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Operative Planning of the Production Program in a Textile Enterprise with the Help of MKO-1 Software System*

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Abstract: *The paper describes an application of MKO-1 software system in the operative planning of the production program of the spinning department in a textile enterprise. Brief analysis of the software systems for multicriteria optimization recently developed is presented. The main features of the general purpose software system MKO-1, which is intended to aid the solution of linear and linear integer problems of multicriteria optimization, are discussed. The criteria, the variables and the constraints groups of the multicriteria optimization problem, to which one basic problem for operative planning of the production program of a spinning department in a textile enterprise is reduced, are described. The last three iterations in the solution process of this multicriteria operative planning problem, with the help of the MKO-1 system, are given.*

Keywords: *multicriteria optimization, operative planning, decision support systems.*

1. Introduction

The software systems, developed to support the solution of multicriteria optimization problems, find various applications (E h r g o t t and W i e c e k [4], A l v e s and C l i m a c o [11], M i e t t i n e n and M a k e l a [11], W i e s t r o f f e r and N a r u l a [23]). These systems could be divided in the following two groups: software systems of general purpose and problem-oriented software systems. The first group of program systems serves to aid the solution of different problems of multicriteria optimization by different Decision Makers (DMs). Usually one method that solves multicriteria problems is realized in them. This is due to the following reasons:

– the different methods are designed to solve different types of multicriteria optimization problems (linear, nonlinear, discrete, continuous, network, etc.);

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– different types of procedures are used in the different methods to derive and transfer information from and to the DM, which causes considerable difficulties in the realization of the modules for user-friendly interface;

– different strategies are used in the different methods to educate the DM in the specifics of the problem being solved, as well as different approaches are implemented to decrease the time of the scalarizing problem solving;

– the developers of the software systems are usually interested in the implementation of their own methods.

Some well-known software systems of general purpose supporting the solution of multicriteria optimization problems are the following systems: NLPJOB (S c h i t t-k o w s k i [12]), MOMILP (A l v e s and C l i m a c o [1]), NIMBUS (M i e t t i-n e n and M a k e l a [11]), SOMMIX (C l i m a c o et al. [2]), LBS (J a s z k i e-w i c z and S l o w i n s k i [5]), MOLP-16 (V a s s i l e v et al. [16]), DIDAS (L e w a n d o w s k i and W i e r z b i c k i [8]), VIG (K o r h o n e n [7]) and NBI package for Matlab (**http://www.owlnet.rice.edu/~indra/-NBIhomepage.html**).

The problem-oriented software systems for multicriteria optimization are most often included in other information-control systems. They serve to solve one or several types of multicriteria optimization problems and a problem-oriented users' interface is usually developed for them. In some of these systems more than one method is realized to solve multicriteria optimization problems. Special attention deserves the following systems: Multicriteria DSS for planning the quality of the river water (L o t o v et al. [10]) and ADELAIS system for portfolio selection (Z o p o u n i d i s et al. [24]).

The software systems, using different multicriteria evolution methods (algorithms), are also included in the group of the multicriteria optimization software systems. In spite of the fact that they do not guarantee the obtaining of exact solutions, they can successfully find approximations of the sets of Pareto optimal solutions in discrete, combinatorial and non-convex nonlinear multicriteria problems. Many program systems of this type have been developed, four of them being the following systems: PAES (K n o w l e s and C o r n e [6]), NSGM system (S r i n i v a s and D e b [13]), MOSES system (C o e l l o and Ch r i s t i a n s e n [3]) and MOEA Toolbox for MATLAB (**http://vlab.ee.nus.edu.sg/~kctan/moea.htm**).

The systems aiding the solution of multicriteria optimization problems are a part of the systems supporting decision making. The quality of such a system depends on the possibilities which it provides to the DM for:

– input data entering and editing;

– description of DM's local and global preferences;

– generation of new Pareto optimal solutions for evaluation;

– visualization of different types of information that is necessary for DM's education concerning the multicriteria problem being solved;

– control of the multicriteria problem solution process, alteration of separate parameters, storing of the current Pareto optimal solutions found, interrupt of the computing process, multifold starting of the computing process from different current Pareto optimal solutions, etc.

The new programming languages and operating environments enable the significant improvement of the control programs and of the interface modules of these systems, so that the possibilities above described are realized. The description of DM's preferences and the generation of new solutions for evaluation depend strongly on the type of the multicriteria and single-criterion optimization methods included. In their larger part, the systems aiding the solution of multicriteria optimization problems, developed up to now, comprise interactive multicriteria methods of the reference point designed to solve continuous problems. This has influenced the design of these systems with respect to the input data entry, the solution of the multicriteria problems and the visualization of the current and final results.

The present paper describes the application of the general purpose software system MKO-1 in solving the operative planning problem of the production program of a spinning department in a textile factory. The problem for operative planning is reduced to a linear integer multicriteria optimization problem.

The rest of the paper is organized as follows. Section 2 gives the basic characteristics of MKO-1 system. The problem for operative planning of the production program of a spinning department is described in Section 3, and Section 4 shows the use of MKO-1 system in the solution process of this applied problem. The conclusions are given in the last section.

2. MKO-1 software system

MKO-1 software system is designed to aid the solution of linear and linear integer problems of multicriteria optimization and it is oriented towards operation under the control of MS Windows operating system. It has been developed (V a s s i l e v et al. [20], V a s s i l e v et al. [18], V a s s i l e v et al. [19]), on the basis of classification-oriented interactive methods and 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-1 system, as well as for linking and execution 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-1 system. The second group of functional possibilities encloses the control of the interactions between the modules realizing:

– creation, modification and storing of files associated with MKO-1 system, which contain input data and data connected with the process of solution of linear and linear integer problems of multicriteria optimization;

– interactive solution of the linear and linear integer multicriteria optimization problems entered;

– localization and identification of the errors occurring during the process of operation with MKO-1 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 control program is built on the principle of the multi-document interface (MDI) in MS Visual Basic software environment. In the main form there is a menu with the standard for MS Windows applications, drop down menus for files control, for edition, for windows control and Help. The basic functions of the system are realized with the help of several daughter forms and context menus.

In order to realize the communication with the optimization modules, the independent "CSolver" class is developed that is of the type of a data processor. The class contains methods for input data setting, obtaining of the output data and realization of the corresponding setups for the type of variables and type of solution which is obtained. The other main class, used in the system, is the "CHistory" class. Its purpose is to create a structure, in which the results obtained at each step are stored – the criteria values, the variables values, the preferences given by the DM and the scalarizing problem generated by the method.

The optimization modules realize two classification-oriented interactive algorithms (V a s s i l e v et a l. [17], V a s s i l e v a et a l. [21]), two simplex methods solving continuous single-criterion problems (Linear Programming Software Survey [9], V a n-d e r b e i [14]), a method of "branches and bounds" type for exact solution of linear integer single-criterion problems (W o l s e y [22]) and a method (V a s s i l e v and G e n o v a [15]) for approximate solution of linear integer single-criterion problems.

The interface modules provide the dialogue between the DM and the system during the entry and correction of the input data of the multicriteria problems solved, during the interactive process of these problems solution and for dynamic numerical and graphical visualization of the main parameters of this process. With the help of an editing module the descriptions 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, as well as the possibilities for their comparison. Dynamic Help is provided, which gives specific information about the denotation and way of use of each one of the fields and radio buttons.

MKO-1 software system is developed at the Institute of Information Technologies of the Bulgarian Academy of Sciences and it is a modern professional system with user-friendly interface, with efficient single-criterion methods and with interactive multicriteria methods providing wide possibilities to the DM in setting his/her preferences. MKO-1 software system is designed both for education and also for solving real-life problems. It is applied for the entry and solution of different problems for operative planning such as the one being described in Section 3 and Section 4, which follow below.

3. Description of the operative planning problem

The operative planning of the production program of a spinning department is a labour consuming, complex and slow process. The large number of various machines with different productivity and different shift schedule obstruct the operative planning. Besides this, a given type of yarn is produced on exactly defined groups of machines. The planning is also hampered by the large number of output products – yarns, wastes and their connection with the input raw materials and the production park available. The constantly entering alterations in the orders for a given type of yarn imply constantly updated planning. Each new plan requires re-setup of the machines, which is an expensive and slow operation. Planning is an important process, in which even the smallest errors cause a profit loss for the department, and the missed opportunities in the new organization structure decrease the production efficiency.

One of the main problems for operative planning is reduced to a linear integer problem of multicriteria optimization with 4 criteria, 109 constraints, 19 continuous and 64 integer variables. The other problems have the same form, but they differ in the number of the continuous and integer variables, as well as in the constraints number. The formal statement of the multicriteria optimization problem will take too long, hence only the values of the variables, of the criteria and of the separate constraint groups will be described.

The variables have the following real values:

X_i – yarns for the needs of the company (t), $i \in I$, $I = \{1, 2, ..., 41\}$;

Y_i – yarns for realization (t), $i \in I$, $I = \{1, 2, ..., 32\}$;

R_i – irretrievable wastes (t), $i \in I$, $I = \{1, 2, ..., 6\}$;

COTTON_k – input raw materials, different types of cotton (t), $k \in K$, $K = \{1, 4, 5\}$;

POLYESTR – input raw material polyester (t).

The meaning of the criteria (the objective functions), are described below:

• VOLUME – the first criterion – maximization of the total volume of industrial production (yarns in the case) in natural expression (t).

The criterion has the following type:

$$\sum_i X_i + \sum_i Y_i \to \max .$$

• PRIME COST – the second criterion – minimization of the cost price of the production in value expression (Lv).

The criterion has the following type:

$$\sum_i a_i X_i + \sum_i b_i Y_i \to \min ,$$

where a_i is the prime cost of each article X_i (Lv/kg); b_i is the prime cost of each article Y_i (Lv/kg).

• PROFIT – the third criterion – maximization of the total profit from all output products in value expression (Lv).

The criterion is of the type:

$$\sum_i m_i X_i + \sum_i n_i Y_i + \sum_i d_i R_i \to \max ,$$

where m_i, n_i are coefficients reflecting the profit from X_i-th and Y_i-th article respectively in (Lv/kg); m_i and n_i are obtained as differences between the price and the cost price of the corresponding article, i.e.

$$m_i = c_i - a_i , \qquad n_i = c_i - b_i ,$$

where: c_i is the price of the article with an index i; d_i is a coefficient reflecting the profit from R_i-th waste in (Lv/kg). This is in fact the price of the i-th waste, since its prime cost is transferred to the cost prices of the yarns.

• RAW MATERIALS – the fourth criterion – minimization of the quantities of raw materials used in production, expressed in natural units (t).The criterion is of the type:

$$\sum_k \text{COTTON}_k + \text{POLIESTR} \to \min .$$

The feasible area of solutions is defined by a system of constraints separated in the following eight groups:

- THE FIRST GROUP OF CONSTRAINTS refers to the fund machine time of limiting production machines and they reflect the requirement that the necessary fund of machine time for the corresponding group of machines does not exceed the available fund for the plan period. Their number is equal to the corresponding limiting groups of machines.
- THE SECOND GROUP OF CONSTRAINTS is connected with the quantity of raw materials necessary for the production of the ready articles. Their number is equal to the number of raw materials (COTTON_k , POLYESTR). They reflect the condition that the total quantity of a given raw material in all types of production, i.e. X_i or Y_i, in which it is contained, must be smaller than or equal to the total quantity of input raw materials COTTON_k or POLYESTR.

- THE THIRD GROUP OF CONSTRAINTS indicates the upper bounds of the different groups of yarns. Their number is equal to the number of groups, in which the production is generally divided. The constraints reflect the condition that the total quantity of output products (the variables X_i and Y_i) in groups must not exceed the technological limit. The technological limit guarantees the free passing of the flows of yarns obtained X_i and Y_i through all groups of machines.

- THE FOURTH GROUP OF CONSTRAINTS represents the lower bounds of the pairs of variables Y_i (yarns for realization). The constraints are implied by the specifics of the output production, since some variables Y_i represent one and the same yarn, but in some cases it is realized rolled in spools, while in others, after additional processing – in bobbins. This means difference in their prime costs and prices, but it is actually one and the same type of yarn, with a common order. This order is the lower bound of the pairs of variables Y_i. The constraints number is equal to the number of variables pairs Y_i.

- THE FIFTH GROUP OF CONSTRAINTS is the lower bounds of groups of yarns Y_i. The constraints are lower bounds of the planned orders referring to the yarns types. The meaning of these constraints is concluded in the obligatory including of these types of yarns in the production program for the year, a part of the plan orders having optional character, dictated by the prognoses of market demands. The number of the constraints is equal to the number of the variables X_i and Y_i.

- THE SIXTH GROUP OF CONSTRAINTS is the lower bounds of the irretrievable wastes R_i. The constraints show the orders having entered the spinning department for realization of the irretrievable wastes R_i of other enterprises. These orders are an obligatory minimum, which must be reflected in the plan. It is necessary that these orders have to be smaller in quantity than the maximal feasible volume of irretrievable wastes R_i. The number of these constraints depends on the number of the different types of irretrievable wastes.

- THE SEVENTH GROUP OF CONSTRAINTS comprises the upper bounds of the quantities of irretrievable wastes in types R_i. The constraints show the requirement that the quantities of wastes R_i must be smaller than or equal to the technologically admissible quantities for every R_i, computed on the basis (%) of wastes normative quantities. The number of constraints is defined by the number of the types of irretrievable wastes R_i.

• THE EIGHTH GROUP OF CONSTRAINTS contains the lower bounds of the quantities of raw materials, necessary for the production of the planned quantities of output production. The constraints define the necessity that the input raw materials (cotton and polyester) must be in quantities, at least satisfying the orders for the required types of yarns X_i and Y_i in the spinning section. The number of the constraints is equal to the number of the input raw materials.

4. Solution of the applied problem with the help of MKO-1 software system

When solving the multicriteria problem for operative planning of the production program of the spinning department, the DM is interested in the improvement of the economic indicators of the production. Hence, his/her attempts are mainly directed towards profit rise and production prime cost decrease at admissible for him/her volumes of the realized production and the input raw materials losses. In what follows, the last three iterations of the computing process will be considered. In them the DM uses almost all possibilities provided by MKO-1 software system for local preferences setting. The solution process of the problem from the following continuous Pareto optimal solution found will be described: VOLUME=5115, PRIME COST=25533.5439, PROFIT=1419.7906 and RAW MATERIALS=6518.4079 (Fig. 1). Let the DM define the following preferences: for the criterion VOLUME– a possible alteration within the range (–50, +50), for the criterion PRIME COST– improvement with a value of

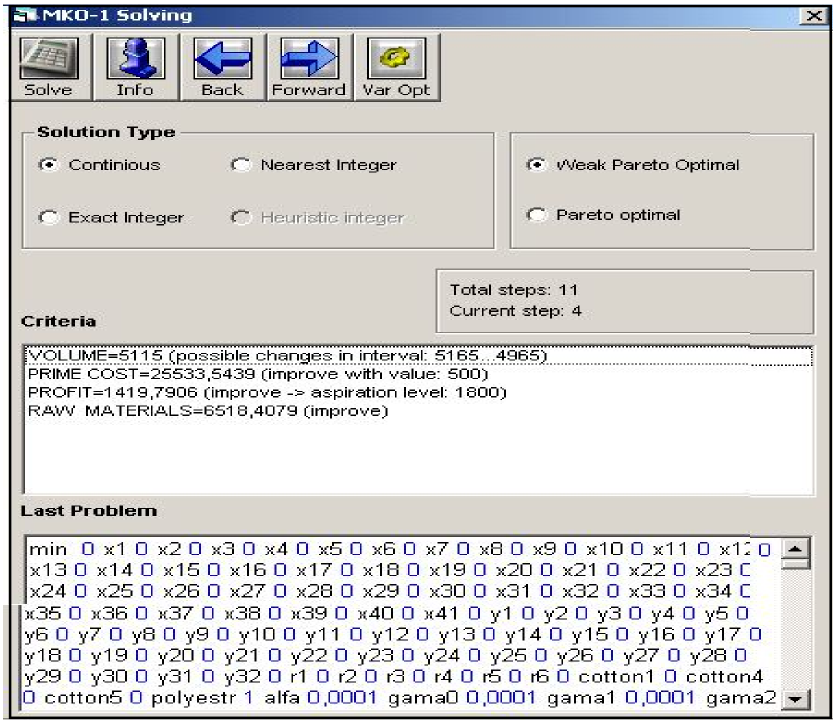

Fig. 1

500, for the criterion PROFIT – improvement up to an aspiration level of 1800, and for the fourth criterion RAW MATRIALS – free improvement. Fig. 1 represents the setting of DM's preferences. The continuous Pareto optimal solution obtained is the following one: VOLUME=4965, PRIME COST=1596.3921, PROFIT=2304.3451 and RAW MATERIALS=5699.557 (Fig. 2).

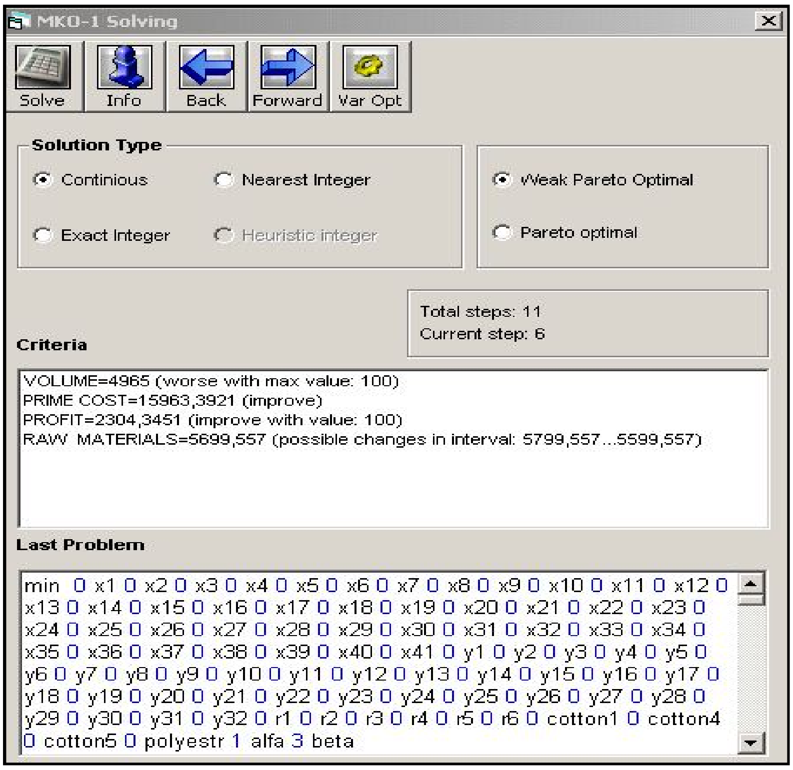

Fig. 2

As it could be seen, the criterion Profit has improved a little bit, the criterion Prime Cost and the criterion Raw Materials have also improved, and the production Volume criterion has dropped down to the lower bound set by the DM. At the next iteration the DM decides to continue in the same direction for profit improvement, to improve the prime cost with small steps and the input raw materials volume on account of a compromise decrease of the volume of the production output. The DM sets his/her preferences in the following way: for the criterion VOLUME – deterioration with maximal feasible value of 100, for PRIME COST criterion – free improvement, for criterion PROFIT – improvement by a value of 100, and for the fourth criterion RAW MATERIALS – a possible alteration within the range (5599.557, 5799.557).

Fig. 2 indicates the continuous Pareto optimal solution obtained and the local preferences set by the DM. After solving the corresponding scalarizing problem, the following new continuous Pareto optimal solution is obtained: VOLUME=4865, PRIME COST=15336.2398, PROFIT=2357.9333 and RAW MATERIALS=5599.557. Fig. 3 shows this solution and the new local preferences set by the DM.

As a last iteration the DM wishes to find a mixed integer Pareto optimal solution (Fig. 4) and the solution obtained is the following: VOLUME=4800, PRIMECOST= 14928.5908, PROFIT = 2428.4309 and RAW MATERILS = 5488.357.

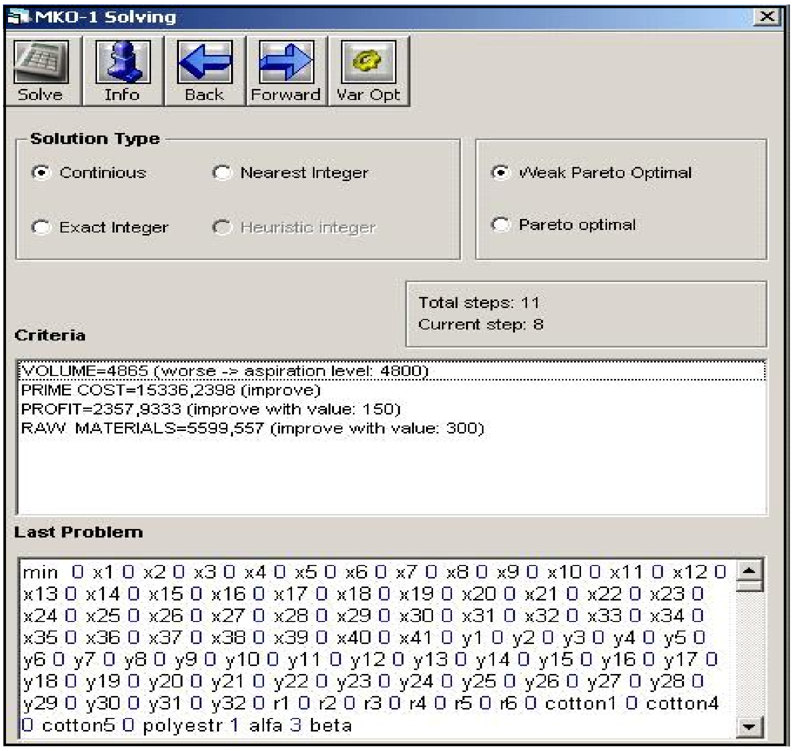
MKO-1 Solving
Solve
Info
Back
Forward
Var Opt
Solution Type
Continious
Nearest Integer
Exact Integer
Heuristic integer
Weak Pareto Optimal
Pareto optimal
Total steps: 11
Current step: 8
Criteria
VOLUME=4865 (worse -> aspiration level: 4800)
PRIME COST=15336,2398 (improve)
PROFIT=2357,9333 (improve with value: 150)
RAW MATERIALS=5599,557 (improve with value: 300)
Last Problem

Fig. 3

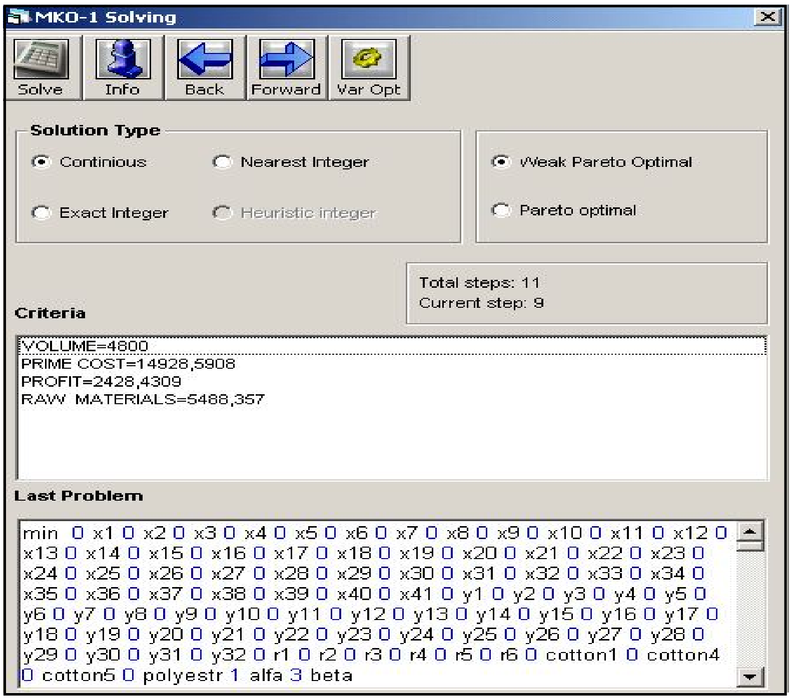
MKO-1 Solving
Solve
Info
Back
Forward
Var Opt
Solution Type
Continious
Nearest Integer
Exact Integer
Heuristic integer
Weak Pareto Optimal
Pareto optimal
Total steps: 11
Current step: 9
Criteria
VOLUME=4800
PRIME COST=14928,5908
PROFIT=2428,4309
RAW MATERIALS=5488,357
Last Problem

Fig. 4

The criteria values are not integers, because they are a function of integer and of continuous variables, as well.

Let us assume that this solution is satisfactory for the DM and hence, this will be the final solution of the multicriteria operative planning problem described in previous section.

5. Conclusion

The software system MKO-1 supporting the solution of multicriteria optimization problems may find various applications in solving real-life problems. The user-friendly interface, the efficient single-criterion and multicriteria methods assure wide possibilities for the DM in setting his/her preferences and in searching for new solutions. This enables the solution of real-life production problems with the help of MKO-1 system such as the problem, described in the paper, for operative planning of the production program of the spinning department in a textile enterprise.

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