

MULTICRITERIA DECISION SUPPORT SYSTEM MULTIOPTIMA

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Keywords: Multicriteria Decision Making, Multicriteria Decision Support System, Multicriteria Analysis, Multicriteria Optimization, Interactive Method, Scalarizing Problem.

Abstract: The paper presents a multicriteria decision support system, called *MultiOptima*. It consists of two independent parts - the MKA-2 system and the MKO-2 system. The *MultiOptima* system is designed to support the decision maker in modelling and solving different problems of multicriteria analysis and linear and linear integer problems of multicriteria optimization. The system implements four methods for multicriteria analysis, as well as an innovative generalized interactive method for multicriteria optimization with variable scalarization and parameterization, which can apply twelve scalarizing problems and is applicable for different ways of defining preferences by the decision maker. The class of the solved problems, the system structure, the implemented methods and the graphical user interface of the MKA-2 and MKO-2 systems are discussed in the paper. The *MultiOptima* system can be used both for education and for solving of real-life problems.

1 INTRODUCTION

Multicriteria decision making problems are weak formalized problems, the solution of which requires the participation of the so-called decision maker (DM). The solutions obtained are to a great extent subjective and depend on DM's preferences. Different problems of planning, control, analysis and monitoring in economy, transport, industrial production, education, ecology and other spheres may be reduced to multicriteria decision making problems. The multicriteria decision making problems can be divided into two subclasses. In the first class (the so-called problems of multicriteria optimization) a finite number of explicitly set constraints in the form of functions defines an infinite number of feasible alternatives. In the second class (the so-called problems of multicriteria analysis) a finite number of alternatives is explicitly given in a tabular form. In multicriteria analysis and multicriteria optimization problems several criteria

are simultaneously optimized in the feasible set of alternatives. In the general case, there does not exist one alternative, which optimizes all the criteria. There is a set of alternatives characterized by the following property: each improvement in the value of one criterion leads to deterioration in the value of at least one other criterion. This set of alternatives is called a set of the non-dominated or Pareto optimal alternatives (solutions). Each alternative in this set could be a solution of the multicriteria problem. In order to select one alternative, it is necessary to have additional information set by the DM.

Many real-life problems in management may be formulated as problems of multicriteria analysis (choice, ranking or sorting) of resources, strategies, projects, offers, policies, credits, products, innovations, designs, costs, profits, portfolios, etc. (Paschetta and Tsoukiàs, 2000). Many real-life problems in planning, control and industrial production may be formulated as problems of multicriteria optimization (Rajesh et al., 2001).

Different methods have been developed to solve multicriteria analysis problems. A great number of the methods, developed up to now, can be grouped in three separate classes. The first class of methods (Dyer, 2004) includes the multiattribute utility (value) theory methods (e.g., Value Tradeoff Method, UTA method, MACBETH method, Direct Weighting Method, and AHP weighting methods). These methods are based on the assumption that there does not exist limited comparability among the alternatives. The second class of methods are called outranking methods (e.g., ELECTRE methods (Figueira et al., 2005), and PROMETHEE methods (Brans and Mareschal, 2005)) and they are based on the assumption that there exists limited comparability among the alternatives. In these methods one (or several) outranking relation(s) are first built to aggregate DM's global preferences, after which this outranking relation is used to assist the DM in solving the multiple criteria decision analysis problem. The interactive methods (e.g., RNIM method (Narula et al., 2003)) belong to the methods of the third group. They are "optimizationally motivated" and are oriented to solve multicriteria analysis problems with a large number of alternatives and a small number of criteria.

There are two main approaches in solving multicriteria optimization problems: the scalarizing approach (Miettinen, 2003) and the approximation approach (Ehrgott and Wiecek, 2005). Interactive methods are the major representatives of the scalarizing approach. Multicriteria optimization problem is treated in these methods as a decision making problem and the emphasis is put on the real participation of the DM in the process of its solution. The interactive methods are the most developed and widespread due to their basic advantages – a small part of the Pareto optimal solutions must be generated and evaluated by the DM; in the process of solving the multicriteria problem, the DM is able to learn with respect to the problem; the DM feels more confident in his/her preferences concerning the final solution of the problem being solved.

The interactive methods of the reference point (direction) and the classification-based interactive methods (Vassileva, 2005) are the most widely spread interactive methods when solving multicriteria optimization problems. Though the interactive methods of the reference point are still dominating, the classification-based interactive methods (e.g., GENWS-IM method (Vassileva, 2005)) enable the better solution of some important problems in the dialogue with the DM, relating to his/her preferences defining, and also concerning the

time of waiting for new non-dominated solutions that are evaluated and selected.

A variety of methods to approximate the set of Pareto optimal solutions of different types have been proposed (Ehrgott and Wiecek, 2005). Their main representatives are the multicriteria genetic (evolutionary) methods (Deb, 2001). The multicriteria optimization problem is treated in these methods rather as a vector optimization problem, than as a decision making problem.

The developed software systems supporting the solution of multicriteria analysis and multicriteria optimization problems may be classified in two groups: software systems with general purpose and problem-oriented software systems. The general-purpose software systems aid the solution of different multicriteria analysis or multicriteria optimization problems by different decision makers. The problem-oriented software systems serve to support the solution of one or several types of specific multicriteria analysis or multicriteria optimization problems and very often are included in other information-control systems.

The following general-purpose software systems (Weistroffer et al., 2005) aid the solution of different multicriteria analysis problems – VIMDA, Expert Choice, PROMCALC, GAIA, ELECTRE III-IV, MACBETH, VIP, Decision Lab, Web-HIPRE, MultiChoice and KnowCube. One problem-oriented multicriteria analysis system is the Agland Decision System for agricultural property (Parsons, 2002). Some well-known general-purpose multicriteria optimization software systems (Weistroffer et al., 2005) are the following: VIG, DIDAS, DINAS, MOLP-16, LBS, SOMMIX, MOIP, WWW-NIMBUS, MOLIP, NLPJOB and MOMILP. The ADELAIS system for portfolio selection (Zopounidis et al., 1998) is an attractive problem-oriented multicriteria optimization system. In the class of multicriteria optimization systems must also be included software systems, which implement different multicriteria evolutionary methods (e.g., MOSES system (Coello and Christiansen, 1999)).

The paper describes some basic elements of the multicriteria decision support system *MultiOptima*, which consist of two separate parts - the MKA-2 system and MKO-2 system. The system is designed to support the DM in solving different multicriteria analysis and multicriteria optimization problems. The class of the solved problems, the system structure, the operation with the interface modules for entering the information about DM's local preferences and for visualization of the current and

final solutions, as well as the help information, given in a digital and graphical form, are discussed.

The rest of the paper is organized as follows. The second section describes the basic features of the first part of the *MultiOptima* system - MKA-2 system. The main characteristics of the second part of the *MultiOptima* system – MKO-2 system, are presented in brief in the third section. Finally, the conclusions are given in the last section.

2 MKA-2 SYSTEM

The MKA-2 system, which is the first part of the *MultiOptima* system, operates under MS Windows operating system and it is designed to support DM in solving different multicriteria analysis problems. The MKA-2 system consists of internal-system modules, four solving modules and interface modules. It is realised in MS Windows environment, including the standard user interface elements. The internal-system modules contain all global definitions of variables, functions and procedures of general purpose. The object possibilities of Visual Basic are utilized in the MKA-2 system, creating the following classes with respect to internal-system structures: a class for messages, which encapsulates the output of error messages, dynamic context help information and logging events in the debug window, localization and identification of errors occurring during the system operation; a class matrix with some specific procedures, necessary for the AHP method; a class for storing the information specific for the criteria in the ELECTRE III and PROMETHEE II methods and a class for storing elements of the RNIM interactive method history. MKA-2 handles files with “*.mka” extension. Standard operations for creating, editing, loading and saving of files are implemented. The MKA-2 files contain input data and data related to the process and the results from solving multicriteria analysis problems.

The solving modules realize four methods - AHP method, ELECTRE III method, PROMETHEE II method and RNIM method, and procedures for transformation of qualitative, ranking and weighting criteria into quantitative criteria. The AHP method 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 by normalizing the eigenvector corresponding to the largest eigenvalue of this matrix. The ELECTRE III is one of the most

often used outranking methods. It is based on an outranking relation, characterized by the definition of an outranking degree $S(a, b)$ associated with each ordered pair (a, b) of alternatives, representing the more or less great outranking credibility of a over b . There are two matrix needed to be evaluated - the concordance matrix (requires indifference and preference thresholds) and the discordance matrix (requires additional threshold, called veto threshold, which allows the outranking relation to be rejected). In order the degree of credibility of outranking to be obtained, the two measures from concordance and discordance matrix have to be combined. The obtained credibility matrix is essential for generating two distillation orders that show whether one alternative outranks the other or such an alternative is incomparable to the other. In order the final ranking to be obtained, the two orders are combined. The PROMETHEE II method is the other most often used outranking method. The intensity of the preference of one alternative over another regarding each criterion is measured in terms of the so-called preference function. Six types of preference functions are used, formed on the basis of indifference and preference thresholds. The method provides a complete ranking of the alternatives through a pair-wise dominance comparison of net positive and net negative outranking flows. The RNIM method is a representative of the interactive methods and it is appropriate for solving multicriteria analysis 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 any iteration. On the basis of this information, the method 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 the MKA-2 system, DM and operating system. This interaction includes the entry of the data for the multicriteria analysis problem; entry of specific information for every method; entry of information about DM's preferences; visualization of the current and final results; graphical presentation of the solutions; printing out, reading and storing of files; multi-language support, dynamic help, etc. The editing module enables entering, alteration and storing of quantitative, qualitative, ranking and weighting criteria. The interface preference modules aid 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, as well as the printing of the information, given by DM. The solution process can be interrupted at any stage and activated from the place of its interruption at any time. The MKA-2 system has comparatively rich printing functions – the entire process of decision making is documented and could be printed out.

Figure 1 shows the initial information entered for the real-life problem, concerning the choice of a building site for new European electric power station (Mladineo et al., 1987).

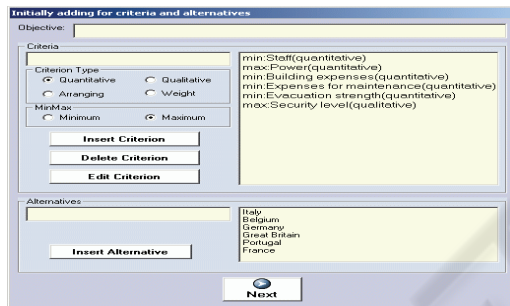


Figure 1: Initial information.

Figure 2 presents a window with information about DM's preferences in operation with the PROMETHEE II method.

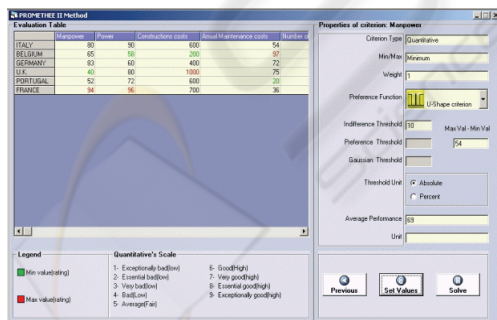


Figure 2: DM's preferences in PROMETHEE II method.

Figure 3 shows the final result, obtained for six countries when solving the ranking problem with the ELECTRE III method.

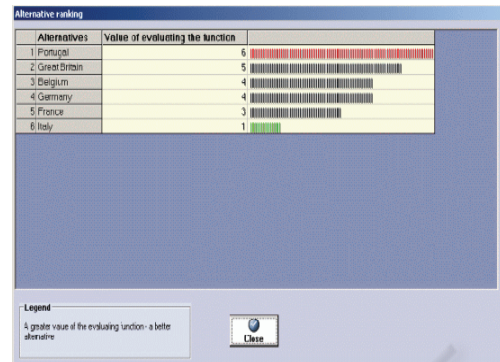


Figure 3: The final result by ELECTRE III method.

3 MKO-2 SYSTEM

The MKO-2 system, which is the second part of the *MultiOptima* software system, operates also under MS Windows operating system and it is designed to aid the DM in the solution of linear and linear integer problems for multicriteria optimization. The system implements the innovative generalized interactive method for multicriteria optimization GENWS-IM (Vassileva, 2005) with variable scalarization and parameterization, which can apply twelve scalarizing problems and is applicable for different ways of defining DM's preferences.

The MKO-2 software system consists of three main groups of modules – a control program, optimization modules and interface modules. The control program is integrated software environment for creation, processing and storing of files associated with MKO-2 system, as well as for linking and executing of different types of software modules. The basic functional possibilities of the control program may be separated in three groups. The first group includes the possibilities to use the applications, menus and system functions being standard for MS Windows ("File", "Edit", "View", "Window", "Help") in the environment of MKO-2 system. The second group of functional possibilities encloses the control of the interactions between the modules realizing the creation, modification and storing of files associated with MKO-2 system, which contain input data and data connected with the process of interactive solution of linear and linear integer multicriteria optimization problems, as well as the localization and identification of the errors occurring during the process of operation with MKO-2 system. The third group of functional possibilities of the control program includes the possibilities for visualization of essential

information about the DM and information of the system operation as a whole.

The optimization modules realize the generalized interactive algorithm GENWS-IM, two simplex algorithms solving continuous single-criterion problems (Vanderbei, 1996), and an algorithm of “branches and bounds” type solving linear integer single-criterion problems (Wolsey, 1998).

The interface modules provide the dialogue between DM and the system during the entry and correction of the input data of the multicriteria problems being solved, during the interactive process of these problems solution, as well as for dynamic numerical and graphical visualization of the main parameters of the solving process. With the help of an editing module the formulations of the criteria and constraints are input, altered and stored, and also the type and limits of the variables alteration. Another interface module serves to supply two types of graphic presentation of the information about the values of the criteria at the different steps of the solving process, as well as the possibilities for their comparison.

One of the main functions of MKO-2 system is to enable the extension of DM’s possibilities to set his/her preferences with the help of criteria weights, ϵ – constraints, desired and acceptable levels of alteration in the criteria values, desired and acceptable directions of change of the criteria values, desired and acceptable levels, directions and intervals of alteration of the criteria values. Twelve scalarizing problems are generated in the MKO-2 system in order to realize these possibilities. Depending on DM’s preferences, these scalarizing problems are automatically generated by the generalized scalarizing problem GENWS by changing its structure and parameters.

The MKO-2 system presents to the DM different windows intended for entry and correction of the criteria and constraints of the multicriteria problem being solved, for setting his/her preferences, for choosing the solving method and for visualizing the current and the final solutions. Figure 4, Figure 5 and Figure 6 show three of these windows. The window in Figure 4 is designed to identify the type of the DM’s preferences. The DM may select among five types of preferences and let assume that he/she has selected to set the preferences in the form of desired and acceptable levels, directions and intervals of alteration in the criteria values (operating with DALDI scalarizing problem). The screen in Figure 5 shows the setting of a new aspiration level for the value of the third criterion.

Choosing “Graphic” command enables the visualization of two types of graphical information about the solving process. For this, a window with two types of graphics is opened (Figure 6).

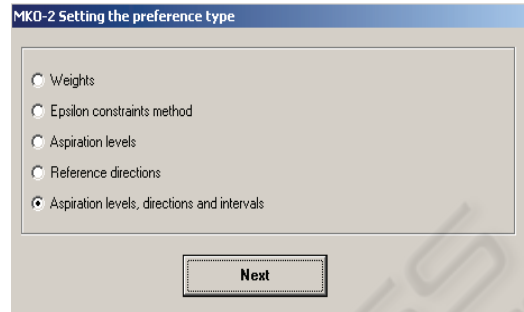


Figure 4: Type of the DM’s Preferences.

With the help of the upper bar-graphic, it can be made a visual comparison of the solutions found at two iterations, selected in the fields for step selection.

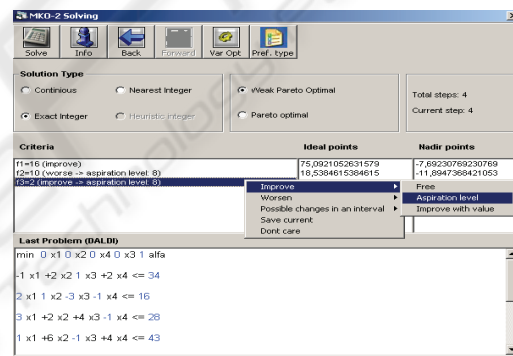


Figure 5: Setting of an aspiration level.

The lower graphic in Figure 6, can trace visually the alteration of the values of the separate criteria at different steps of the interactive process of searching for a better solution. The initial and final steps of the iteration interval can be defined, in which the values of all the criteria are traced.



Figure 6: Two types of graphic.

4 CONCLUSIONS

The *MultiOptima* system is designed to support DM in solving multicriteria analysis and multicriteria optimization problems. The first part of the system – the MKA-2 system, is designed to support the DM in modelling and solving problems of multicriteria ranking and multicriteria choice. The second part of the system – the MKO-2 system, is designed to model and solve linear and linear integer problems of multicriteria optimization. The user-friendly interface of the MKA-2 and MKO-2 systems facilitates the operation of decision makers with different qualification level relating to the multicriteria analysis and multicriteria optimization methods and software tools. The MKA-2 and MKO-2 systems can be used both for education and for real-life problems solving. The *MultiOptima* system is a local multicriteria decision support system and operates in two languages – Bulgarian and English. A number of Bulgarian universities use the system for education purposes, as well as for experimental and research problems solving. A number of governmental and private organizations and companies use the system to solve real-life decision making problems. The future development of the *MultiOptima* system will be realized in two directions. The first one is connected with the implementing and adding of new methods for multicriteria analysis and multicriteria optimization. The second direction refers to developing of a web-based version, enabling distant decision making.

ACKNOWLEDGEMENTS

This paper is partially supported by the National Science Fund of Bulgarian Ministry of Education and Science under the contract № I-1401\ 2004, and by the Institute of Information Technologies - BAS under the project № 010080 “Optimization methods and systems” and the project № 010079 “Methods and Tools for Processing Semantic Information”.

REFERENCES

- Brans, J., Mareschal, B., 2005. PROMETHEE Methods. In *Multiple Criteria Decision Analysis: State of the Art Surveys* (J. Figueira, S. Greco and M. Ehrgott, Eds). Springer Verlag, London, 163-196.
- Coello C., Christiansen, A., 1999. MOSES: A Multiobjective Optimization Tool for Engineering Design. In *Engineering Optimization*, 31, 3, 337-368.
- Deb, K., 2001. *Multi-Objective Optimization Using Evolutionary Algorithms*, Wiley-Interscience Series in Systems and Optimization, John Wiley & Sons. Chichester.
- Dyer, J., 2005. MAUT-Multiattribute Utility Theory. In *Multiple Criteria Decision Analysis: State of the Art Surveys* (J. Figueira, S. Greco and M. Ehrgott, Eds). Springer Verlag, London, 265-297.
- Ehrgott, M., Wiecek, M., 2005. Multiobjective Programming. In *Multiple Criteria Decision Analysis: State of the Art Surveys* (J. Figueira, S. Greco and M. Ehrgott, Eds). Springer Verlag, London, 990-1018.
- Figueira, J., Mousseau, V., Roy, B., 2005. ELECTRE Methods. In *Multiple Criteria Decision Analysis: State of the Art Surveys* (J. Figueira, S. Greco and M. Ehrgott, Eds). Springer Verlag, London, 133-162.
- Mladineo, N., Margeta, J., Brans, J. P., Mareshal, B., 1987. Multicriteria Ranking of Alternative Locations for Small Scale Hydroplants. In *European Journal of Operational Research*, 31, 215-222.
- Miettinen K., 2003. Interactive Nonlinear Multiobjective Procedures. In *Multiple Criteria Optimization: State of The Art Annotated Bibliographic Surveys* (M. Ehrgott et al., Eds.). Springer, New York, 227-276.
- Narula S., Vassilev, V., Genova, K., Vassileva, M., 2003. A Partition-Based Interactive Method to Solve Discrete Multicriteria Choice Problems. In *Cybernetics and Information Technologies*, 2, 55-66.
- Parsons, J., 2002. Agland Decision Tool: A Multicriteria Decision Support System for Agricultural Property. In *Integrated Assessment and Decision Support*, 3, 181-187.
- Paschetta, E., Tsoukiàs, A., 2000. A Real World MCDA Application: Evaluating Software. In *Journal of Multiple Criteria Decision Analysis*, 9, 205 – 226.
- Rajesh, J. K., Gupta, S. K., Rangaih, G. P., Ray, A. K., 2001. Multi-Objective Optimization of Industrial Hydrogen Plants. In *Chemical Engineering Science*, 56, 999-1010.
- Vanderbei, R., 1996. *Linear Programming: Foundations and Extensions*, Kluwer Academic Publishers. Boston.
- Vassileva, M., 2005. Generalized Scalarizing Problem of Multicriteria Optimization. In *Comptes Rendus de l'Academie Bulgare des Sciences*, 58, 5, 537-544.
- Vassileva M., Vassilev V., Staykov B., Dochev D., 2007. Generalized Multicriteria Optimization Software System MKO-2. In *Proceedings of the 9th International Conference ICEIS 2007*, (G. Cordoso et al., Eds.). Madeira, Portugal, 283-289.
- Weistroffer, H., Smith, C., Narula, S., 2005. Multiple Criteria Decision Support Software. In *Multiple Criteria Decision Analysis: State of the Art Surveys*, (J. Figueira, S. Greco and M. Ehrgott, Eds). Springer Verlag, London, 990-1018.
- Wolsey, L. A., 1998. *Integer Programming*, Wiley-Interscience.
- Zopounidis, C., Despotis, D. K., Kamaratou, I., 1998. Portfolio Selection Using The ADELAIS Multiobjective Linear Programming System. In *Computational Economics*, 11, 189–204.