way the input data as text files and calculated, using confidence variables, the functions that indicate the proposed order of variants, accordingly to each of the three different methods.

In negotiation, as well as in most other circumstances, people must make a decision from among a lot 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. Mathematical models appeared and were used in the process of decision making in business, particularly in negotiation, quite from the necessity to sustain the logical reasoning in negotiation and to manage a great number of factors simultaneously. Furthermore, applying these mathematical models permits the approach of some new qualitative problems, so that it's not surprising at all the fact that in negotiation there are used more and more mathematical tools, methods and techniques.

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