

Multicriteria Decision Support System *MultiChoice**

Vassil Vassilev, Krassimira Genova, Filip Andonov, Boris Staykov

Institute of Information Technologies, 1113 Sofia

Abstract: *A multicriteria decision support system called MultiChoice is presented in the paper. It is intended to support decision makers in solving various multicriteria analysis problems. Different well-known methods and software systems are considered. The structure, the functions and the user interface of the system are described.*

Keywords: *multicriteria decision support system, multicriteria analysis.*

1. Introduction

The decision making problems are non-formalized or weak formalized problems, the solution of which requires the participation of the so-called decision maker (DM) (Sprague and Garson, [19]). The solutions obtained are to a great extent subjective and depend on DM's preferences. The decision making problems are divided into three basic classes: decision making problems in the presence of many criteria (multicriteria problems); decision making problems under risk conditions and decision making problems under uncertainty conditions.

Different tasks in planning, management, analysis and control in economy, transport, industrial production, education, ecology and other spheres may be reduced to multicriteria decision making problems. Multicriteria decision making (Steuere et al., [20]) is evaluated as the fifth in priority (among fifteen in number) investigation directions of "Operational research" scientific branch. Multicriteria decision making problems may be divided in two separate classes according to their formal statement. A finite number of explicitly set constraints in the form of functions define an infinite number of feasible alternatives in the first class. These problems are called continuous multicriteria decision making problems or multicriteria optimization problems. A finite number of alternatives are explicitly set in a tabular form in the second class of problems. These problems are called discrete multicriteria decision making problems or multicriteria analysis (MA) problems.

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In MA problems (V i n c k e, [23]), several criteria are simultaneously optimized in a feasible set of alternatives. In the general case there does not exist one alternative, which optimizes all the criteria. There is a subset of non-dominated alternatives, which are a solution of the multicriteria problem from a mathematical viewpoint. Only one non-dominated alternative is used in practice, however. In order to select this non-dominated alternative, additional information supplied by the DM, is necessary. The information given by the DM reflects his/her preferences with respect to the quality of the alternative sought.

The MA methods use two types of preference models or DM preference structures, [23] to compare two non-dominated alternatives. The first type of DM preference model does not allow the existence of incomparable alternatives and the preference information obtained by the DM is sufficient to determine whether one of the alternatives is to be preferred or the two alternatives are equivalent to the DM. This type of DM preference model is used in the multi-attribute utility theory methods (K e e n e y and R a i f f a [7], F a r q u h a r [4]) and in the weighting methods [S a a t y [17], S a a t y [18], M a r e s c h a l [10], V o n W i n t e r f e l d t and E d w a r s [24]. The second type of DM preference model allows the existence of incomparable alternatives and the preference information obtained by the DM may be insufficient to determine whether one of the alternatives is to be preferred or whether the two alternatives are equivalent for the DM. This type of DM preference model is used by the outranking methods (B r a n s and M a r e s c h a l [1]), R o y [16], V a n s n i c k [22]. In the outranking methods the DM provides inter- and intra-criteria information, whereas in most of the weighting methods he/she has to provide pair-wise information about the criteria. To solve multicriteria analysis problems with a large number of alternatives and a small number of criteria, the “optimizationally motivated” interactive methods have been suggested (K o r h o n e n [8], S u n and S t e u e r [21], N a r u l a e t a l. [13], L o t f i e t a l. [9] and J a s z k i e w i c z and S l o w i n s k i [6]. The first three methods use the first type of DM preference model and the DM has to define the desired or acceptable values of the criteria at each iteration. The last two methods use the second DM preference model and the DM has to provide at every iteration not only the desired values of the criteria but also inter- and intra-criteria information.

The software systems supporting the solution of multicriteria analysis problems (MDSS) can be divided in two classes – software systems of general purpose and problem-oriented software systems. The general-purpose MDSS systems (Expert Choice (S a a t y [18]), Web-HIPRE (M u s t a j o k i and H a m a l a i n e n [12]), HIVIEW (P e t e r s o n [15]), ELECTRE III-IV (R o y [16]), PROMCALC and GAIA (B r a n s and M a r e s c h a l [2]), Decision Lab (B r a n s and M a r e s c h a l [3]), VIMDA (K o r h o n e n [8]) are used to assist the solution of different multicriteria analysis problems by different DMs. One method or several methods of one and the same group, above described are usually realized in them to solve multicriteria analysis problems. The problem-oriented MDSS systems (Agland Decision Tool (P a r s o n s [14])) are included in other information-control systems and serve to aid the solution of one or several types of specific multicriteria analysis problems. Some simplified user’s interface modules are usually implemented in them. That is why methods of different groups are included in some of these systems to solve MA problems.

The present paper describes MDSS system MultiChoice, in which one well-known representative of the three groups of methods is realized – AHP method (S a a t y [17]), PROMETHEE II method (B r a n s and M a r e s c h a l [2]) and CBIM method

(Narula et al. [13]). The interface modules built in the system enable the successful realization of different types of procedures for deriving information by the DM and also for the entry of different types of criteria – quantitative, qualitative and ranking criteria.

2. Multicriteria analysis problem description

MA problem may be described by a decision matrix A ($n \times k$), which can be defined in two ways (rf. to Tables 1 and 2), where: a_i denotes an alternative with an index i , $i=1, \dots, n$; $k_j(\cdot)$ or $f_j(\cdot)$ denotes a criterion with an index j , $j=1, \dots, k$.

Table 1

k_j a_i	$k_1(\cdot)$	$k_2(\cdot)$	...	$k_j(\cdot)$	...	$k_k(\cdot)$
a_1	a_{11}	a_{12}	...	a_{1j}	...	a_{1k}
a_2	a_{21}	a_{22}	...	a_{2j}	...	a_{2k}
...
a_i	a_{i1}	a_{i2}	...	a_{ij}	...	a_{ik}
..
a_n	a_{n1}	a_{n2}	...	a_{nj}	...	a_{nk}

Table 2

f_k a_i	$f_1(\cdot)$	$f_2(\cdot)$	...	$f_j(\cdot)$	...	$f_k(\cdot)$
a_1	$f_1(a_1)$	$f_2(a_1)$	...	$f_j(a_1)$	...	$f_k(a_1)$
a_2	$f_1(a_2)$	$f_2(a_2)$	...	$f_j(a_2)$	...	$f_k(a_2)$
...
a_i	$f_1(a_i)$	$f_2(a_i)$	...	$f_k(a_i)$	...	$f_k(a_i)$
..
a_n	$f_1(a_n)$	$f_2(a_n)$	...	$f_j(a_n)$	...	$f_k(a_n)$

The set of alternatives indices is denoted by I , and the indices set of the criteria – by J .

The evaluation of i -th alternative with respect to all the criteria is given by a row vector $(a_{i1}, a_{i2}, \dots, a_{ik})$ or $(f_1(a_i), \dots, f_k(a_i))$. The evaluation of all the alternatives with respect to j -th criterion is given by a column vector $(a_{1j}, a_{2j}, \dots, a_{nj})^T$ or $(f_1(a_j), \dots, f_n(a_j))^T$.

MA problems can be classified into three main groups, (Hwang and Yoon [5]). In the first group of problems, i.e., the discrete multicriteria choice problems, the objective is to search for the most preferred non-dominated alternative. In the second group of problems, the ranking problems, the non-dominated alternatives are ranked in a descending order, i.e., starting from the best toward the worst alternative. In the third group of problems, the sorting problems, the set of alternatives is partitioned into a separate group.

The feasible alternative with an index i' is called a non-dominated alternative if there does not exist another alternative with an index i , satisfying the condition:

$$a_{ij} \geq a_{i'j}, j = 1, \dots, k$$

and at least for one index $j=s$ the condition below given is satisfied:

$$a_{is} > a_{i's}$$

The non-dominated alternative is called the most preferred alternative, if it reflects best DM's preferences.

From a practical point of view, the solution of MA problem is finding the most preferred alternative, which satisfies the DM to the highest degree.

3. Structure of *MultiChoice* system

MultiChoice system consists of the following three main modules: a control program, solving modules and interface modules.

The control program is an integrated software environment for creating, processing and saving of files associated with *MultiChoice* system (ending with **.mch** extension) and also for linking and executing different types of software modules. The basic functional possibilities of the control program can be divided in three groups. The first group includes possibilities to use the standard for MS Windows applications menus and system functions – “File”, “Options”, “View”, “Window”, “Help” and also toolbars for quick access to the most often used functions. The second group of control program facilities includes the control of the interaction between the modules realizing the creating, modification and saving of **.mch** files associated with *MultiChoice* system, which contain input data and data relating to the process and the results from solving MA problems; interactive solution of MA problems by CBIM method; localization and identification of errors occurring during the system operation. The third group of the control program options consists in possibilities for visualization of important information concerning the DM and the system operation as a whole. The control program is developed on the principle of Multy Document Interface (MDI) in MS Visual Basic software environment. In its main form it has a menu containing the standard for MS Windows applications drop-down menus for control of files, options of the system, windows control and Help. The main functions of the system are realized with the help of several daughter forms and context menus.

The solving models realize three methods of MA – one representative from the three groups of methods – AHP method, PROMETHEE II method and CBIM method. AHP method (S a t y [18]) is one of the most widely spread weighting methods. Pair-wise criteria comparison is used in this method to set DM's preferences. On this basis a pair-wise comparison matrix is constructed. The estimates of the weights can be found normalizing the eigen vectors corresponding to the largest eigen value of this matrix. PROMETHEE II method (B r a n s and M a r e s c h a l [2]) is one of the most often used outranking methods. In this method the intensity of the preference of one alternative over another alternative regarding each criterion is measured in terms of the so-called preference function. Six types of preference functions are used in the method. The method provides a complete preordering of the alternatives through a pair-wise dominance comparison of net positive and net negative outranking flows. CBIM method (N a r u l a et al. [13]) is a representative of the interactive methods

and is appropriate for solving MA problems with a large number of alternatives and a small number of criteria. The DM can provide desired or acceptable levels, directions and intervals of changes in the values of the criteria at every iteration. On the basis of this information, the method proposed enables the use of discrete optimization scalarizing problems, with the help of which the DM has the possibility for a more systematic and successful screening of the alternatives set.

The interface modules ensure the interaction between MADSS MultiChoice system, the DM and MS Windows. This interaction includes the entry and correction of the data for the multicriteria problems, the entry of information, specific for every method, information about DM's preferences, visualization of the current results and of the final result, print out, reading and storing of files, multi-language support, etc. The editing module enables the entry, alteration and storing of the criteria – quantitative, qualitative and ranking. The interface preference modules aid the DM in the entry of criteria pair-wise comparison information, inter- and intra-criteria information and information about the desired or acceptable levels, directions and intervals of change in the values of the criteria. The current and final results, and the parameters for the separate methods selected by the DM are presented digitally and graphically with the help of visual interface modules. The input/output interface modules enable the reading and storing in files, the printing of the current and final results obtained and also of the information, given by the DM. The rest of the interface modules realize dynamic Help, multi-language maintenance, etc.

4. Operation with *MultiChoice* system

MultiChoice system is installed under MS Windows. It can be added to the Programs group and/or with a Desktop icon, from where it is started. The system registers the **.mch** extension and associates it. Thus at double clicking on a valid **.mch** file, the system will be started and this file will be loaded. There is a menu in the main window with the standard for MS Windows drop-down menus and a toolbar. With their help the operation of a new file is started or an existing **.mch** file is loaded and the operation may continue with the information stored in it.

For better understanding of these problems, we shall discuss one real example, described in (M l a d i n e o e t a l. [11]). The aim of the problem is to choose a building site for an European electric power station. The criteria to be evaluated can be grouped in four classes: economic criteria (costs, manpower, etc.); technical criteria (power, etc.); ecological criteria (influence on the environment); other criteria (safety, etc). Six probable locations for building the electric power station in Europe and six criteria for their evaluation are considered. The possible alternatives are as follows: Italy, Belgium, Germany, Great Britain, Portugal, France. The criteria for evaluation are the following: Manpower for running the plant (number); Power (Megawatts); Construction costs ($\times 10^6$ \$ US); Ecology (number of villages to evacuate); Safety level. The criterion "Manpower for running the plant" reflects the number of persons, who would be necessary to maintain the station. It has to be minimized. The criterion "Power" reflects the quantity of the energy produced. This criterion must be maximized. The criterion "Construction costs" reflects the cost price of the project in \$US, hence it has to be minimized. The criterion "Annual maintenance costs" must be minimized as well. In order to find an appropriate site, satisfying the requirements for electric power

station building, it is supposed that some inhabited places will be necessarily evacuated. The criterion “Ecology (number of evacuated villages)” must be minimized. The criterion “Safety level” is maximized. This real problem of multicriteria choice is presented in Table 3.

Table 3

Criteria Alternatives	Manpower for running the plant (number)	Power (Megawatts)	Construction cost ($\times 10^6$ US\$)	Annual maintenance cost ($\times 10^6$ US\$)	Villages to evacuate (number)	Safety level
Italy	80	90	600	54	8	Satisfactory
Belgium	65	58	200	57	1	Very low
Germany	83	60	400	72	4	High
Great Britain	40	80	1000	75	7	Exclusively high
Portugal	52	72	600	20	3	Very high
France	94	96	700	36	5	High

In this example the criteria Manpower running the plant, Power, Construction costs, Annual maintenance costs and Ecology have quantitative measures – a number, Megawatts and $\times 10^6$ US\$, while the criterion Safety level has a qualitative measure.

The entry of the input data for every MA problem is done with the help of three types of windows. The entry of the objective of the problems solved, the names of the alternatives and the names and the types of the criteria is completed in the first window. A separate window is used to enter the data for each criterion. Fig. 1 shows the window with data about the quantitative criterion Construction costs.

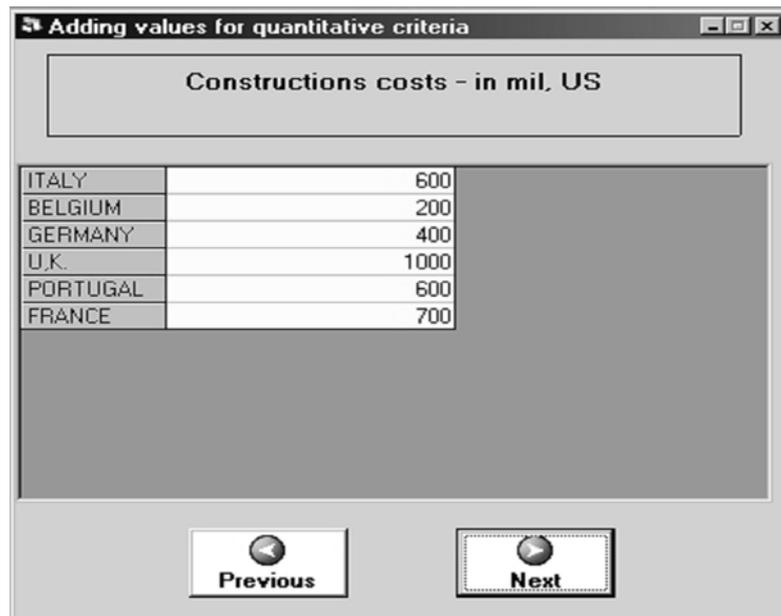


Fig. 1

Fig. 2 shows a window containing data about the qualitative criterion Safety level. The qualitative evaluation of every alternative is selected in a respective visualized bipolar scale. After the data for each criterion are input, a window is automatically opened for entry of data for the next criterion. The data for a given example can be entered in pieces, criteria and alternatives can be added and deleted, quantitative and qualitative data corrected, and so on.

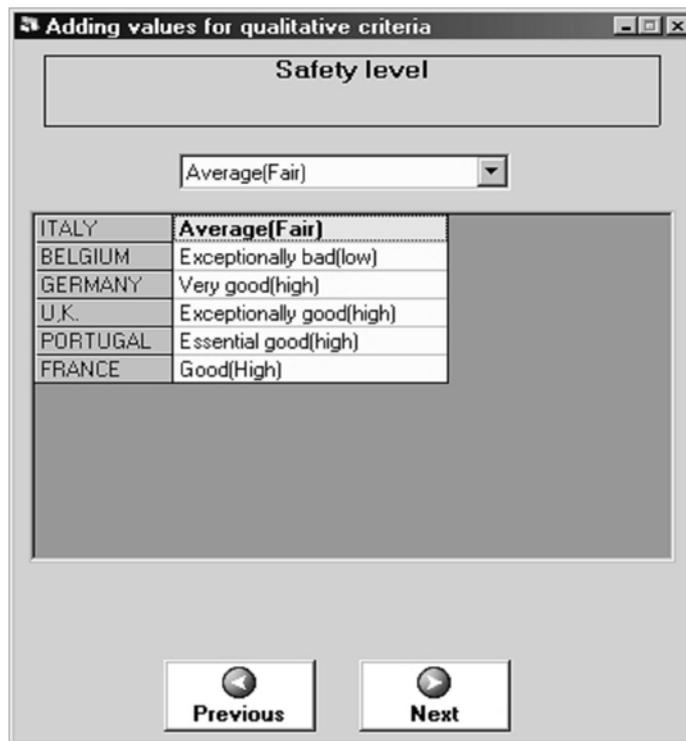


Fig. 2

When solving every MA problem entered, depending on the method chosen, different windows are used. The type of the windows is defined by the type of the preference information of the DM, which is used in the respective method. In solving MA problem by AHP method, a window is used for pair-wise criteria comparison information, a window with the computed criteria weights and a window with the final ranking of the alternatives. The pair-wise criteria comparison is implemented with the help of a "slider", as shown in Fig. 3. In MA problems solution, returning backward and alteration of the information about the pair-wise criteria comparison is possible, which leads to new results. In this way the program version of AHP method possesses certain aspect of interactivity.

When solving MA problems by PROMETHEE II method a window, consisting of two parts, is used. The left part shows a decision matrix, and the right one – inter- and intra-criteria information about the criterion selected. Each criterion is chosen in the left part of the window, and the information about it is entered in the right part of the window. Fig. 4 shows this window with data for the criterion "Annual maintenance costs". In solving MA problems, returning back is admissible and also alteration of the

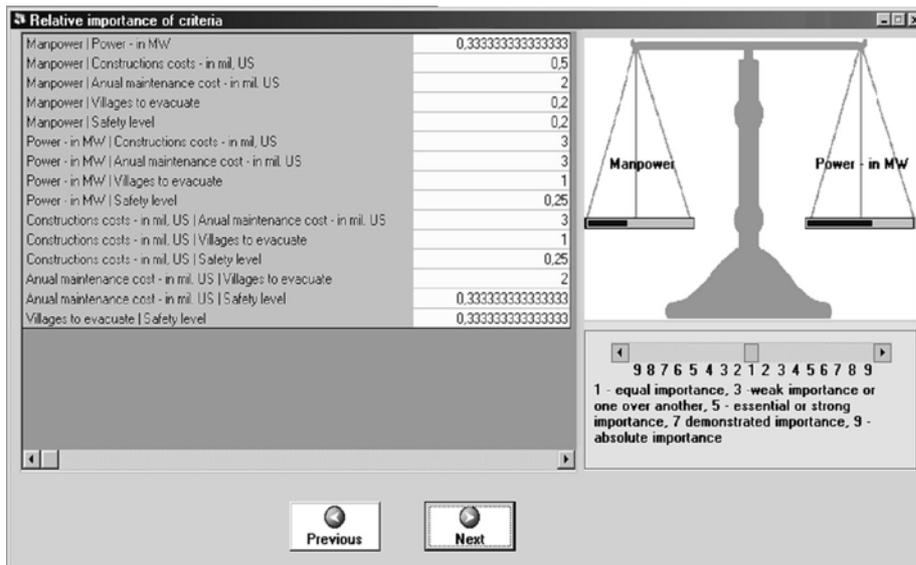


Fig. 3

inter- and intra-criteria information, which brings new results. In this way the program version of PROMETHEE II method also gets a certain feature of interactivity.

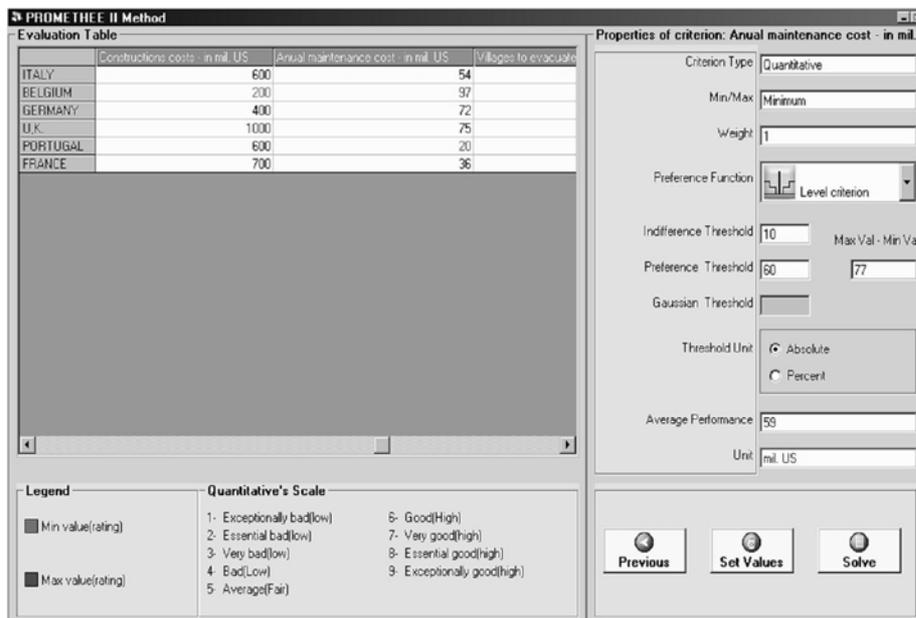


Fig. 4

Two windows are used in solving MA problems by CBIM method. The desired or acceptable levels, directions and intervals for change of the criteria values in relation to the currently preferred alternative are set with the help of the first window. The second window shows the currently preferred alternative, generated by the method. In case the DM wishes to find a new, better than this alternative, he passes to the first window and

gives his/her new local preferences. Fig. 5 shows the new local preferences for the currently preferred alternative.

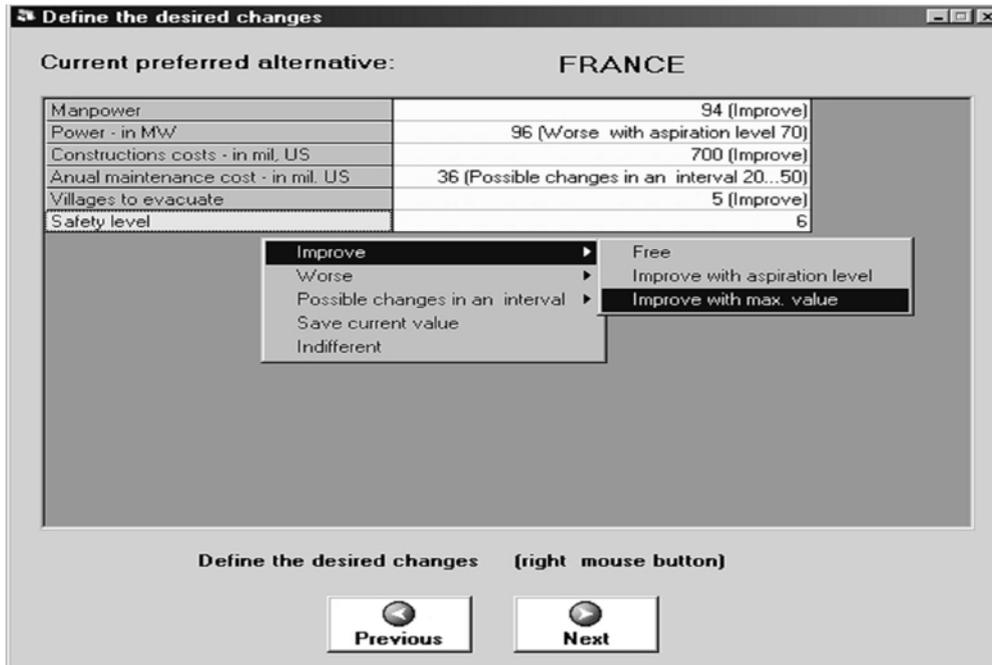


Fig. 5

The final results for the three methods are shown in one and the same type, called "Alternatives order" window. Fig. 6 shows the final result, obtained after solving the

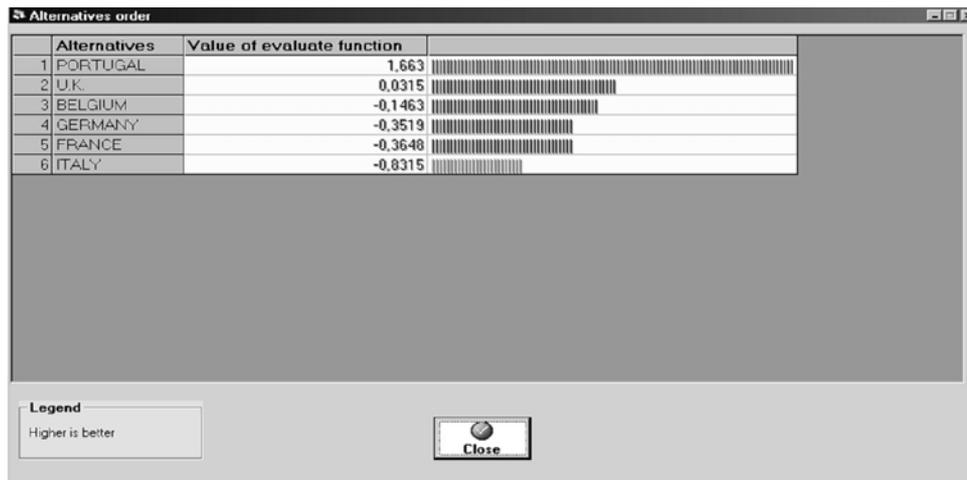


Fig. 6

problem for selection of a building site for an European electric power station by PROMETHEE II method. After the solution of every MA problem, printing and documentation of the problem data can be done and also of DM's preference information, of the current and final results.

6. Conclusion

The multicriteria decision support system *MultiChoice* is designed to support the DM in modeling and solving problems of multicriteria ranking and multicriteria choice. The integrating of three different types of methods expands DM's possibilities to set his/her preferences about the quality of the most preferred solution. The user-friendly interface of *MultiChoice* system facilitates the operation of DMs of different qualification with respect to the analysis methods and the software tools used. *MultiChoice* system can be used for the purposes of education and for solving experimental and research problems as well.

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MultiChoice – многокритериална система за подпомагане вземането на решения

Васил Василев, Красимира Генова, Филип Андонов, Борис Стайков

Институт по информационни технологии, 1113 София

(Резюме)

В статията е представена многокритериална система *MultiChoice* за подпомагане вземането на решения. Тя е предназначена за подпомагане на лицата, вземащи решения при решаване на различни задачи на многокритериалния анализ. Разгледани са известни методи и софтуерни системи на многокритериалния анализ. Описани са структурата, функциите и потребителският интерфейс на системата *MultiChoice*.