

Working Paper

Short Software Descriptions

Marek Makowski, Tadeusz Rogowski

WP-91-18
July 1991



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Foreword

This paper briefly presents the software for interactive decision support that was developed in 1990-1991 within the Contracted Study Agreement between the System and Decision Sciences Program at IIASA and several Polish scientific institutions, namely:

- Institute of Automatic Control, Warsaw University of Technology,
- Institute of Computing Science, Technical University of Poznań,
- Institute of Informatics, Warsaw University,
- Systems Research Institute of the Polish Academy of Sciences.

This Contracted Study Agreement has been a continuation of the same type of activity conducted since 1985. Therefore many of the software packages are actually improved versions of the programs developed in 1985-1989.

The theoretical part of the results developed within this scientific activity is presented in the IIASA Collaborative Paper CP-90-008 by A. Ruszczyński, T. Rogowski and A. P. Wierzbicki entitled *Contributions to Methodology and Techniques of Decision Analysis (First Stage)*. Detailed descriptions of the methodology and the user guide for each particular software package are published in separate Collaborative Papers.

Each software package described here is available in executable form for non-profit educational and scientific purposes, however, any profit-oriented or commercial application requires a written agreement with IIASA. Inquires about the software should be directed to the System and Decision Sciences Program at IIASA, Methodology of Decisions Analysis Project.

Alexander B. Kurzhanski
Chairman
System and Decision Sciences Program

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Short Software Descriptions

*Marek Makowski, Tadeusz Rogowski**

1 Introduction

This Working Paper contains the short software description of the following Decision Support System (DSS) software packages that have been developed for IBM compatible personal computers :

DINAS – is an implementation of the aspiration-led methodology for transportation and location problems. It is a highly efficient solver. Problems can be defined in terms of a graph and the specialized network editor can be used for this purpose.

FLIP – is an implementation of the aspiration-led methodology for LP problems with imprecise coefficients. The user friendly interface also provides information on the implemented methodology.

HYBRID – is a DSS framework with non-simplex algorithm for multicriteria analysis of LP systems based on the aspiration-led methodology. Due to the solution technique Hybrid is capable of solving relatively large problems.

HYBRID-FMS – is a specialized version of Hybrid for the FMS model. The user interface allows for the modification of data that defines the model. The package can generate and solve two versions of the corresponding model: the linearized FMS model and the bilinear model.

IAC-DIDAS-L – is an implementation of the aspiration-led DSS methodology for LP problems. Special attention has been paid to the simplicity of the user interface, tools for problem definition and analysis of results.

IAC-DIDAS-N – is an implementation of the aspiration-led DSS methodology for nonlinear problems. Highly efficient and robust nonlinear solver algebraic manipulation tools which allow model analysis and differentiation. The model can be formulated in terms of algebraic equations;

MCBARG – is the experimental implementation of aspiration-led methodology for analysis of a decision situation and for mediation in multicriteria bargaining processes.

MPS – is a DSS for solving a general class of precedence and resources constrained project scheduling problems. The DSS either computes the exact solution (if sufficient time is available) or uses one of the three built-in heuristics to compute a suboptimal solution.

ROZKROJ – is a DSS for solving a two-dimensional irregular cutting problem (elements can be of arbitrary shapes and a sheet of rectangular material is assumed to have a constant width).

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The software listed above has been developed by the group of researches in Poland within the cooperation between the System and Decision Sciences Program and the Polish Academy of Sciences. Within the next few weeks several other packages will be available that are currently being developed by a group of scientists organized by the Bulgarian Academy of Sciences.

In addition to these software packages the following DSS software is also available:

DISCRET – supports analysis of finite (but large) set of alternatives: supports a selection of nondominated alternatives according to the additional constraints given, computation of approximation of Pareto set and aspiration-based analysis of alternatives.

MIDA – is a demonstration package for supporting spatial allocation of resources in the programming of development of the chemical industry.

MIPS – is a DSS for multicriteria project scheduling processes in real-life applications in the planning of the development of the chemical industry.

The distributable versions of the software are usually tailored for the illustration of methodology and of possible applications. However, for most of these software packages there exists a version made for a specific application and it is possible to modify each software package for a specific real-life application (if the corresponding mathematical programming model is of the type for which a particular package has been designed).

DINAS, v. 3.0

Dynamic Interactive Network Analysis System

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1 Executive summary

DINAS is a transferable scientific software tool which enables the solution of various multi-objective transshipment problems with facility locations. A network model of such problems consists of nodes connected by a set of direct flow arcs. It is assumed that some of the nodes are fixed, whereas the others represent the possible locations of new points in the network (potential nodes). A homogeneous good is distributed along the arcs among the nodes. The good flows through the arcs and potential nodes are assumed to be bounded by given capacities. A few linear objective functions are considered to evaluate location-distribution patterns. The problem is to find the best (Pareto-optimal) location and flow scheme in the network.

DINAS assists the user in choosing the the best solution during interactive work with the system. For this purpose an extension of the reference point optimization is utilized. According to some user's requirements (aspirations and reservations) DINAS generates various efficient solutions which can be examined in detail and compared to each other. The user works with the computer in an interactive way so that he can change his requirements during the sessions to reach the appropriate solutions. DINAS searches for the appropriate solution while using an achievement scalarizing function as a criterion in single-objective optimization.

DINAS is prepared as a menu-driven and east to use system. The system consists of three programs prepared in C programming language: the network screen editor, the solver and the main interactive procedure for handling multiple objectives. The basic version of the system is capable of solving problems with seven objectives, about one hundred of fixed nodes, a few hundreds of arcs, and fifteen potential nodes.

To make the DINAS system an extremely friendly tool, a number of extensions are provided, such as:

- additional windows in the network editor allowing one to examine and modify data while visiting both the list of nodes and the network scheme;
- an additional way of editing the user requirements while moving the cursor along the utopia-nadir scale;
- the mouse installation;
- the preparation of the MPS data file.

The MPS data file option allows the user to use professional mainframe solvers working with standard MPS input files, for solving distribution-location problems edited with the DINAS network editor.

2 References to applications

With DINAS one can analyze and solve such problems as: the transportation problem with new supply and/or demand points location, the problem of warehouse location, the problem of store location for the agricultural production, the problem of the location of service centers, districts reorganization, and many others. The PC version of the DINAS system was successfully used for solving the five-objective problem connected with reorganization of the primary health service in a district of Warsaw (62 fixed nodes, 8 potential nodes and 240 arcs). Moreover, a real-life, two-product transportation problem was modelled as a single-commodity network problem (about 50 nodes and 150 arcs) and successfully solved with DINAS.

3 Hardware and software requirements

DINAS runs under Disk Operating System DOS (version 3.00 or higher) on an IBM-PC XT/AT or compatible equipped with Hercules, EGA or CGA card and requires 640K RAM. One DS/DD floppy disk drive is sufficient to run DINAS, but a hard disk is recommended. A printer is useful, but not necessary since all the reports can also be routed to a disk file for printing at a later time.

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FLIP

Multiobjective Fuzzy Linear Programming Package

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1 Executive summary

FLIP (Fuzzy Linear Programming) is a package designed to help in the analysis of multiobjective linear programming (MOLP) problems in an uncertain environment. The uncertainty of data is modeled by L-R type fuzzy numbers. They can appear in the objective functions as well as on both sides of the constraints.

Formally, the fuzzy MOLP problem which can be solved by FLIP, may be described in the following way:

$$\begin{aligned} & \text{minimize} \begin{bmatrix} \tilde{z}_1 = \tilde{c}_1 \underline{x} \\ \vdots \\ \tilde{z}_k = \tilde{c}_k \underline{x} \end{bmatrix} \\ & \text{s.t.} \quad \begin{array}{ll} \tilde{a}_i \underline{x} \leq \tilde{b}_i & i = 1, \dots, m_1 \\ \tilde{a}_i \underline{x} \geq \tilde{b}_i & i = m_1 + 1, \dots, m \\ \underline{x} \geq \underline{0} \end{array} \end{aligned}$$

where \underline{x} is a column vector of n decision variables, $\tilde{c}_1, \dots, \tilde{c}_k$ are row vectors of fuzzy cost coefficients corresponding to the objective functions $\tilde{z}_1, \dots, \tilde{z}_k$, \tilde{a}_i is the i -th row of the matrix of fuzzy coefficients, and \tilde{b}_i is its corresponding fuzzy right-hand-side. It is assumed, moreover, that for the particular objectives, the decision maker (DM) is in a position to define fuzzy aspiration levels as goals, denoted by $\tilde{g}_1, \dots, \tilde{g}_k$. All fuzzy coefficients are given as fuzzy numbers, i.e. normal and convex fuzzy subsets of the real line.

The input of data into the FLIP package is supported by a graphical presentation of fuzzy coefficients.

The idea of FLIP relies on an observation that for a given \underline{x} , the main question to be answered consists of the comparison of the left- and right-hand-sides in objectives and constraints which are fuzzy numbers. Assuming an $L - R$ representation of fuzzy coefficients, a comparison principle has been proposed (Słowiński, 1986,1990) which allows a transformation of the fuzzy MOLP problem into a multiobjective linear fractional programming problem. It is then solved in the calculation phase with an interactive method using a linear programming procedure as the only optimizer. In every iteration, one gets a series of solutions which are presented to the DM both numerically, in terms of \underline{x} and middle values of $z(\underline{x}), l = 1, \dots, k$, and graphically, in terms of mutual positions of fuzzy numbers corresponding to objectives and aspiration levels on the one hand, and to left- and right-hand-sides of constraints, on the other hand. In this way, the DM gets quite a complete idea about the quality of each proposed solution. The quality is evaluated taking into account:

- the scores of fuzzy objectives in relation to the goals,
- the dispersion of values of the fuzzy objectives due to uncertainty,
- the safety of the solution or, using a complementary term, the risk of violation of the constraints.

In FLIP, interaction with the user takes place at two levels: first, when safety parameters have to be defined in the transformation phase, and second, when the associate deterministic problem is solved.

2 References to application

Flip has been applied to solve the following real-life problems: the composition of a daily diet for farm animals, farm structure optimization, land-use planning, and water supply system development planning.

3 Hardware and software requirements

The package is written in TURBO-Pascal and can be used on microcomputers compatible with IBM-PC XT/AT with hard disc and a graphic card. The full version permits handling fuzzy MOLP problems with up to 500 variables, 250 constraints and 10 objective functions on a standard PC.

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HYBRID

A Mathematical Programming Package

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1 Executive summary.

Hybrid is a mathematical programming package which includes all the functions necessary for the solution of linear programming problems. Hybrid may be used for both single- and multi-criteria problems. A Pareto-optimal solution can be found by the minimization of the achievement scalarizing function. Therefore, the multicriteria optimization problem is transformed by Hybrid to an equivalent single criterion LP problem by generating additional variables and constraints.

For solving a linear programming problem Hybrid uses a non-simplex algorithm — a particular implementation of the augmented Lagrangian (or Lagrange multiplier) method — for solving linear programming problems. General linear constraints are included within an augmented Lagrangian function. The LP problem is solved by minimizing a sequence of piecewise quadratic functions subject to simple constraints (lower and upper bounds). This minimization is achieved by the use of a method which combines the conjugate or preconditioned conjugate gradient method and an active constraint set strategy.

The ordinary or preconditioned conjugate gradient algorithms can be used for finding a minimum. Theoretically, those algorithms guarantee that the exact minimizer will be found after a finite number of iterations. However, during computations the rounding errors often cause numerical problems, especially for large or badly conditioned problems. To overcome these difficulties, two numerically stable methods for piecewise quadratic strongly convex functions have been implemented. The method is based on the active set algorithm and two types of factorization of the base matrix, namely Cholesky and Q-R factorizations. We solve a sequence of minimization quadratic functions without constraints. After a finite number of steps, a set of indices of constraints which are active at solution is found.

Hybrid is oriented towards an interactive mode of operation in which a sequence of problems is to be solved under varying conditions (e.g., different objective functions, reference points, values of constraints or bounds). Criteria for multiobjective problems may be easily defined and updated with the help of the package.

The chosen method of allocating storage in the memory takes maximal advantage of the available computer memory and of the features of typical real-world problems. In general, the matrix of constraints is large and sparse, while the number of all non-zero coefficients that take different numerical values is much smaller than the number of all non-zero coefficients. A sparse-matrix technique is therefore applied to store the data that define the problem to be solved. The memory management is handled in a flexible way. Hybrid is coded in C and is composed of 4 mutually linked modules. Besides that Hybrid offers many options useful for diagnostic and verification of a problem being solved. The data format for the input of data follows the MPS standard adopted by most commercial mathematical programming systems.

2 Hardware and software requirements.

Hybrid has been made operational in two versions: one for Unix (currently implemented for Sun Sparc 1+ running under SunOS 4.1 and for VAX 6210 running under Ultrix-32) and one for a PC compatible with PC IBM-386//AT/XT (with any graphic card). The PC version requires around 350kB RAM for small problems, and for larger problems a configuration with more RAM is needed (since Hybrid allocates the memory dynamically, only the amount of available memory determines the size of the problem that can be solved). A hard disk, with at least 2 MB free space, is necessary. The coprocessor is strongly recommended, but a version of Hybrid is available also for a PC configuration without coprocessor.

The package is stand-alone, i.e. it does not require any additional software.

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HYBRID-FMS

A DSS Framework for Flexible Manufacturing Problems

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1 Executive summary.

Hybrid-FMS is a dedicated multicriteria optimization package which allows the formulation and solution of a multicriteria problem related to a selection of a Flexible Manufacturing System taking into account different criteria such as productivity, cost and flexibility. Flexible Manufacturing Systems (FMS) have been playing an increasingly important role in the effort to improve productivity. Among the basic features of such systems there is the ability to produce variations of products with different degrees of complexity, easy change of production volumes and batch sizes. The design of FMS is a multilevel and multicriteria task. Hybrid-FMS is aimed at the multicriteria optimization of the model developed by the Computer Integrated Manufacturing Project at IIASA (Ranta and Alabian, 1988). So far this is still a prototype of an element which will be included in a DSS which is planned to assist the designing process of a FMS.

Hybrid-FMS runs on a PC compatible with IBM PC. It is assumed that a user need not to be skilled in computer usage. However, good knowledge of the FMS model and an understanding of multicriteria optimization basics are essential for the rational use of the software. The package accepts the standard MPSX format of LP problem formulation but it also offers an option for reading original data from an ASCII file (in a free format that may easily be generated by any DBMS). In the latter case it is possible to interactively modify all coefficients of the FMS model defined by (Ranta and Alabian, 1988) and the corresponding optimization model is generated by the package. Such an approach allows for avoiding the cumbersome procedure of generating and updating an LP or bilinear model.

Hybrid-FMS allows for the generating of the simplified LP model in which a group of variables is fixed. This option corresponds to the initial formulation the FMS model which has been solved by LP packages (cf Kuula and Stam, 1989). The main purpose of the Hybrid-FMS, however, is to generate and solve a multicriteria non-linear (bilinear) problem.

The formulation and solution of the multicriteria problem is based on the reference point approach (cf Makowski and Sosnowski, 1989) which allows the conversion of the multicriteria problem to a single criterion one. Therefore the multicriteria problem is solved as a sequence of parametric single objective optimization problems – modified by a user in an interactive way upon analysis of previous results.

Solution of a single objective bilinear optimization problem is based on a technique which combines a Newton type method for finding solutions which satisfies Kuhn–Tucker (K–T) conditions with the augmented Lagrangian method.

2 Hardware and software requirements.

Hybrid-FMS can be run on a PC compatible with PC IBM-386//AT/XT (with any graphic card). For small problems it requires around 350kB RAM, and for larger problems a configuration with more RAM is needed (since Hybrid allocates dynamically the memory, therefore only the amount of available memory determines the size of the problem that can be solved). A hard disk, with at least 2 MB free space, is necessary. A coprocessor is strongly recommended, but a version of Hybrid is available also for a PC configuration without coprocessor.

The package is stand-alone, i.e. it does not require any additional software.

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IAC – DIDAS – L, v. 5.7

Dynamic Interactive Decision Analysis and Support System for Linear Models

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1 Executive summary

The package IAC-DIDAS-L is designed to help in the analysis of linear models and to support decision-making with multiple objectives. IAC-DIDAS-L is an interactive system in which all phases of model definition and decision making are carried out in the dialogue mode.

IAC-DIDAS-L can be used by a wide group of users, from the inexperienced to the modeling and linear programming experts.

There are two phases of an IAC-DIDAS-L operation:

- interactive model editing,
- interactive multiobjective analysis.

In the model editing phase the substantive model is edited in an easy format of a spreadsheet. The decision variables and (possibly) model parameters are represented by columns and constraints and outcome variables are represented by rows. Thus the model in IAC-DIDAS-L is just a collection of linear expressions (rows) in a given set of variables (columns) together with upper and lower bounds for these expressions and for the decision variables. The role played by a row is not yet specified; in the next phase of multiobjective analysis any row can become an objective row or a constraint.

The model editing phase allows for the addition of new models and for corrections in the already existing ones. IAC-DIDAS-L has an option of storing and restoring models, so we can in fact, have a whole library of them.

In the multiobjective analysis phase a wide variety of functions are available. First, we can specify which rows will be treated as objectives and which rows will be treated as constraints. We can still modify lower and upper bounds for rows and for decision variables (columns).

Secondly, we can perform a fully automatic multiobjective analysis of the problem. This one-button function calculates the best available levels for each objective separately (*utopia point*) and suggests a solution which approaches these levels as near as possible (*neutral solution*), when all objectives are treated as equally important.

Thirdly, IAC-DIDAS-L supports a user-friendly way of specifying preferences by means of the so-called *reference points* in the space of objectives. The user can define values of objectives which he considers reasonable or satisfactory. The following optimization run produces a solution which has objective values as close as possible to the specified ones (if they are not attainable) or even better (if the reference point is attainable). In this way the user can influence the solutions generated by the system and he can achieve a satisfactory trade-off of the objectives. The user can also specify his preferences by setting scaling factors for the objectives; otherwise they are scaled automatically.

Finally, IAC-DIDAS-L has extensive data base management functions. It can store models, problems and results, and recall each of them when needed. The user can compare results in a numerical or graphical mode. An extra function is the possibility of multiobjective analysis in the graphical mode by graphical modification of reference points.

2 References to applications

IAC-DIDAS-L is a general-purpose system which can handle linear models of size limited by the spreadsheet technology. In its general form it can find direct applications in research and some commercial applications when models are not excessively large.

Because the DIDAS approach proved to be convenient, useful and efficient, it can serve as a basis for dedicated versions aimed at definite applications. One such version for water management problems is currently under development. Other versions can be generated on request.

3 Hardware and software requirements

IAC-DIDAS-L requires a microcomputer compatible with IBM-PC with CGA, EGA, VGA or Hercules graphic card (Borland's drivers for ATT, IBM8514, PC3270 included but never tested). Hard disk and coprocessor are not required, but are strongly recommended.

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IAC – DIDAS – N, v. 4.0

Dynamic Interactive Decision Analysis and Support System for Nonlinear Models

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1 Executive summary

The decision analysis and support systems of the DIDAS family - that is, Dynamic Interactive Decision Analysis and Support systems - are specially designed to support interactive work with a substantive model while using multicriteria optimization tools. They stress the learning aspects of such work, including the right of a decision maker to change his priorities and preferences when learning new facts. DIDAS systems can be used either by analysts who want to analyze their substantive models, or by teams of analysts and decision makers, or even by decision makers working alone with a previously defined substantive model; in any case, we shall speak further about *the user* of the system.

There are several classes of substantive models that all require special technical means of support. The IAC-DIDAS-N version is designed to support models of the **multiobjective nonlinear programming** type. Models of this type include two classes of variables:

- *input variables* that can be subdivided into *decision variables* and *parametric variables*,
- *outcome variables* that can be subdivided into several types, the most important of them being *optimized outcomes* or *objectives* (that can be either maximized or minimized or stabilized, that is, kept close to a desired level) and *constrained outcomes* that have to be kept within specified bounds.

The user may change the classification of outcome variables and select his objectives among various outcome variables when defining a multiobjective analysis problem.

For all input and outcome variables a reasonably defined nonlinear model should include *lower* and *upper bounds*, in other words, reasonable ranges of admissible changes of these variables. Moreover, an essential part of a nonlinear model definition are model equations, that is, nonlinear functions that define the dependence of all outcome variables on input variables. To make the model definition easier for the user, it is assumed that outcome variables are defined consecutively and that they can depend not only on input variables, but also on previously defined outcome variables.

The IAC-DIDAS-N system provides user-friendly interactive tools for defining, editing, initial analysis and verification, optimization and multiobjective analysis of a rather broad class of nonlinear models. An important feature of IAC-DIDAS-N is that it also supports automatic calculations of all derivatives of nonlinear model functions.

A typical working session with the IAC-DIDAS-N system consists of several phases.

In the first phase, a user - typically, an analyst - defines the substantive model and edits it on the computer. IAC-DIDAS-N supports the definition and edition of models in an easy, but flexible standard format of a spreadsheet, where the input variables correspond to spreadsheet columns and the outcome variables - to spreadsheet rows; special cells are reserved for various additional information. Another feature of IAC-DIDAS-N is a symbolic differentiation facility that supports automatic calculations of all derivatives required by a nonlinear programming algorithm. The user does not need to laboriously calculate many derivatives and to check whether he did not make any mistakes; he only defines model equations or outcome functions in a form that is acceptable for the symbolic differentiation program - which admits functions from a rather wide class. The spreadsheet format also allows for the display of computed values of automatically determined formulae for derivatives in appropriate cells. The user of IAC-DIDAS-N can also have several substantive models recorded in a special model directory. A previously created model may be used to speed up the definition of a new model etc., while the system automatically supports the recording of all new or modified models in an appropriate directory.

In further phases of work with DIDAS-N the user - here typically an analyst working together with the decision maker - specifies a multiobjective analysis problem related to his substantive model and participates in an initial analysis of this problem. There might be many multiobjective analysis problems related to the same substantive model: the specification of a multiobjective problem consists in designating types of model outcomes, especially objective outcomes that shall be optimized, and specifying bounds on outcomes. For a given definition of the multiobjective analysis problem, the decisions and outcomes in the model are subdivided into two categories: those that are **efficient** with respect to the multiobjective problem (that is, such that no objective can be improved without deteriorating some other objective) and those that are inefficient. It is assumed that the user is interested only in efficient decisions and outcomes.

One of main functions of DIDAS-N is computing efficient decisions and outcomes - following interactively various instructions of the user - and displaying them to the user for analysis. This is done by solving a special parametric nonlinear programming problem resulting from the specification of the multiobjective analysis problem. For this purpose, IAC-DIDAS-N contains a specialized nonlinear programming algorithm called *solver*.

The main phase of work with the IAC-DIDAS-N system consists in interactive scanning of efficient outcomes and decisions, guided by the user. The user can specify two *reference points* called the *reservation point* and the *aspiration point* in the objective space, i.e. *reservation levels* and *aspiration levels* for all objectives. The system also admits a simpler option of specifying only an aspiration level or a reservation level for some objectives. Reservation levels reflect the user's opinion about the values that should be achieved, while aspiration levels are desired values. The user can get additional information about the range of possible outcomes during the so-called initial analysis of multiobjective problem and thus can reasonably specify his reference levels. The system suggests some initial values for both reference points.

IAC-DIDAS-N uses the aspiration and reservation levels as parameters in a special *achievement function* coded in the system, compute the solution of a nonlinear programming problem equivalent to maximizing this achievement function, and which responds to the user with an attainable, efficient solution and outcome that strictly corresponds to the specified references.

The IAC-DIDAS-N system (Institute of Automatic Control, Dynamic Interactive Decision Analysis and Support, Nonlinear version) is a decision support system designed to help in the analysis of decision situations where a mathematical model of substantive aspects of the situation can be formulated in the form of a multiobjective nonlinear programming problem.

The system supports the following general functions:

- the definition and edition of a substantive model of the decision situation in a user-friendly format of a spreadsheet,
- the specification of a multiobjective decision analysis problem related to the substantive model,

- an initial multiobjective analysis of the problem, resulting in estimating bounds on efficient outcomes of decisions and in learning about some extreme and some neutral decisions,
- an interactive analysis of the problem stressing the learning of possible efficient decisions and outcomes, organized through system's response to user-specified aspiration and reservation levels for objective outcomes. The system responds with efficient objective outcomes obtained by the maximization of an achievement function that is parameterized by user-specified aspirations and reservations.

2 Hardware and software requirements

The program can be run on an IBM-PC-XT, AT or a compatible computer with Hercules Graphics Card, Color Graphic Adapter or Enhanced Graphics Adapter and, preferably, with a numeric coprocessor and a hard disk. If a numeric coprocessor is available then all the computations are performed by the coprocessor, taking advantage of its computational capacity, otherwise the emulation procedures are used with less computational capabilities. The program is recorded on one diskette. The diskette contains compiled code of the system together with some data files with demonstrative examples of nonlinear models.

The system is permanently updated and developed. The version (version 4.0) currently being released has two important enhancements:

- an integrated data base system for storing models and resulting data; it replaces the rather complicated system of many DOS files and directories used in previous versions of the system,
- a model debugger with visualization of formulae for derivatives, automatic error tracking and a step-by-step calculations option; it facilitates the development of complex models.

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MCBARG

Enhanced a System Supporting Multicriteria Bargaining¹

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1 Executive summary

Many aspects of economic, environmental, or technological activity are influenced directly by bargaining between and among individuals, firms, and nations ("players"). In the pure bargaining problem the bargaining conditions are determined entirely by the bounds of discussion, within which the final outcome is determined by the interaction of the players. Even in the case of one individual, firm or nation, there are many complex situations in which the decision maker needs help to learn about possible decision options and decision consequences.

The MCBARG system is a decision support system designed to help in the analysis of a decision situation and mediation in multicriteria bargaining problem.

The multicriteria bargaining problem is a generalization of classical bargaining problem (see Nash 1950, Raiffa 1953, Roth 1979, Thomson 1986), under the assumption that an aggregation of players' objectives with use of utility functions is impossible. The problem is defined by an agreement set — the set of outcomes that can be reached under unanimous agreement of the players, and by a disagreement (status quo) point which is a result of the problem if there is no such agreement.

The MCBARG system enables learning the process of the players, and supports reaching the final outcome in the multicriteria bargaining problem. It is based on new theoretical results on interactive mediation processes applying aspiration-led methodology of decision support systems, presented in Kruś, Bronisz, Lopuch (1990), Bronisz, Kruś, Wierzbicki (1988).

The system supports:

- Defining and editing of a model of the bargaining problem.
- Interactive learning of the problem nature and mediation process.

The defining and editing of the model should be done by a system analyst called an "operator" in the MCBARG system.

The interactive mediation process proceeds in a number of rounds in which the players generate a sequence of successive agreement outcomes leading to a nondominated solution. Such an approach is recommended when several criteria exist to be negotiated simultaneously (see Raiffa 1982). The process is based on a limited confidence principle (see Fandel, Wierzbicki 1985), taken from practical observation, which says that the players have limited confidence in their ability to predict consequences and possible outcomes, hence each player tries to prevent other players from receiving disproportionately large gains. In each round the players have the possibility of making unilateral, interactive analysis of the problem and of selecting the outcomes

¹This system has been developed under the sponsorship of the Research Program CPBP 02.15 of the Systems Research Institute, Polish Academy of Sciences, Poland, and under a contracted study agreement with the Systems and Decision Sciences Program of the International Institute for Applied Systems Analysis, Laxenburg, Austria.

according to their preferences. The process assures some fairness of rules and is resistant to the various manipulations of the players.

The MCBARG system is self-explaining, it includes a set of information facilitating working with the system. Users ("operator" and "players") are provided with a set of menus. The main options include: **INFORMATION**, **MODEL**, **OLD SESSION**, **NEGOTIATION**.

The **INFORMATION** option presents general information about the system.

The **MODEL** option enables the defining and editing of a model of the bargaining problem.

The **OLD SESSION** option makes it possible to analyse and to restart the previous session.

The **NEGOTIATION** option activates the mediation process. The process consists of a number of rounds, each round starts from the previous agreement outcome. At each round each player can interactively explore the bargaining problem and receive substantial information enabling selection of his preferable confidence coefficient and his preferable improvement direction. After that, the system calculates a new agreement outcome. The process terminates when the nondominated solution in the agreement set is reached.

2 References to applications

The MCBARG system can be applied to the multicriteria bargaining problem in which a mathematical model of the problem is formulated by a status-quo point and a system of inequalities describing agreement set in objective space of the players.

Two demonstrative examples have been prepared. The first deals with the cooperation between two farms. The problem consists of the proper allocation of surplus resulting from the above cooperation. The second example refers to the international cooperation on the acid rain problem (see Kruś, Bronisz, Lopuch 1990).

3 Hardware and software requirements

The program is recorded on one diskette that can be installed on an IBM-PC-XT, AT or compatible computer with Hercules Graphics Card, Color Graphic Adapter (CGA), Enhanced Graphics Adapter (EGA) or Video Graphics Array (VGA). A diskette contains compiled code of the program together with some data files for demonstrative examples of the bargaining problem.

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MPS

Decision Support System

for Multiobjective Project Scheduling

subject to Multiple-Category

Resource Constraints

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1 Executive summary

The DSS supports the process of solving a general class of precedence and resource constrained project scheduling problems. In the set of resources used for the project, three categories are distinguished: renewable (e.g. machines, manpower) for which only usage at every moment is constrained, nonrenewable (e.g. money, energy) for which only consumption during the project performance is constrained and doubly-constrained (e.g. investment funds, power) for which both usage and consumption are constrained. For each activity of the project, multiple performing modes are known to differ by types and amounts of resources, as well as by duration. The following project performance measures are considered: project duration, resource smoothing, mean weighted activity lateness, total number of tardy activities, mean weighted flow time, total resource consumption, weighted resource consumption and net present value.

The DSS, called MPS, is based on three kinds of heuristics: parallel priority rules, simulated annealing and branch-and-bound. The last algorithm can even yield exact solutions when sufficient processing time is available. Some parts of the MPS are interactive, in particular, the search for a best compromise schedule in the multiobjective case. In every decision phase, the DM can evaluate a set of feasible schedules not confined to a single proposal. Graphical representation of schedules, including Gantt charts and resource profiles, enables their thorough evaluation.

MPS has been created to support and enhance rather than replace managerial judgment. Our idea was to achieve this goal due to the following features of the system:

- generation of a set of feasible schedules not confined to a single proposal,
- evaluation of these schedules from different, in general conflicting, points of view - multi-objective analysis,
- organization of a constructive interactive process,
- table and graphic representation of schedules, including Gantt charts and resource profiles,
- taking into account renewable, nonrenewable and doubly constrained resources in a common model,

- dealing with multiple performing modes of activities,
- consideration of various time and cost objectives and resource smoothing,
- a user-friendly model editor.

2 References to applications

MPS has been applied for scheduling agricultural projects composed of up to 100 farm activities. Using a standard PC, it handles up to 4 renewable, 4 nonrenewable and 4 doubly constrained resource types, up to 3 performing modes per activity and up to 8 project performance measures simultaneously.

3 Hardware and software requirements

MPS runs on a PC compatible with IBM having the following minimal configuration:

- 640 kb RAM,
- MS-DOS ver. 3.10 or higher,
- one floppy disk driver or, preferably, a hard disk.

The MPS diskette or the MPS directory on the hard disk must contain the following files:

- MPS.EXE — a compiled system
- 4x6.fon — fonts for CGA card
- 8x3.fon — fonts for EGA or VGA card
- 14x9.fon — fonts for HERCULES card

MPS has been written in TURBO-PASCAL 5.0 with Borland Graphics Toolbox 4.0. Program MPS must be compiled for a graphic card available on a user's computer.

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ROZKROJ, v.2.1

Decision Support System for Two-Dimensional Cutting Problem

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1 Executive summary

Decision Support System ROZKROJ was designed for solving a two-dimensional irregular cutting problem. The problem arises in cutting, packing and partitioning processes in glass, steel, wooden, paper or textile industries.

A problem solved by the use of Decision Support System - ROZKROJ can be formulated as follows:

There is given a set of two-dimensional elements of arbitrary shapes and a sheet of rectangular material with a constant width. One should find an allocation of elements in the sheet minimizing the waste. In our case this means a length of the material required should be minimized. Additionally, we have assumed that:

1. Every element must lay entirely in the stock sheet.
2. No overlap of elements is admitted.
3. Flipping the element from "left" to the "right" side (mirror symmetry) is not allowed.
4. Rotations with some step depending on the algorithm, are allowed.
5. Elements can be concave or convex.
6. The edge of element consists of sections of a line or sections of a circle.

The basis of this system are two methods: Gurel's method and Albano-Sapuppo's method (cf [2]) adjusted to particular problem in question. In the first method [1] elements are allocated at the left end of the stock sheet and then placed on the right side of the elements already allocated to minimize a waste generated. The second method [3] is well defined for elements of similar size allowing for their clustering into columns.

After the start of the program execution the first screen is displayed with some information about the version of the program and the authors. Then the main menu screen appears. There are the following options in the program:

1. Quit the program.
2. Gurel's method.
3. Albano-Sapuppo's method.
4. Display solutions.

5. Program help.

The options allow for the breaking the execution of the program, computing a new solution by the use of the selected method, and evaluation of the solutions. The help option gives information about the program, in particular, about the format of input and output data files. The input data are supplied to the program in the specified format in text file prepared by the use of special program assigned for digitalization of droughts or any text editor. All accessible data files with right data file extension used in program option are easily selectable after choosing the option.

2 References to applications

The system has been purchased by the software firm TEKOMA for the use in steel mill industry. It has been also used by the firm SOFTOP.

3 Hardware and software requirements

This DSS can operate on the IBM PC compatible computers. Suggested minimal hardware configuration is 640 kB of RAM; CGA, HGC or VGA graphic card; floppy disk drive. A hard disc drive and printer are optional.

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