WORKING PAPER

Dynamic Interactive Network Analysis
System - DINAS Version 2.1 (1988)
User's Manual

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Foreword

This paper is one of the series of 11 Working Papers presenting the software for interactive decision support and software tools for developing decision support systems. These products constitute the outcome of the contracted study agreement between the System and Decision Sciences Program at IIASA and several Polish scientific institutions. The theoretical part of these results is presented in the IIASA Working Paper WP-88-071 entitled *Theory, Software and Testing Examples in Decision Support Systems*. This volume contains the theoretical and methodological bacgrounds of the software systems developed within the project.

This paper describes the methodological background and user manual of the Dynamic Interactive Network Analysis System (DINAS) which enables the solution of various multi-objective transshipment problems with facility location. DINAS utilizes an extension of the classical reference point approach to handling multiple objectives. A special TRANSLOC solver was developed to provide DINAS with solutions to single-objective problems. It is based on the branch and bound scheme with a new implementation of the simplex special ordered network (SON) algorithm with implicit representation of the simple and variable upper bounds (VUB & SUB). DINAS has been designed as a menu-driven and user–friendly system armed with a special network editor which reduces to minimum effort associated with defining real-life problems.

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Dynamic Interactive Network Analysis System — DINAS
version 2.1 (1988)
User's Manual

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Contents

1 Introduction

DINAS (Dynamic Interactive Network Analysis System) is a scientific transferable software tool which enables the solution of various multiobjective transshipment problems with facility locations. For a given number of fixed facilities and customers and for a number of potential facilities to be optionally located, DINAS provides you with a distribution pattern of a homogeneous product under multicriteria optimality requirements. While working in an interactive mode, you get optimal locations of the potential facilities and a system of optimal flows of the product between nodes of the transportation network.

With DINAS you can analyse and solve such problems as:

- the transportation problem with new supply and/or demand points location,
- the problem of warehouses location,
- the problem of stores location for the agricultural production,
- the problem of service centers location and districts reorganization,

and many other real–life distribution–location problems.

DINAS is implemented on IBM–PC XT/AT as a menu–driven and easy in usage system armed with a special network screen editor for a friendly data input and results examination. While working with DINAS you will get a permanent assistance by the help lines which will inform you about operations available at this moment. Moreover, at any moment you will have opportunity to get more general information from the help file.

This manual is organized as follows. In Chapter 2 a short characteristic of the system is given. There is also included the problem statement.

Chapter 3 provides you with the theoretical and methodological backgrounds of the DINAS system. It describes in details the mathematical formulation of the problem, the interactive procedure for handling multiple objectives as well as some sophisticated techniques of the solver. This chapter can be skipped by the users who are interested only in learning functions and operations of DINAS without a deep knowledge of the methodology.

Chapter 4 takes a part of a tutorial. The purpose of it is to help a new user become familiar with the DINAS system. It does not provide you with any formal commands description. It rather shows capabilities of the system. In this chapter we present in details using of DINAS to analyse a tutorial problem. The tutorial problem is constructed as a small part of the real–life problem of health service districts reorganization connected with a location of new health–care centers.

Chapters 5 and 6 describe in details all the operations performed in the DINAS system. For each operation they explain, in a rather formal way, the purpose of the operation, the execution process as well as troubleshooting. Thus these chapters can be regarded as an extended reference manual. Chapter 5 presents the main system operations whereas the operations connected with problem input and editing are considered in Chapter 6.

2 General information

2.1 The problem statement

DINAS works with problems formulated as multiobjective transshipment problems with facility location. A network model of such a problem consists of nodes connected by a set of direct flow arcs. The set of nodes is partitioned into two subsets: the set of fixed nodes and the set of potential nodes. The fixed nodes represent "fixed points" of the transportation network,

i.e., points which cannot be changed, whereas the potential nodes are introduced to represent possible locations of new points in the network.

Some groups of the potential nodes represent different versions of the same facility to be located (e.g., different sizes of a warehouse etc.). For this reason, potential nodes are organized in the so–called selections, i.e., sets of nodes with the multiple choice requirements. Each selection is defined by the list of included potential nodes as well as by a lower and upper number of nodes which have to be selected (located).

A homogeneous good is distributed along the arcs among the nodes. Each fixed node is characterized by two quantities: supply and demand on the good, but for the mathematical statement of the problem only the difference supply–demand (the so–called balance) is used. Each potential node is characterized by a capacity which bounds maximal good flow through the node. The capacities are also given for all the arcs but not for the fixed nodes.

A few linear objective functions are considered in the problem. The objective functions are introduced into the model by given coefficients associated with several arcs and potential nodes (the so–called cost coefficients, independently of their real character). The cost coefficient connected to an arc is treated as the unit cost of the flow along the arc. The cost coefficient connected to a potential node is considered as the fixed cost associated with locating of the node (e.g., an investment cost).

Summarizing, the following groups of input data define the transshipment problem under consideration:

- objectives,
- fixed nodes with their supply-demand balances,
- potential nodes with their capacities and (fixed) cost coefficients,
- selections with their lower and upper limits on number of active potential nodes,
- arcs with their capacities and cost coefficients.

In the DINAS system there are two restrictions on the network structure:

- there is no arc which directly connects two potential nodes;
- each potential node belongs to at most two selections.

The first restriction does not imply any loss of generality since each of two potential nodes can be separated by an artificial fixed node, if necessary. The second requirement is not very strong since in practical models usually there are no potential nodes belonging to more than two selections.

The problem is to determine the number and locations of active potential nodes and to find the good flows (along arcs) so as to satisfy the balance and capacity restrictions and, simultaneously, optimize the given objective functions. A mathematical model of the problem is described in details in Section 3.1.

2.2 DINAS and Multiple Criteria Decision Making

The problem under consideration is a specialized form of Multiple Criteria Decision Making (MCDM). The basic concept of the multiple objective optimization was introduced by Pareto over 80 years ago. He developed the idea of the so–called efficient (or Pareto–optimal) solution, that is a solution which cannot be improved in any objective without some other objective being worsened. However the set of all the efficient solutions is, in practice, extremely huge. Therefore development of practical MCDM tools has begun from the 70's

when the computer technique reached a sufficient level for an efficient implementation of various interactive (decision support) systems.

The interactive system does not solve the multiobjective problem. It rather makes the user selecting the best solution during interactive work with the system. According to some user's requirements, the system generates various efficient solutions which can be examined in details 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.

DINAS is such an interactive decision support system. The DINAS interactive procedure utilizes an extension of the reference point optimization. The basic concept of that approach is as follows:

- the user forms his requirements in terms of aspiration and reservation levels, i.e., he specifies acceptable and required values for given objectives;

- the user works with the computer in an interactive way so that he can change his aspiration and reservation levels during the sessions.

- after editing the aspiration and reservation levels, DINAS computes a new efficient solution while using an achievement scalarizing function as a criterion in single-objective optimization (see Section 3.2 for more details).

- each computed efficient solution is put into a special Solution Base and presented to the DM as the Current Solution in the form of tables and bars which allow him to analyse performances of the Current Solution in comparison with the previous solutions.

A special TRANSLOC solver is included in the system to provide the multiobjective analysis procedure with optimal solutions to single–objective problems. The solver is hidden from the user but it is the most important part of the DINAS system. It is the numerical kernel of the system which generates efficient solutions. The concept of TRANSLOC is based on the branch and bound scheme with a pioneering implementation of the simplex special ordered network (SON) algorithm and with implicit representation of the simple and variable upper bounds (VUB & SUB). The mathematical backgrounds of the TRANSLOC solver are given in Chapter 3.

3 Theoretical and methodological backgrounds of the system

3.1 The internal network model

For simplicity of the model representation and the solution procedure the network problem is transformed in DINAS into a special internal form. Namely, the potential nodes are transformed into artificial arcs.

The transformation is performed by duplication of all potential nodes. After the duplication is done all the nodes can be considered as fixed and each potential node is replaced by an artificial arc which leads from the node to its copy. Due to the transformation we get a network with the fixed structure since all the nodes are fixed. Potentiality of artificial arcs does not imply any complication because each arc in the network represents a potential flow. Moreover, all the bounds on flows (i.e., capacities) are connected to arcs after this transformation. Additional nonstandard discrete constraints on the flow are generated only by the multiple choice requirements associated with the selections. Cost coefficients are connected only to arcs, but the coefficients connected to artificial arcs represent fixed costs.

A mathematical statement of this transformed problem takes the form of the following generalized network model:

$$\text{minimize} \quad \sum_{(i,j)\in A\backslash A_a} f_{ij}^p x_{ij} + \sum_{(i,j)\in A_a} f_{ij}^p y_{ij}, \quad p = 1, 2, \ldots, n_0 \qquad (1)$$

$$\text{subject to} \quad \sum_{(i,j)\in A} x_{ij} - \sum_{(j,i)\in A} x_{ji} = b_i, \quad i \in N \qquad (2)$$

$$0 \le x_{ij} \le c_{ij}, \quad (i,j) \in A \setminus A_a \qquad (3)$$

$$0 \le x_{ij} \le c_{ij}y_{ij}, \quad (i,j) \in A_a \qquad (4)$$

$$g_k \le \sum_{(i,j)\in S_k} y_{ij} \le h_k, \quad k = 1, 2, \ldots, n_s \qquad (5)$$

$$y_{ij} = 0 \text{ or } 1, \quad (i,j) \in A_a \qquad (6)$$

where the following notations are used:

n_0 number of objective functions,

N set of nodes (including copies of potential nodes),

n_s number of selections,

A set of arcs (including artificial arcs),

A_a set of artificial arcs,

f_{ij}^p cost coefficient of the p-th objective associated with the arc (i,j),

b_i supply-demand balance at the node i,

c_{ij} capacity of the arc (i,j),

g_k, h_k lower and upper number of (artificial) arcs to be selected in the k-th selection,

S_k set of (artificial) arcs that belong to the k-th selection,

x_{ij} decision variable that represents flow along the arc (i,j),

y_{ij} decision variable equal 1 for selected arc and 0 otherwise.

The generalized network model of this form includes typical network constraints (2) with simple upper bounds (3) as well as a special discrete structure (5) — (6) connected to the network structure by variable upper bounds (4). While solving the model we have to take advantages of all these features.

3.2   Interactive procedure for handling multiple objectives

There are many different concepts for handling multiple objectives in mathematical programming. We decided to use the so-called reference point approach which was introduced by Wierzbicki (1982). This concept was further developed in many papers and was used as a basis for construction of the software package DIDAS (Dynamic Interactive Decision Analysis and Support system). The DIDAS package proved to be useful in analysing conflicts and assisting in decision making situations (Grauer et al., 1984).

The basic concept of the reference point approach is as follows:

1. the decision-maker (DM) forms his requirements in terms of aspiration levels, i.e., he specifies acceptable values for given objectives;

2. the DM works with the computer in an interactive way so that he can change his aspiration levels during sessions of the analysis.

In our system, we extend the DIDAS approach. The extension relies on additional use of reservation levels which allow the DM to specify necessary values for given objectives (Wierzbicki, 1986).

Consider the multi–objective program associated with the generalized network model:

$$
\begin{aligned}
minimize \quad & q \\
subject\ to \quad & q = F(x, y) \\
& (x, y) \in Q
\end{aligned}
$$

where

q represents the vector,

F is the linear objective vector–function defined by (1),

Q denotes the feasible set of the generalized network model, i.e., the set defined by conditions (2)—(6).

The reference point technique works in two stages. In the first stage the DM is provided with some initial information which gives him an overview of the problem. The initial information is generated by minimization of all the objectives separately. More precisely, the following single objective programs are solved:

$$
\min\{F^p(x, y) + \frac{r_0}{n_0} \sum_{i=1}^{n_0} F^i(x, y) : (x, y) \in Q\}, \qquad p = 1, 2, \ldots, n_0 \qquad (7)
$$

where F^p denotes the p-th objective function and r_0 is an arbitrarily small number.

The so–called pay–off matrix

$$
R = (q_{pj}), \qquad p = 1, \ldots, n_0; \qquad j = 1, \ldots, n_0
$$

which yields information on the range of numerical values of each objective is then constructed. The p-th row of the matrix R corresponds to the vector (x^p, y^p) which solves the p-th program (7). Each quantity q_{pj} represents a value of the j-th objective at this solution (i.e., $q_{pj} = F^j(x^p, y^p)$). The vector with elements q_{pp}, i.e., the diagonal of R, defines the utopia (ideal) point. This point, denoted further by q^u, is usually not attainable but it is presented to the DM as a lower limit to the numerical values of the objectives.

Taking into consideration the j-th column of the matrix R we notice that the minimal value in that column is $q_{pp} = q_p^u$.

Let q_j^n be the maximal value, i.e.,

$$
q_j^n = \max_{1 \leq p \leq n_0} \{q_{pj}\}
$$

The point q^n is called the nadir point and may be presented to the DM as an upper guideline to the values of the objectives. Thus, for each objective F^p a reasonable but not necessarily tight upper bound q^n and a lower bound q^u are known after the first stage of the analysis.

In the second stage, an interactive selection of efficient solutions is performed. The DM controls the selection by two vector–parameters: his aspiration level q^a and his reservation level q^r, where

$$
q^u \leq q^a < q^r \leq q^n
$$

5

The support system searches for the satisfying solution while using an achievement scalarizing function as a criterion in single–objective optimization. Namely, the support system computes the optimal solution to the following problem:

$$minimize \quad \max_{1 \leq p \leq n_0} u_p(q, q^a, q^r) + \frac{r_0}{n_0} \sum_{p=1}^{n_0} u_p(q, q^a, q^r) \quad (8)$$

$$subject \; to \quad q = F(x, y)$$

$$(x, y) \in Q$$

where r_0 is an arbitrarily small number and u_p is a function which measures the deviation of results from the DM's expectations with respect to the p-th objective, depending on a given aspiration level q^a and reservation level q^r.

The computed solution is an efficient (Pareto–optimal) solution to the original multiobjective model. It is presented to the DM as a current solution. The DM is asked whether he finds this solution satisfactory or not. If the DM does not accept the current solution he has to enter new aspiration and/or reservation levels for some objectives. Depending on this new information supplied by the DM, a new efficient solution is computed and presented as a current solution. The process is repeated as long as the DM needs.

The function $u_p(q, q^a, q^r)$ is a strictly monotone function of the objective vector q with value $u_p = 0$ if $q = q^a$ and $u_p = 1$ if $q = q^r$. In our system, we use (similarly as in Wierzbicki 1986) a piece–wise linear function u_p defined as follows:

$$u_p(q, q^a, q^r) = \begin{cases} a_p(q_p - q_p^a)/(q_p^r - q_p^a), & \text{if } q_p < q_p^a \\ (q_p - q_p^a)/(q_p^r - q_p^a), & \text{if } q_p^a \leq q_p \leq q_p^r \\ b_p(q_p - q_p^r)/(q_p^r - q_p^a) + 1, & \text{if } q_p^r < q_p \end{cases}$$

where a_p and b_p $(p = 1, 2, \ldots, n_0)$ are given positive parameters. In the DINAS system, the parameters a_p and b_p are defined according to the formulae

$$a_p = \frac{a(q_p^r - q_p^a)}{(q_p^a - q_p^u)}$$

$$b_p = b(q_p^r - q_p^a)$$

where a and b are positive parameters computed as follows

$$a = 0.1 \min_{1 \leq j \leq n_0} \frac{(q_j^a - q_j^u)}{(q_j^r - q_j^a)^2}$$

$$b = 10 \max_{1 \leq j \leq n_0} \frac{1}{(q_j^r - q_j^a)}$$

The parameters a_p and b_p satisfy inequalities: $a_p < 1$ and $b_p > 1$, and thereby the achievement functions u_p are convex. Minimization of the function u_p is then equivalent to minimization of a variable u_p defined as follows:

$$u_p = v_p + b_p v_p^- - a_p v_p^+ \quad (9)$$

$$v_p - v_p^+ + v_p^- = (q_p - q_p^a)/(q_p^r - q_p^a) \quad (10)$$

$$0 \leq v_p \leq 1 \quad (11)$$

$$v_p^+ \geq 0, \quad v_p^- \geq 0 \quad (12)$$

6

3.3 General concept of the TRANSLOC solver

The TRANSLOC solver has been prepared to provide the multiobjective analysis procedure with solutions to single–objective problems. According to the interactive procedure described in Section 3.2 the TRANSLOC solver has to be able to solve two kinds of single–objective problems: the first one associated with calculation of the pay–off matrix (problems (7)) and the second one associated with minimization of the scalarizing achievement function (problems (8)). Both kinds of the problems have, however, the same main constraints which represent the feasible set of the generalized network model. Moreover, the other constraints of both the kinds of problems can be expressed in very similar ways. So, we can formulate a general single–objective problem for the TRANSLOC solver as follows:

$$\text{maximize} \quad s \tag{13}$$

$$\text{subject to} \quad \sum_{(i,j)\in A} x_{ij} - \sum_{(j,i)\in A} x_{ji} = b_i, \qquad i \in N \tag{14}$$

$$w_k + \sum_{(i,j)\in S_k} y_{ij} = h_k, \quad k = 1, 2, \ldots, n_s \tag{15}$$

$$u_p - v_p + d_p^+ - d_p^- = 0, \quad p = 1, 2, \ldots, n_0 \tag{16}$$

$$v_p - \frac{1}{a_p}d_p^+ + \frac{1}{b_p}d_p^- - \sigma_p \left(\sum_{(i,j)\in A\setminus A_a} f_{ij}^p x_{ij} + \sum_{(i,j)\in A_a} f_{ij}^p y_{ij} \right) = \delta_p,$$

$$p = 1, \ldots, n_0 \tag{17}$$

$$u_0 - \sum_{p=1}^{n_0} u_p = 0 \tag{18}$$

$$s + z + \frac{r_0}{n_0}u_0 = 0 \tag{19}$$

$$0 \le x_{ij} \le c_{ij}, \qquad (i,j) \in A \setminus A_a \tag{20}$$

$$0 \le w_k \le h_k - g_k, \qquad k = 1, 2, \ldots, n_s \tag{21}$$

$$x_{ij} \le c_{ij}y_{ij}, \qquad (i,j) \in A_a \tag{22}$$

$$u_p \le z, \qquad p = 1, 2, \ldots, n_0 \tag{23}$$

$$y_{ij} = 0 \text{ or } 1, \qquad (i,j) \in A_a \tag{24}$$

and depending on the kind of optimization:

$$d_p^+ = 0, \qquad d_p^- = 0, \qquad p = 1, 2, \ldots, n_0 \tag{25}$$

for the utopia point calculation or

$$d_p^+ \ge 0, \qquad d_p^- \ge 0, \qquad 0 \le v_p \le 1, \qquad p = 1, 2, \ldots, n_0 \tag{26}$$

for the achievement scalarizing function optimization, respectively, where: $\sigma_p = 1$ and $\delta_p = 0$ during utopia point calculation, $\sigma_p = 1/(q_p^r - q_p^a)$ and $\delta_p = -q_p^a/(q_p^r - q_p^a)$ during the minimization of the achievement scalarizing function, whereas all the other quantities are the same as in Sections 3.1 and 3.2.

The above single-objective problem is a typical mixed integer linear program, i.e., it is a typical linear program with integrality conditions for some variables (namely y_{ij}). Mixed integer linear programs are usually solved by branch and bound approach with utilization of the simplex method. The TRANSLOC solver also uses this approach. Fortunately, only a

7

very small group of decision variables is required to be integer in our model. Therefore we can use a simple branch and bound scheme in the solver.

Even for a small transshipment problem with facility location, the corresponding linear program (13) – (23) has rather large size. For this reason it cannot be solved directly with the standard simplex algorithm. In order to solve the program on IBM–PC XT/AT microcomputers, it is necessary to take advantages of its special structure.

Note that the inequalities (20) – (21) and (25) or (26) are standard simple upper bounds (SUB) which are usually processed outside of the linear programming matrix (Orchard–Hays, 1968). Similarly, inequalities (22) and (23) can be considered as the so–called variable upper bounds (VUB) and processed outside of the matrix due to a special technique. Basic rules of the technique for SUB & VUB processing are developed in Section 3.4.

The main group of equality constraints (14) represents typical network relations. Similarly, the equalities (15) and (16) include only variables with unit coefficients. All the rows (14) – (16) can be handled in the simplex method as the so–called special ordered network (SON) structure. Basic rules of the SON technique used in the TRANSLOC solver are developed in Section 3.5.

Thus only a small number of inequalities (17) – (19) has to be considered as typical rows of linear program. While taking advantage of this fact, the TRANSLOC solver can process transhipment problems of quite large dimensions.

3.4 Implicit representation of VUB & SUB constraints

The single–objective program (13) – (26) includes many inequalities of special simple forms. They can be partitioned into two groups. The first one consists of the so-called simple upper bounds (SUB), i.e., inequalities of the form $0 \leq x_j \leq c_j$ for some variables x_j and constants c_j, such as conditions (20) – (21), (26) with respect to variables v_p, and continuous form of (24). The second one includes the so–called variable upper bounds (VUB), i.e., inequalities of the form $x_j \leq c_j x_k$ for some variables x_j, x_k and constants c_j, such as conditions (22).

SUB constraints are usually implicitly represented in commercial simplex codes (see e.g. Orchard–Hays, 1968). Schrage (1975) proposed some technique for implicit representation of VUB constraints. The technique was further developed and led to effective implementations (see e.g. Todd, 1982).

The techniques presented in the literature deals, however, only with a simple form of VUB constraints. Namely, it is assumed that $c_j = 1$ in all VUBs and there are no upper bounds on x_k variables. The restriction of consideration to only unit variable upper bounds usually does not imply any loss of generality since it can be attained by a proper scaling of the problem. Unfortunately, in our model such scaling techniques cannot be used without destroying of the special SON structure (see Section 3.5). Therefore we were forced to extend the VUB techniques in such a way that nonunit variable upper bounds as well as some simple upper bounds on x_k variables were acceptable.

With respect to the VUB & SUB structure the linear program under consideration can be formulated as follows. The numerical data consist of an $m \times n$ matrix A of rank m, a column m-vector b, a row n-vector f and a column n-vector c. In addition, the index set $N = \{1, 2, \ldots, n\}$ is partitioned into $J \cup K$, where J represents the so–called sons, i.e., variables which appear on the left–hand–side of variable upper bounds, and K represents the so–called fathers, i.e., variables which appear on the right–hand–side of variable upper bounds. Any variable that is not involved in any variable upper bound is regarded as a childless father. The set J is further partitioned into the sets $J(k)$, $k \in K$, where $J(k)$ is the

8

set (possible empty) of sons of the father $k \in K$. It is assumed that the son has only one father and that no father has a father. The father connected to a son x_j will be denoted by $k(j)$. The problem is then

$$\begin{array}{ll}
\max & fx \\
subject\ to & Ax = b \\
& x_j \leq c_j x_k \quad \text{for all} \quad k \in K \text{ and } j \in J(k) \\
& x_k \leq c_k \quad \text{for all} \quad k \in K \\
& x \geq 0
\end{array}$$

Let s_j be a slack variable for the variable upper bound $x_j \leq c_j x_k$, so that

$$x_j + s_j = c_j x_k, \qquad x_j \geq 0, \qquad s_j \geq 0$$

Consider a basic solution to the problem. The basis consists of the $m + v$ columns corresponding to some sons x_j, some fathers x_k and some slacks s_j (where v denotes the number of VUBs). From each VUB either one slack s_j or one son x_j belongs to the basis. Calculation of the basic slacks is out of our interest and they can be simply dropped from the basis, i.e., the corresponding rows and columns can be dropped. Further, the basic sons which arrive in the other VUBs can be eliminated by submission $x_j = c_j x_k$. So, the whole basic solution can be computed from an $m \times m$ basis consisting of some linear combinations of columns from matrix A.

A basic solution to the problem is characterized as follows. The set of sons is partitioned into the three sets $J = JL \cup JU \cup JB$, where JL denotes the set of nonbasic sons fixed at their lower limits (i.e., $x_j = 0$), JU denotes the set of nonbasic sons fixed at their upper limits (i.e., $x_j = c_j x_k$) and JB denotes the set of basic sons. Similarly, the set of fathers is partitioned into three sets $K = KL \cup KU \cup KB$, where KL denotes the set of nonbasic fathers fixed at their lower limits (i.e., $x_k = 0$), KU denotes the set of nonbasic fathers fixed at their upper limits (i.e., $x_k = c_k$), and KB denotes the set of basic fathers. The basis B consists of the columns corresponding to basic sons $B_j = A_j$ and of the columns corresponding to basic fathers given by the formula

$$B_k = A_k + \sum_{j \in J(k) \cap JU} c_j A_j$$

Consider a basic solution given by a basis B and sets JL, JU, JB, KL, KU, KB. For the determination of a nonbasic variable to be enter the basis in the simplex algorithm it is necessary to compute the so–called reduced costs. Let z_i denote an ordinary reduced cost connected to the column A_i, i.e.,

$$z_i = f_i - f_B B^{-1} A_i, \qquad i \in J \cup K$$

where f_B denotes the basic part of the cost vector f. Due to implicit representation of VUBs the reduced costs associated with several nonbasic variables take then form

$$\begin{array}{ll}
d_j = z_j & \text{for} \quad j \in J \\
d_k = z_k + \displaystyle\sum_{j \in J(k) \cap JU} c_j z_j, & \text{for} \quad k \in K
\end{array}$$

Thus, in comparison with pricing in the standard simplex algorithm, the pricing with implicit representation of VUBs needs a calculation of linear combinations of ordinary reduced costs as the only one additional operation.

Due to handling of the SUB structure together with the VUB constraints, a nonbasic variable x_j or x_k is considered as potential incoming variable if one of the following conditions fulfils:

$$
\begin{aligned}
d_j &< 0 \quad \text{and} \quad j \in JL, \\
d_j &> 0 \quad \text{and} \quad j \in JU, \\
d_k &< 0 \quad \text{and} \quad k \in KL, \\
d_k &> 0 \quad \text{and} \quad k \in KU.
\end{aligned}
$$

Implicit representation of VUBs makes some degenerated simplex iterations so simple that they can be performed on line during pricing. Namely, if x_j is an incoming variable and $k(j) \in KL$, then the corresponding simplex iteration depends only on change sets JL and JU, i.e., x_j is moved from the set JL to the set JU or vice versa. Such an operation can be performed while pricing before the computation of reduced costs for fathers.

Let x_s $(s \in J$ or $s \in K)$ be a variable chosen for enter the basis. Considering changes in the basic solution while the value of x_s is either increased for $s \in JL \cup KL$ or decreased for $s \in JU \cup KU$ by a nonnegative parameter Θ we get six formulae for upper bounds on the parameter Θ and six corresponding formulae for determination of the outgoing variable (for details see Ogryczak et al., 1987). Crossing these formulae with four types of incoming variables we get 19 types (5 criss-crossings are not allowed) of the simplex transformations performed in the algorithm with implicit representation of the VUB & SUB structure. The simplest transformation depends only on moving some variable from one set to another without any change of the basis. Most of the transformations depend on performing one of the following operations:

(a) some basic column multiplied by a scalar is added to another basic column;

(b) some basic column is replaced by a nonbasic column or a linear combination of nonbasic columns.

More complex transformations use both the above operations and the most complex one needs two operations of type (a) and one operation of type (b).

3.5 The simplex SON algorithm

The simplex special ordered network (SON) procedure was developed by Glover & Klingman (1981, 1985). It is a partitioning method for solving LP problems with embedded network structure. Every problem of this type is characterized by a full row rank matrix A partitioned as follows:

$$
A = \begin{pmatrix} ANN & ANL \\ ALN & ALL \end{pmatrix}
$$

where $ANN(m \times n)$ denotes the matrix corresponding to a pure network problem and the other submatrices $ANL(m \times p)$, $ALN(q \times n)$, $ALL(q \times p)$ consist of any real elements.

The matrix A of the auxiliary LP problem discussed in Section 3.2 has obviously this form. The matrix ANN is an incidence matrix corresponding to the transportation network studied in Section 3.1. Therefore each constraint represented by a row of ANN corresponds to a node of the network and will be referred to as node constraint. Moreover, each variable represented by a column of ANN corresponds to an arc of the network and will be referred to as arc variable. There are two classes of the ANN columns: columns containing exactly two non-zero entries in ANN (one $+1$ and one -1) called ordinary arcs and columns containing

exactly one non-zero entry in ANN ($+1$ or -1) called slack arcs. The -1 entry in a column indicates the node where the arc begins and the $+1$ entry in a column indicates the node where the arc ends. If a column has exactly one nonzero element pointing one of the arc endpoints then an artificial node outside the network can be meant as the second arc endpoint.

The SUB and VUB simplex algorithms use a basis B which is composed of $m + q$ linearly independent columns selected from the matrix A. Any basis B may be partitioned as follows:

$$B = \begin{pmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{pmatrix}$$

where B_{11} is a nonsingular submatrix of ANN. It appears to be better for the effectiveness of the algorithm if rank of B_{11} is as large as possible.

Let $x_B = (x_{B_1}, x_{B_2})$ denote the basic part of the decision variable vector x, where x_{B_1}, x_{B_2} correspond to the B_{11} and B_{12} submatrices, respectively. Thus the basic variables x_{B_1} are exclusively arc variables. The basic variables x_{B_2} may also contain arc variables. Similarly, the rows of B_{11} are exclusively node rows but the matrix (B_{21}, B_{22}) may also contain node rows.

The basis inverse B^{-1} may be written as follows

$$B^{-1} = \begin{pmatrix} B_{11}^{-1} + B_{11}^{-1} B_{12} V^{-1} B_{21} B_{11}^{-1} & -B_{11}^{-1} B_{12} V^{-1} \\ -V^{-1} B_{21} B_{11}^{-1} & V^{-1} \end{pmatrix}$$

where $V = B_{22} - B_{21} B_{11}^{-1} B_{12}$.

Define the so called master basis tree (MBT) associated with a given basis. The set of nodes of the tree contains all the nodes of our LP/embedded network problem plus an external node called the master root. Thus MBT always contains $m + 1$ nodes

$$N = \{0, 1, \ldots, m\}$$

where 0 is the master root, and m arcs. The nodes of MBT that correspond to rows of B_{21} are called externalized roots (ER's). Each ER is connected to the master root by an externalized arc (EA).

All of the ordinary arcs in B_{11} belong to MBT. There may be two types of slack arcs associated with B_{11}. If a slack arc in B_{11} is a slack arc of ANN then the arc is replaced by an arc between the master root and its unique node. If a slack arc in B_{11} is an ordinary arc in ANN, it is replaced by an arc between its nodes in ANN (one of these endpoints is an ER node).

The arcs in the master basis tree have a natural orientation defined as follows: if an edge (u, v) belongs to MBT and node u is nearer the master root than v, then u is called the predecessor of v, and v is called the immediate successor of u. Thus we will refer to a basis arc as conformable if its ANN direction agrees with its MBT orientation, and refer to the arc as nonconformable otherwise.

The master basis tree is represented by the following node functions.

1. PRED

   The values of the function are defined as follows:

   $PRED[i] =$ the predecessor of node i in MBT .

   For convenience $PRED[0] = -1$.

2. **THREAD**

   The function defines a connecting link (thread) which passes through each node exactly once. If i is a node on the thread, then $THREAD[i]$ is the next one. The alternation of the nodes on the thread is defined by using the preorder method of tree passage.

3. **RETHREAD**

   It is a pointer which points in the reverse order of the thread, i.e., if $THREAD[i] = j$ then $RETHREAD[j] = i$.

4. **DEPTH**

   The value $DEPTH[i]$ specifies the number of arcs in the predecessor path of node i to the master root.

5. **LAST**

   The value $LAST[i]$ specifies the node in the subtree $T(i)$ that is the last node of this subtree in THREAD order.

6. **CONF**

   Each node i in MBT represents the predecessor arc of the node. If the arc is conformable then $CONF[i] = +1$, otherwise $CONF[i] = -1$.

Let $P = \begin{pmatrix} P_1 \\ P_2 \end{pmatrix}$ denote the column vector selected to enter the basis matrix (P_1 specifies the part of P associated with B_{11} and P_2 the part associated with B_{21}). Similarly $\alpha = \begin{pmatrix} \alpha_{B1} \\ \alpha_{B2} \end{pmatrix}$ denotes the representation of P in terms of B.

We have $\alpha = B^{-1}P$ and hence using the partitioning formula for B^{-1} we obtain the following system of equations

$$\alpha_{B2} = V^{-1}(-B_{21}B_{11}^{-1}P_1 + P_2)$$
$$\alpha_{B1} = B_{11}^{-1}(P1 - B_{12}\alpha_{B2})$$

Suppose that the matrix $D = V^{-1}$ (i.e., the right down corner part of the matrix B^{-1}) is attained in the explicit form. Thus, the multiplication by the matrix in the former formula may be simply performed. Both the formulae include a multiplication $x = B_{11}^{-1}G$ with some vector G. This multiplication is equivalent to solving an upper triangular system $\tilde{B}_{11}\tilde{x} = \tilde{G}$, where the matrix $\tilde{B}_{11}$ consists of the rows and columns of B_{11} ordered according to the corresponding nodes and arcs on the THREAD line of MBT.

Each column of $\tilde{B}_{11}$ has at most two nonzero elements. One of them is located at the diagonal and corresponds to a node v while the second one (if exist) is located above the diagonal and corresponds to the predecessor of v. Hence, if the THREAD line is passed backward and the node v is came across then the value of the variable represented by v is computed and simultaneously the value of the variable represented by the predecessor of v is modified. Thus a single pass through the master basis tree along the RETHREAD line is sufficient for computing the x solution. The cost of such a procedure is proportional to the number of nodes in MBT.

Let $c_B = (c_{B1}, c_{B2})$ denote the vector of basis cost coefficients. The dual vector $w = (w_1, w_2) = c_B B^{-1}$ is needed at the pricing step of the simplex method and may be computed as follows:

$$w_2 = (c_{B2} - c_{B1}B_{11}^{-1}B_{12})V^{-1}$$
$$w_1 = (c_{B1} - w_2 B_{21})B_{11}^{-1}$$

The multiplication by the matrix V^{-1} may be directly computed since the matrix is assumed to be kept in the explicit form. Further, both the last formulae include multiplications of the form $w = HB_{11}^{-1}$ which can be effectively executed using the master basis tree structure for B_{11}, similarly as while computing the primal solution x.

Consider a single step of the simplex method. When the incoming and outgoing variables are chosen then the whole basis representation has to be changed and adjusted to the new situation. Thus, the problem arises how to change in a single simplex iteration the matrix D and the functions describing the master basis tree.

Let x_s and x_r denote the incoming and outgoing variables, respectively, and let x_t be the so-called transfer variable that belongs to x_{B2} and replaces x_r in x_{B1}, if it is possible.

At each iteration, the variables can alter by the transitions:

- Incoming variable x_s : $x_N \to x_{B1}$ or x_{B2}

- Outgoing variable x_r : x_{B1} or $x_{B2} \to x_N$

- Transfer variable x_t : $x_{B2} \to x_{B1}$, or no change

- Transfer ER nodes : $x_{B1} \to x_{B2}$ (one ER more),

  or $x_{B2} \to x_{B1}$ (one ER less), or no change.

If an arc is added to the master basis tree then a loop is closed. In order to have a tree in the next iteration also, the loop must be cut and exactly one arc from the loop must be deleted. It is the fundamental exchange rule for the master basis tree.

At each iteration the matrix D is transformed by elimination using a given pivot row. The following cases appear when the elimination is performed:

- the pivot row is within the rows of D;
- the pivot row is outside of D;
- a row and a column of D are dropped;
- a new row and a new column are added to D;
- a column (row) of D is replaced by another column (row) from outside of D.

Combining the elimination cases with the transition rules for the incoming, outgoing and transfer variables we get seven types of basis exchange steps. When x_{B1} is maximal relative to x_{B2}, exactly one of the seven types of basis exchange steps will occur and their updating prescriptions will maintain x_{B1} maximal.

The main features of the discussed approach are cheap multiplication algorithms with basis inverse, accelerated labelling algorithms for modifying the master basis tree in an efficient manner and a compact form of the basis inverse occupying a small memory space only.

4 A tutorial

4.1 The tutorial problem

To illustrate the interactive procedure and the system capabilities we present in this chapter using of DINAS to analyse a small testing example. As the test problem we use an artificial part of the real–life model for the health service districts reorganization.

The problem of health service districts reorganization connected with location of new health–care centers can be formulated as follows. The region under consideration is assumed
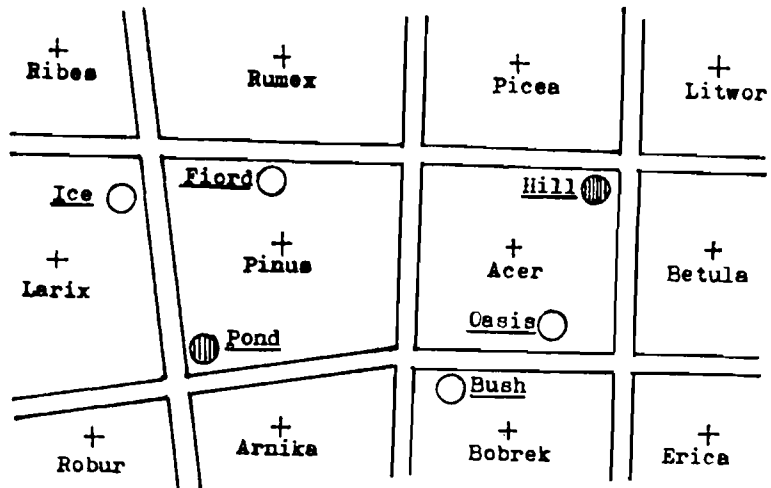
13

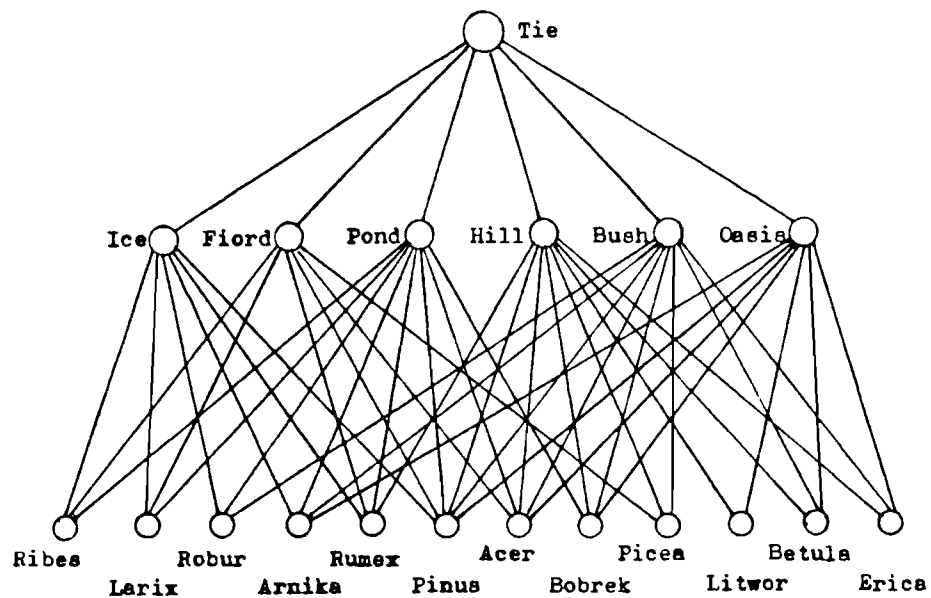Figure 1: The region under consideration

Figure 2: A scheme of the network

14

to consist of some number of geographically defined subareas or census blocks with known distribution of the population. A number of health-care centers is available in the region but their capabilities to offering health services is not sufficient. Therefore some new facilities are located. The problem depends on determination of the locations and capacities of some new centers as well as on assignment of individuals to the centers (new and old). The proposed solution should be optimal with respect to a few objective functions and simultaneously it must be accepted by the competent decision maker.

To set the stage, we consider as a region a part of city as it is shown in Fig. 1. The five major highways divide the region into 12 subareas. For each of these areas the demand on health-care services is identified in thousands of visits per year. These quantities are included in Table 1.

Area	Demand
Ribes	24.5
Larix	25.0
Robur	21.0
Arnika	20.5
Rumex	19.0
Pinus	20.0
Acer	16.0
Bobrek	22.0
Picea	15.0
Litwor	20.5
Betula	13.0
Erica	23.5

Table 1: Demands on health services

Within the region there are two health-care centers offering services: Pond and Hill. They can offer 100 and 90 thousands of visits per year, respectively. Thus the total supply of services amounts 190 while the total demand on services in the region is 240. Therefore some new health-care centers should be located within the region.

There are considered four potential locations for the new centers: Ice, Fiord, Bush and Oasis. The locations are divided into two subsets associated with the corresponding two subregions:

$$North = \{Ice, Fiord\},$$

$$South = \{Bush, Oasis\}.$$

The distance between two potential locations in the same subregion are relatively small whereas each of them can meet the demands on health services. Therefore the locations belonging to the same subregion are considered as exclusive alternatives, i.e., no more than one location from the subregion can be used. Moreover, different designed capacities of health centers are associated with several locations. Table 2 lists capacities of the designed potential health-care centers.

One must decide which potential health-care centers have to be built so as to meet the total demand on health services. The decision should be optimal with respect to the following criteria:

- minimization of the average distance per visit;
- maximization of the overall proximity to centers;

15

Location	Capacity	Subregion
Ice	50	North
Fiord	60	North
Bush	50	South
Oasis	60	South

Table 2: Potential health–care centers

- minimization of the investment cost;
- maximization of the population satisfaction.

The first two criteria are connected with distances between health–care centers and areas assigned to them. Taking into account the urban morphology and the transportation network, it was accepted that the city–block metric was the best approximation to real distances. Therefore we define the distance between an individual and the health center as the rectangular distance between the centre of the corresponding area and the location of the health–care center. Certain connections between the areas and the health centers are eliminated as unacceptable due to too long distances or other troubles with transport. The distances between several areas and all the health centers are given in Table 3. The unacceptable connections are denoted by putting asterisks (*) as a distance.

	Pond	Hill	Ice	Fiord	Bush	Oasis
Ribes	4.14	* * *	2.34	3.03	* * *	* * *
Larix	2.61	* * *	1.35	3.63	* * *	* * *
Robur	2.19	* * *	3.96	* * *	4.38	* * *
Arnika	1.74	* * *	4.08	* * *	2.70	3.51
Rumex	4.53	4.32	2.85	1.35	* * *	* * *
Pinus	2.28	4.14	1.80	0.81	2.94	4.14
Acer	4.02	1.95	* * *	3.27	1.77	1.56
Bobrek	3.84	4.17	* * *	* * *	1.35	1.65
Picea	* * *	2.01	* * *	3.30	4.71	* * *
Litwor	* * *	2.22	* * *	* * *	* * *	4.65
Betula	* * *	1.95	* * *	* * *	4.02	3.06
Erica	* * *	3.72	* * *	* * *	3.42	2.46

Table 3: Distance coefficients

The overall proximity to the health care services is defined as a sum of all the individual proximity coefficients. The individual proximity is assumed to be inversely proportional to square of the distance to the health–care center. More precisely, the individual proximity coefficients are defined according to the following formula (compare Abernathy and Hershey, 1972):

$$p_{ac} = 1/(d_{ac} + \varepsilon)^2$$

where d_{ac} denotes the distance between the corresponding area a and the health–care center c, and ε is an arbitrarily small positive number. The proximity coefficients for the whole region under consideration are given in Table 4.

The investment cost and the population satisfaction level are assumed to be a sum of fixed costs and a sum of fixed satisfaction levels connected with several possible locations, respectively. In our example the fixed coefficients take values given in Table 5.

	Pond	Hill	Ice	Fiord	Bush	Oasis
Ribes	5.83	★ ★ ★	18.26	10.89	★ ★ ★	★ ★ ★
Larix	14.68	★ ★ ★	54.87	7.59	★ ★ ★	★ ★ ★
Robur	20.85	★ ★ ★	6.38	★ ★ ★	5.21	★ ★ ★
Arnika	33.03	★ ★ ★	6.01	★ ★ ★	13.72	8.12
Rumex	4.87	5.36	12.31	54.87	★ ★ ★	★ ★ ★
Pinus	19.24	5.83	30.86	152.42	11.57	5.83
Acer	6.19	26.30	★ ★ ★	9.35	31.92	41.09
Bobrek	6.78	5.75	★ ★ ★	★ ★ ★	54.87	36.73
Picea	★ ★ ★	24.75	★ ★ ★	9.18	4.51	★ ★ ★
Litwor	★ ★ ★	20.29	★ ★ ★	★ ★ ★	★ ★ ★	4.62
Betula	★ ★ ★	26.30	★ ★ ★	★ ★ ★	6.19	10.68
Erica	★ ★ ★	7.23	★ ★ ★	★ ★ ★	8.55	16.52

Table 4: Proximity coefficients

	Ice	Fiord	Bush	Oasis
Investment	200	212	186	201
Satisfaction	176	87	100	192

Table 5: Investment and satisfaction coefficients

In the next section we show how the above problem can be formulated as a multiobjective transshipment problem with facility location, i.e., in the form which can be processed by the DINAS system.

4.2 The network model

The problem of health service districts reorganization connected with location of new health–care centers stated in the previous section can be easy formulated as a multiobjective transshipment problem with facility location. The areas and existing health–care centers are, certainly, fixed nodes of the network under consideration. Similarly, all the potential locations of new health centers are treated as potential nodes. Arcs represent all the possible assignments of patients to the health–care centers, i.e., arcs are associated with all the nonempty cells in Table 3 or 4. A flow along the arc from a center c to an area a expresses a number of visits in the area a serviced by the center c. In order to balance the problem in terms of supply and demand an artificial node Tie with supply equal to the overall demand is introduced. There are also defined additional arcs from the artificial node to each health–care center (existing or potential). Capacity of the existing health–care centers (Pond and Hill) are then represented as capacities of the arcs from Tie to the corresponding fixed nodes. A scheme of the network is presented in Fig. 2.

Now we can define several groups of data of the multiobjective transshipment problem with facility location. As we have mentioned in Section 1 the fixed node is characterized only by the balance, i.e., difference between the corresponding supply and demand. Table 6 lists supplies, demands and balances for all the fixed nodes in our model. Note that the sum of supplies is equal to the sum of demands and thereby the sum of balances is equal to zero.

In the transshipment problem with facility location objective functions are considered as sums of linear functions of flows along several arcs and fixed costs connected with the used locations. In our model objective functions can be divided into two groups. Functions

17

Node	Supply	Demand	Balance
Ribes	0	24.5	-24.5
Larix	0	25.0	-25.0
Robur	0	21.0	-21.0
Arnika	0	20.5	-20.5
Rumex	0	19.0	-19.0
Pinus	0	20.0	-20.0
Acer	0	16.0	-16.0
Bobrek	0	22.0	-22.0
Picea	0	15.0	-15.0
Litwor	0	20.5	-20.5
Betula	0	13.0	-13.0
Erica	0	23.5	-23.5
Pond	0	0	0
Hill	0	0	0
Tie	240	0	240

Table 6: Fixed nodes

Investment (cost) and Satisfaction (level) are independent of the assignment decisions and thereby they have not coefficients connected with flows along arcs (i.e., these coefficients are equal to 0). On the other hand, functions (average) Distance and (overall) Proximity depend only on assignment decisions and they have not contain fixed terms connected with locational decisions. Fixed coefficients of the functions Investment and Satisfaction can be directly taken from Table 5. Similarly, the linear coefficients of the function Proximity are given in Table 4. The linear coefficients of the function Distance are defined as quotients of the corresponding distances by the sum of demands, i.e., as $d_{ac}/240$.

There are four potential nodes which represent the potential locations of the health-care centers, i.e., Ice, Fiord, Bush, Oasis. The data connected with the potential nodes are listed in Table 7. Here and thereafter the objective functions are denoted by abbreviations of the corresponding names.

Node	Capacity	Fixed costs			
		Invest	Satisf	Dist	Prox
Ice	50	200	176	0	0
Fiord	60	212	87	0	0
Bush	50	186	100	0	0
Oasis	60	201	192	0	0

Table 7: Potential nodes

As we have already mentioned the locations belonging to the same subregion are considered as exclusive alternatives, i.e., no more than one location from the subregion can be used. Therefore we introduce into the network model selections which represent such a type of requirements. In our model there are two selections associated with to subregions: North and South. Both the selections have the lower numbers equal to 0 and the upper numbers equal to 1. It guarantees that at most one potential node in each selection is active. The complete data connected with selections are given in Table 8.

The last group of data is connected with the arcs. The arcs are characterized by their capacities and objective functions coefficients. The cost coefficients have been already dis-

Selection	Alternative nodes	Lower number	Upper number
North	Ice, Fiord	0	1
South	Bush, Oasis	0	1

Table 8: Selections

cussed while consideration of the objective functions. Capacities of the arcs from the artificial node Tie to the nodes representing health–care centers (Pond, Hill, Ice, Fiord, Bush, Oasis) express capacities of the corresponding centers. The arcs connecting the nodes representing health–care centers with the nodes representing the areas have essentially unlimited capacities. However, in practice, flows along these arcs are also bounded by capacities of the corresponding health–care centers and we use them as arcs capacities. All the data connected with arcs are listed in Table 9.

4.3 Getting started

To perform interactive analysis of the multiobjective problem with DINAS you need not to be familiar with neither computer techniques nor mathematical programming. DINAS is a menu–driven system with very simply commands. It is also equipped with the HELP file.

DINAS is started simply by typing command DINAS. Make sure that the drive containing the DINAS diskette is the default drive or the corresponding directory on the hard disk is the default directory. Type DINAS and press <ENTER>. The system cover is then visible on the display and there is a short pause while DOS finds and loads the execution program. When the loading procedure has already finished the blinking message:

Press any key to continue!

appears at the bottom of the display. Pressing <ENTER> or any other key, you will see the Main Menu screen with the system banner (see Fig. 3). From this moment the HELP file is still available. Press the <F1> function key to recognize it. You will get then full screen information about the Main Menu. Using the <PGDN> or <PGUP> keys you can select several screens which provide you with short characteristics of the menu commands. The same information is listed in Appendix B of this manual.

Operations available in the Main Menu are partitioned into three groups and corresponding three branches of the menu: PROCESS, SOLUTION and ANALYSIS. Command selection is performed with using a reverse image pointer which is controlled by the arrow keys. Namely, using the <LEFT> or <RIGHT> arrow you select a proper menu branch, and using the <UP> or <DOWN> arrow you select a proper item within the branch. Try to go across the menu. Note that only the selected branch is visible in an expanded form with the commands list and the pointer position within a list is automatically restored during the next selection of the same branch. For execution of the selected command you have to press <ENTER>. After a command has been executed you need, usually, to press the <ESC> key in order to return control to the Main Menu.

At the beginning the PROCESS branch is initialized. The PROCESS branch contains basic operations connected with processing of the multiobjective problem and generation of several efficient solutions. There are included problem definition operations such as calling the Network Editor for input or modification of the problem (PROBLEM) and converting of the edited problem with error checking (CONVERT). Further, in this branch the basic optimization

19

From	To	Capacity	Invest	Satisf	Dist	Prox
Tie	Pond	100	0	0	0	0.
Tie	Hill	90	0	0	0	0.
Tie	Ice	50	0	0	0	0.
Tie	Fiord	60	0	0	0	0.
Tie	Bush	50	0	0	0	0.
Tie	Oasis	60	0	0	0	0.
Pond	Ribes	100	0	0	.01725	5.83
Pond	Larix	100	0	0	.010875	14.68
Pond	Robur	100	0	0	.009125	20.85
Pond	Arnika	100	0	0	.00725	33.03
Pond	Rumex	100	0	0	.018875	4.87
Pond	Pinus	100	0	0	.0095	19.24
Pond	Acer	100	0	0	.01675	6.19
Pond	Bobrek	100	0	0	.016	6.78
Hill	Rumex	90	0	0	.018	5.36
Hill	Pinus	90	0	0	.01725	5.83
Hill	Acer	90	0	0	.008125	26.30
Hill	Bobrek	90	0	0	.017375	5.75
Hill	Picea	90	0	0	.008375	24.75
Hill	Litwor	90	0	0	.00925	20.29
Hill	Betula	90	0	0	.008125	26.30
Hill	Erica	90	0	0	.0155	7.23
Ice	Ribes	50	0	0	.00975	18.26
Ice	Larix	50	0	0	.005625	54.87
Ice	Robur	50	0	0	.0165	6.38
Ice	Arnika	50	0	0	.017	6.01
Ice	Rumex	50	0	0	.011875	12.31
Ice	Pinus	50	0	0	.0075	30.86
Fiord	Ribes	60	0	0	.012625	10.89
Fiord	Larix	60	0	0	.015125	7.59
Fiord	Rumex	60	0	0	.005625	54.87
Fiord	Pinus	60	0	0	.003375	152.42
Fiord	Acer	60	0	0	.013625	9.35
Fiord	Picea	60	0	0	.013750	9.18
Bush	Robur	50	0	0	.01825	. 5.21
Bush	Arnika	50	0	0	.01125	13.72
Bush	Pinus	50	0	0	.01225	11.57
Bush	Acer	50	0	0	.007375	31.92
Bush	Bobrek	50	0	0	.005625	54.87
Bush	Picea	50	0	0	.019625	4.51
Bush	Betula	50	0	0	.01675	6.19
Bush	Erica	50	0	0	.01425	8.55
Oasis	Arnika	60	0	0	.014625	8.12
Oasis	Pinus	60	0	0	.01725	5.83
Oasis	Acer	60	0	0	.0065	41.09
Oasis	Bobrek	60	0	0	.006875	36.73
Oasis	Litwor	60	0	0	.019375	4.62
Oasis	Betula	60	0	0	.01275	10.68
Oasis	Erica	60	0	0	.01025	16.52

Table 9: Arcs

```
┌────────────┬──────────────────┬──────────────────┐
│            │     Solution     │     Analysis     │
├──────────┐ │                  │                  │
│ Problem  │ │                                     │
│ Convert  │ │                                     │
│ Pay-Off  │ │                                     │
│ Efficient│ │                                     │
│ Quit     │ │                                     │
└──────────┘                                       │
```
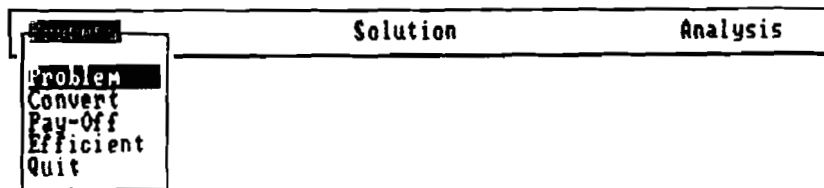
⬆ ⬇ ⬛ ⬛ Pointer Movement   ⬛⬛⬛⬛ Command Execution

Figure 3: Main Menu screen

```
┌─────────────────────────┐
│   Problem Statistics    │
├─────────────────────────┤
│ NAME             demo   │
│ Objectives          4   │
│ Arcs               49   │
│ Fixed Nodes        15   │
│ Potential Nodes     4   │
│ Selections          2   │
└─────────────────────────┘
```

Figure 4: Problem statistics

21

operations are available: the computation of the pay–off matrix with the utopia and nadir vectors (PAY-OFF) and the generation of efficient solutions depending on the edited aspiration and reservation levels (EFFICIENT). As the last command in this branch is placed the QUIT operation which allows you to finish work with the system.

The SOLUTION and ANALYSIS branches collect additional operations on the efficient solutions. So, at the beginning their commands are not available. If you try to execute such a command you will get the error message:

```
There are no solutions !
SELECT ANOTHER COMMAND !
```

You have then to press the <ESC> key to return control to the Main Menu and select a proper command.

Before the multiobjective analysis is launched, a file must be constructed describing the problem to be analysed. This file is called the network file. It is a special binary file generated by the Network Editor. The Network Editor is called by execution of the PROBLEM command. Thus the PROBLEM command is usually selected as the initial step.

In the next section we describe in details the process of the network file preparation for the tutorial problem. However, if you want to learn only the Interactive System without uphill data input you can skip this stage and use our network file. On the distribution diskette there is available a network file DEMO which contains the data for the tutorial problem.

The network file created and saved during the execution of the PROBLEM command is not automatically assigned to the Interactive System. You may edit many various network files during a single editor calling. To assign a specific network file to the system you have to execute the CONVERT command. The execution of the CONVERT command makes the specified problem (network file) available for the system. Thus in both the cases: after the preparation of a network file by yourself as well as while using the DEMO file you have to execute the CONVERT command.

After selecting the CONVERT command you will be asked for a specification of the problem name. For this purpose a special 38–character field is displayed preceded by the message:

```
GIVE Problem Name :
```

You can type then DEMO or the name of your network file, respectively. If you have made a mistake while typing you can correct it by using the <LEFT> or <RIGHT> arrows for cursor movement and the <DEL> key to cancel improper characters. The general field editing rules are summarized in Appendix A.

Next, the specified problem data will be converted with error checking. Any recognized data error will be reported on the display. In case of using the DEMO file no errors should be reported. After a successful conversion the problem statistics will be presented (see Fig. 4). You may read there that the problem is built of 4 objectives, 49 arcs, 15 fixed nodes and 4 potential nodes organized into 2 selections. In order to return control to the Main Menu you have to press the <ESC> key.

4.4 The network file preparation

Let you try to prepare the network file for the tutorial problem. The file has to contain all the information defining the problem, such as:

- the names, types and activities for the objectives;

22

- the names and balances for the fixed nodes;
- the names, capacities, selections and objective coefficients for the potential nodes;
- the bounds for the selections;
- the names (optionally), capacities and objective coefficients for the arcs.

The data need not to be edited sequentially after the fashion of the given data tables (see Tables 6 to 9) but rather following the scheme of the network by visiting nodes and arcs according to the network structure.

To create the network file you have to select the PROBLEM command from the PROCESS branch of the DINAS Main Menu. Then the Network Editor (called EDINET) is loaded and the Editor Menu screen with the editor banner appears after a little while (see Figure 5). From this moment the editor HELP file is still available by pressing the <F1> key. Press the <F1> key to recognize the HELP file.

The editor commands are partitioned into three branches: FILE, PRINT NETWORK and EDIT NETWORK. The FILE branch collects commands associated with file operations and leaving the editor. The PRINT NETWORK branch consists of a single command which generates various reports. The EDIT NETWORK branch collects the editor commands which enable a problem data input or modification. Similarly as in the Main Menu a command is selected using a reverse image pointer which is controlled by the arrow keys.

The head line of the menu contains the names of the branches. The first branch FILE is active so its three commands are listed below. The cursor points out the LOAD command. Press <ENTER> to execute the LOAD command. Then the file name line appears on the display:

File:

and you are asked to define a file name. Type any legal new file name, e.g., Health, and press <ENTER>. Then the message:

Some problems with data file - press ENTER

will be issued since the file Health does not exist as yet. Press <ENTER> again. The new network file Health.net has been just opened and the Editor Menu is again activated.

Select the EDIT NETWORK branch from the menu using the <RIGHT> arrow. Then the display with the listed EDIT NETWORK commands is visible (see Figure 6).

It appears to be most effective if you execute at first the OBJECTIVES command. Having defined the objectives you will be able to edit the objective coefficients while visiting several nodes and arcs since the objective names will be automatically introduced into the corresponding windows.

Thus execute the OBJECTIVES command. Then the OBJECTIVES window is displayed. The cursor points out the field of the first objective name. Type the name of the objective Invest. Next, you should define the TYPE of the objective (MIN for minimization or MAX for maximization) and its ACTIVITY (YES if active, NO otherwise). Since there are highlighted the proper options in the fields TYPE and ACTIVITY (MIN and YES, respectively) press the <DOWN> arrow to finish inserting this objective.

Now, the cursor points out the second objective name. Type the name Satisf. Next, you must change the highlighted option in the TYPE field since the objective have to be maximized. To select the MAX option press <ENTER> and use the <RIGHT> arrow. At the end press the <DOWN> arrow to point out the name field of the next objective. The other objectives may be defined in a similar way. The complete objective window is presented in Figure 7.

23

```
┌──────┐
│ File │              Print Network                      Edit Network
├──────┤
│Load  │
│Save  │
│Quit  │
└──────┘
```
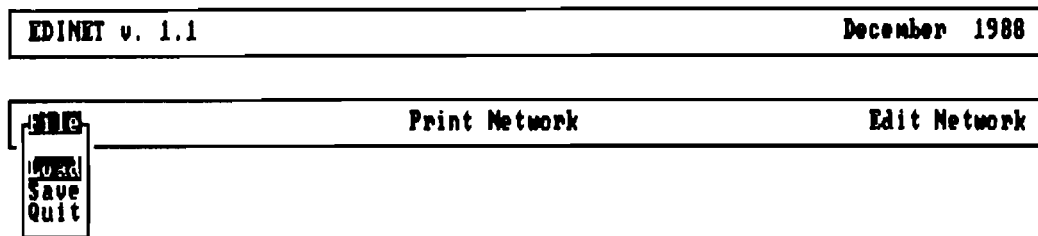
⊔ ⊔ ⊒ ⊒ pointer movement ⬛⬛⬛ command execution

Figure 5: Editor Menu with the FILE branch specified

```
File                   Print Network                  ┌─Edit Network─┐
                                                       │List Nodes    │
                                                       │Network       │
                                                       │Selections    │
                                                       │Objectives    │
                                                       └──────────────┘
```
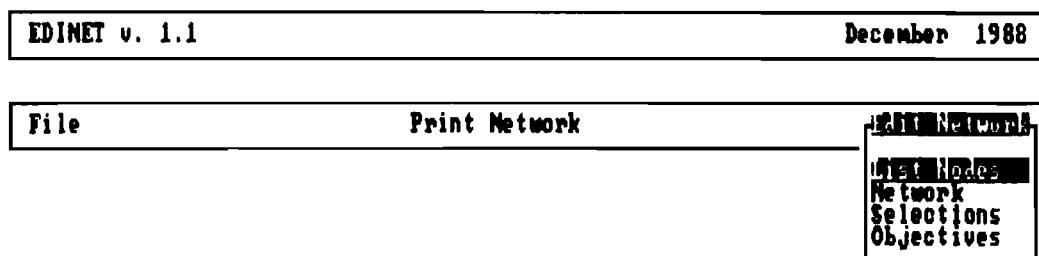
⊔ ⊔ ⊒ ⊒ pointer movement ⬛⬛⬛ command execution

Figure 6: Editor Menu with the EDIT NETWORK branch specified

After the definition of all the objectives is finished press <ESC> to return control to the Editor Menu.

In order to edit nodes and arcs of the network select the LIST NODES command and press <ESC>. The execution of this command causes that the LIST NODES window is displayed. The window is blank since any node has not been defined as yet. To define a node , e.g., Bush, enter the first character of the node name (the capital B). Then the CURRENT NODE name window appears (see Figure 8). The character B is displayed inside the name field as the first character of the name. Finish typing of the name and press <ENTER>. Then the window presented in Figure 9 appears. The cursor points out the default "fixed" option. Use the <RIGHT> arrow to select the "potential" option since the node Bush is a potential one, and press <ENTER>. The potential node window with the node Bush as CURRENT NODE is then displayed (see Figure 10a).

The cursor points out the capacity field inside the window. Edit the capacity of Bush: 50, and press the <DOWN> arrow. Edit the name South of the unique selection containing the node and press the <DOWN> arrow. Now, the block of objectives is displayed inside the window. The cursor points out the coefficient field of the objective Invest. Insert the coefficient 186 and press the <DOWN> arrow to point the next objective field. Insert the coefficient 100 corresponding to the objective Satisf. The editor treats the blank coefficient fields as zeroes. Thus you need not to edit the coefficients corresponding to the Dist and Prox objectives since both of them are equal to zero. The complete potential node window is presented in Figure 10b.

Press <ESC> to finish editing of the data characterizing the node Bush. Then two additional windows are displayed on the screen (see Fig. 11): the NODE FROM list window (on the left hand side) and the NODE TO list window (on the right hand side). The windows allow you to define the predecessors and successors to the node Bush. Press <CTRL>/<LEFT> arrow to activate the NODE FROM window. Type the name Tie of the single predecessor to the node Bush. After the first character T of the name is inserted, the NODE FROM name window appears. The character T is displayed inside the name field. Finish inserting of the name Tie and press <ENTER> to select the default option "fixed" since the node Tie is fixed. The fixed node window with the node Tie as NODE FROM is then displayed. The cursor points out the balance field inside the window. Edit the balance of Tie as 240, and press <ESC>.

At the down–left corner of the window the brief question:

ARC?

appears (see Figure 12). You are asked this way whether you wish to edit data characterizing the arc Tie–Bush.

Press <Y> to display the predecessor arc window. The cursor points out the arc name field. Edit an arc name, e.g., Tiebush, if you wish it. Note that the arc name need not to be inserted due to its optional character (press the <DOWN> arrow to avoid the arc name editing). After pressing <ENTER> (or <DOWN> arrow) the capacity field of the arc is pointed out. Edit capacity as 50, and press <ENTER>. The cursor moves to the objectives block and points out the Invest coefficient field. All the objective coefficients corresponding to the arc Tie–Bush have the zero value so you may to let their fields be blank. Thus the editing of this arc is finished. Press <ESC>.

After pressing <ESC> the NODE FROM list window appears. Activate the CURRENT NODE window using again the <ESC> key. In order to edit the data of successors to the current node Bush press <CTRL>/<RIGHT> arrow. The NODE TO list window (empty as yet) is then activated. Type the name of a successor to the node Bush, e.g., Robur. After inserting of

File   Print Network   Edit Network

Objective Type   Active   List Nodes
                                                  Network
Invest   MINIMAX No :Yes   Selections
Satisf   MIN :MAX No :Yes   Objectives
Dist   MINIMAX No :Yes
Prox   MIN :MAX No :Yes

     Del Delete   Objective   ESC exit
  U D   pointer movement ENTER command execution

Figure 7: OBJECTIVES window

CURRENT NODE

Name B

Figure 8: NODE name window

26

Figure 9: NODE type window

Figure 10a: Initial potential node window

Figure 10b: Complete potential node window

27

the first character R the NODE TO name window is displayed. The character R is found inside the name field. Finish editing of the name and press <ENTER>. The cursor points out the "fixed" option. Press <ENTER> to confirm this option since Robur is a fixed node. The fixed node window with the node Robur as NODE TO is then displayed. The cursor points out the balance field inside the window. Edit the balance of Robur as -21, and press <ENTER>.

At the down-left corner of the window the question:

ARC?

is issued. Press <Y> to edit data of the arc Bush-Robur. Then you can see the ARC window corresponding to the arc Bush-Robur. The cursor points out the arc name field. Edit an arc name, e.g., Burob, the capacity of the arc (50) and the associated objective coefficients (Invest=0, Satisf=0, Dist=0.01825, Prox=5.21). This completed arc window is presented in Figure 13.

Press <CTRL>/<RIGHT> arrow and <ESC> to return to the NODE TO list window. The first line of the window contains the node name Robur and the arc name Burob. Repeat the similar procedure to edit data of the other successors to the node Bush, i.e., Arnika, Pinus, Acer, Bobrek, Picea, Betula, Erica. The NODE TO (likewise NODE FROM) list window may contain at most seven node names and associated arc names. Therefore after editing the eighth successor Erica you have to scroll the list with <DOWN/UP> arrow in order to look over all the successors since either the first or the eighth successor is not visible. The full NODE TO list window is presented in Figure 14.

Suppose that the data of successors to the node Bush are edited and the NODE TO list is displayed. To modify the data of a node or an arc you have at first to select the name of the corresponding successor (e.g., Robur). Press <ENTER> to display the NODE TO window and modify the data of the selected node Robur. If you want to modify the data of the arc Bush-Robur only, e.g., its name, press <CTRL>/<RIGHT> arrow. The corresponding arc window is then displayed. Change the name Burob into Buro (deleting the last character b) and press <CTRL>/<RIGHT> arrow to return to the NODE TO list window.

Use the <ALT>/<N> keys to call a network scheme of the edited part of the network. Verify conformity of the scheme to the network structure. Use the <DOWN> arrow key to introduce the node Bush onto the pointed out position (the highest central position). This compact part of the scheme illustrates the network part just edited (see Figure 15).

Press <LEFT> arrow to point the node Tie and then press <ENTER>. In result this node will occupy the central pointed out position. Use <ENTER> again to display the CURRENT/FROM/TO screen with the node Tie as the current one. The NODE FROM list window is blank since Tie has not any predecessor. Inside of the NODE TO list window there is only the single successor Bush.

Press <CTRL>/<RIGHT> arrow to activate the NODE TO list window. Type the name of another successor to the node Tie, say Hill, to edit data corresponding to this node and to the arc Tie-Hill. The editing may be performed similarly as it was mentioned in case of the node Robur. Repeat this procedure in order to introduce data corresponding to other successors to the node Tie (Pond, Oasis, Fiord, Ice).

After all these successors are introduced with their data press <ALT>/<L> to display the LIST NODES window (see Fig. 16). You may find the following node names inside the window: Acer, Arnika, Betula, Bobrek, Bush, Erica, Fiord, Hill, Ice, Oasis, Picea, Pinus, Pond, Robur, Tie, provided that the editing was performed correctly. Use arrow keys to select the node name Hill and press <ENTER>. This name with the associated balance appears inside the

┌─────NODE FROM──────┐   ┌──CURRENT NODE──┐   ┌─────NODE TO──────┐
│ Node   Arc   │   │   │   │ Node   Arc │
│   │   │ Name   BUSH   │   │   │
│   │   │ Type potential │   │   │
│   │   │ Capacity 50   │   │   │
│   │   │   │   │   │
│   │   │ Selections   │   │   │
│   │   │ South   │   │   │
│   │   │ Objectives   │   │   │
│   │   │ name   coefficient│ │   │
└────────────────────┘   │ Invest   186 │   └──────────────────┘
                            │ Satisf   100 │
                            │ Dist   │
                            │ Prox   │

     ↑↓ ← → move to NODE FROM/TO   ESC exit
 Add   Current Delete List Network Objectives Selections

Figure 11: CURRENT NODE and NODE FROM/TO list windows

┌──NODE FROM──┐   ┌──CURRENT NODE──┐   ┌─────NODE TO──────┐
│ Name   TIE │   │   │   │ Node   Arc │
│ Type fixed │   │ Name   BUSH   │   │   │
│ Balance 210 │   │ Type potential │   │   │
│ ARC?   │   │ Capacity 50   │   │   │
└─────────────┘   │   │   │   │
                     │ Selections   │   │   │
                     │ South   │   │   │
                     │ Objectives   │   └──────────────────┘
                     │ name   coefficient│
                     │ Invest   186 │
                     │ Satisf   100 │
                     │ Dist   │
                     │ Prox   │

     ↵ inspect the arc
 Add   Current Delete List Network Objectives Selections

Figure 12: Fixed node window with the node Tie

29

Figure 13: Arc window

Figure 14: The full NODE TO list window

CURRENT NODE window since the node was defined before. The node Tie occupy the NODE FROM list window alone and the NODE TO list window is empty.

Activate the NODE TO list window pressing <CTRL>/<RIGHT> arrow. The successors to the node Hill are divided into two subsets: the subset of succeeding nodes which are not defined yet (Litwor, Rumex) and the subset of succeeding nodes which are already defined (Acer, Betula, Bobrek, Erica, Picea, Pinus). To define the nodes Litwor and Rumex repeat the procedure used in case of the node Robur. Defining of the other successors is easier since after editing of an existing node name, the NODE TO window with the data associated with this node immediately appears.

Type, say, the name Acer that is already defined. Pressing the first character A causes calling of the NODE TO name window. This character is found inside the name field. Finish editing of the name and press <ENTER>. Then the "fixed" NODE TO window will be automatically displayed with the node name Acer and the corresponding balance -16. After pressing <ESC> you are asked (ARC?) whether you want to define the arc Hill–Acer or not. Define the arc similarly as it was performed in case of the arc Bush–Robur. Define in such a way the other successors (Betula, Bobrek, Erica, Picea, Pinus) and return to the NODE TO list window.

Select the node name Pinus and use <ALT>/<C> keys. The CURRENT NODE window will be then activated with the current node Pinus. Activate the NODE FROM window by pressing <CTRL>/<LEFT> arrow. The window contains two node names: Bush and Hill. Define the other predecessors to the node Pinus: Ice, Fiord, Pond and Oasis, with their arcs.

Similarly, select the node name Ice inside the NODE FROM window and press <ALT>/<C>. The node Ice becomes now the current node and the CURRENT NODE window is activated. Use <CTRL>/<RIGHT> arrow to activate the NODE TO window. Define successors to the node Ice.

Continue defining of the network and verify sometimes (using <ALT>/<L> and <ALT>/<N> commands) whether the introduced data are completed.

After editing of the network is finished press <ALT>/<S> to execute the SELECTIONS command. Then the SELECTIONS window will be issued (see Figure 17). The selections list inside the window contains two selections: North with the nodes Fiord and Ice, and South with the nodes Bush and Oasis. The North selection is pointed out. Press <ENTER> to display the BOUNDS window corresponding to the pointed selection. Edit the lower bound as 0 and the upper bound as 1 and press <ESC>. The selection list appears again. Use the <DOWN> arrow to introduce the South selection into the pointed out position and press <ENTER>. The BOUNDS window for editing of the South selection bounds is then displayed (see Figure 18). Edit the lower bound as 0 and the upper bound as 1 and press <ESC> to leave the BOUNDS window. At the end press <ESC> to leave the SELECTIONS window.

The input data of the network are completed. Now you have to save the edited data on a disk. For this purpose you have to press <ESC> a few times so as to return to the Editor Menu and execute the SAVE command. Then this message:

> File: Health.net

will be issued. To save this network file in the default directory press <ENTER>.

The editing of the network file Health.net is finished. In order to leave the editor select the QUIT command and press <ENTER>.

4.5   Introductory multiobjective analysis

In this and subsequent sections we present an outline of the basic multiobjective analysis performed on our test problem. We do not discuss all the capabilities of the system which

Tie ——————————— Bush ——————————— Robur
                                     — Arnika
                                     — Pinus
                                     — Acer
                                     — Bobrek
                                     — Picea
                                     — Betula
                                     — Erica

Bush ——————————— Erica

Bush ——————————— Picea

Bush ——————————— Pinus

Bush ——————————— Robur

Structure of the network for problem ucho.net

move inside the net   select node
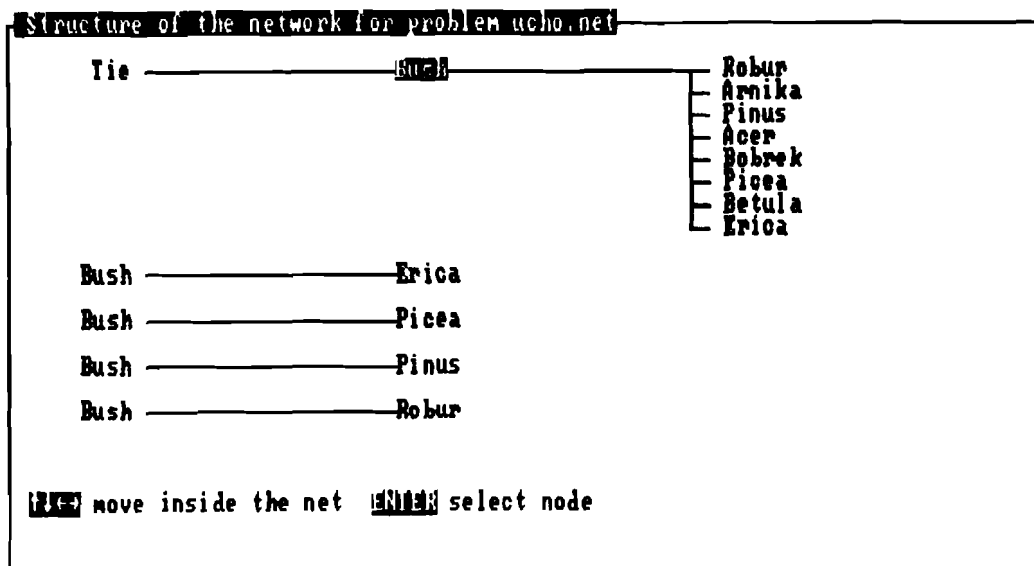
Figure 15: A part of the network scheme

List of nodes for problem ucho.net

Acer	Arnika	Betula	Bobrek	Bush	Erica	Fiord
Hill	Ioe	Oasis	Picea	Pinus	Pond	Robur
Tie						

move cursor   node name or select node   select node

Figure 16: LIST NODES window

32

NODE FROM
Node   Arc
■■■   TIEH

███CURRENT█NODE█
Name   ■■■■
Type fixed
Balance ███████████

NODE TO
Node   Arc
██████   HI ██
Pinus   HIP
Acer   HIA
Bobrek   HIB
          IC
          I

Selection   Nodes
███■   Fiord   Ice
South   Bush   Oasis

███ ■ ■ move to NODE FROM/TO   ███ exit
███ ██rrent ██lete ██st ██twork ██jectives ██lections

Figure 17: SELECTIONS window

NODE FROM
Node   Arc
■■■   TIEH

███CURRENT█NODE█
Name   ■■■■
Type fixed
Balance ███████████

NODE TO
Node   Arc
██████   HI ██
Pinus   HIP
Acer   HIA
Bobrek   HIB
          IC
          I

Selection   Nodes
███■   Bush   Oasis

Selection South
BOUNDS
██per ██████
██wer ██████

███ ■ ■ move to NODE FROM/TO   ███ exit
███ ██rrent ██lete ██st ██twork ██jectives ██lections

Figure 18: BOUNDS window

can be used in such an analysis.

Having defined and converted the problem as the first step of the multiobjective analysis you must perform the PAY-OFF command. It executes the optimization of each objective function separately. While performing of the optimization the computation process is reported by messages like this:

WAIT   Iterations: 57   Solutions: 0

where the numbers represent the number of simplex steps having performed and the number of feasible solutions having examined, respectively. You can suspend the computations at any moment (by pressing <ENTER> or any other key) and cancel them or continue after a break. Try it.

Finally, you get the so–called pay–off matrix presented in Fig 19. The pay–off matrix is a well–known device in multiobjective programming. It gives values of all the objective functions (columns) obtained while solving several single–objective problems (rows) and thereby it helps to understand the conflicts between different objectives.

Execution of the PAY-OFF command provides also you with two reference vectors: the utopia vector and the nadir vector (see Fig. 19). The utopia vector represents the best values of each objective considered separately, and the nadir vector expresses the worst values of each objective noticed during optimization of another objective function. The utopia vector is, usually, not attainable, i.e., there are no feasible solutions with such objective values.

While analysing tables in Fig. 19 you may find out that the objective values vary significantly depending on the selected optimization. Only for the average distance you may notice the relative variation less than 30% whereas for the other objectives it even overstep 100%. Moreover, you may recognize a strong conflict between the investment cost and all the other objectives. While minimizing the investment cost you get the worst values for all the other objectives. On the other hand, while optimizing another objective function you get doubled investment cost in comparison with its minimal value.

Coefficients of the nadir vector cannot be considered as the worst values of the objectives over the whole efficient (Pareto–optimal) set. They usually estimate these values but they express only the worst values of each objective noticed during optimization of another objective function. In further analysis we will show that these estimations can be sometimes overstep.

Due to the special regularization technique used while computation of the pay–off matrix (see Chapter 3) each generated single–objective optimal solution is also an efficient solution to the multiobjective problem. DINAS stores the efficient solutions in a special Solution Base. All the efficient solutions generated (or input from a file) during a session get consecutive numbers and are automatically put into the Solution Base.

DINAS is armed with many operations which help to manage the Solution Base. There are two kinds of operations connected with the Solution Base: operations on a single efficient solution, and operations on the whole Solution Base. Operations addressed to a single solution are connected with the Current Solution. The newest generated efficient solution is automatically assumed to be the Current Solution but any efficient solution from the Solution Base can be manually activated as the Current Solution.

So, you have already available in the Solution Base four efficient solutions connected with several rows of the pay–off matrix. Using different commands of DINAS we can examine in details these solutions.

The SOLUTION branch contains additional operations connected with the Current Solution. You can examine in details the Current Solution using the Network Editor (BROWSE) or analyse

```
┌──────────────Pay-Off Matrix──────────────┐
│          Invest   Satisf   Dist     Prox  │
│ Invest   186      100      2.61e+00 4976  │
│ Satisf   401      368      2.17e+00 6.38e+03│
│ Dist     413      279      2.03e+00 8782  │
│ Prox     398      187      2.12e+00 8854  │
└───────────────────────────────────────────┘
```

```
┌──────────────Utopia/Nadir──────────────┐
│             Utopia        Nadir         │
│ Invest      186           413           │
│ Satisf      368           100           │
│ Dist        2.03144e+00   2.61462e+00   │
│ Prox        8.85469e+03   4.97645e+03   │
└─────────────────────────────────────────┘
```

ESC Menu

Figure 19: PAY-OFF screen

```
┌──────Comparison of Efficient Solutions──────┐
│                   Locations                  │
└──────────────────────────────────────────────┘
```

```
┌──────────────────────────────────┐
│        Sol.1  Sol.2  Sol.3  Sol.4 │
│ Bush   Yes    No     No     Yes   │
│ Fiord  No     No     Yes    Yes   │
│ Ice    No     Yes    No     No    │
│ Oasis  No     Yes    Yes    No    │
└──────────────────────────────────┘
```

A/R Bars, U/N Bars, Locations, Values   ESC Menu

Figure 20: Locations for the pay-off solutions

only short characteristics such as objective values and selected locations (SUMMARY). Values of the objective functions are presented in three ways: as a standard table, as bars in the aspiration/reservation scale and as bars in the utopia/nadir scale. The bars show percentage level of each objective value with respect to the corresponding scale. You may also save the Current Solution on a separate file in order to use it during next runs of the system with the same problem (SAVE). There is also available a special command to delete the Current Solution from the Solution Base if you find it as quite useless (DELETE).

The ANALYSIS branch collects commands connected with operations on the Solution Base. The main command COMPARE allows you to perform a comparison between all the efficient solutions included in the Solution Base or in some subset of the base. In the comparison only short characteristics of the solutions are used, i.e., objective values in the form of tables and bars as well as tables of selected locations. Moreover, some commands included in this branch (PREVIOUS, NEXT and LAST) allow you to select any efficient solution from the Solution Base as the Current Solution. There exist also an opportunity to restore some efficient solution (saved earlier on a separate file) to the Solution Base (RESTORE).

In particular, you can recognize locations structure for several solutions. The simplest way to get this information depends on using of the COMPARE command from the ANALYSIS branch. Let you execute the COMPARE command. At first you are asked to select solutions included into the comparison. For this purpose a special (temporal) Comparison Base is used. The Comparison Base is initialized as containing all the efficient solutions from the Solution Base. You can remove some solutions from the Comparison Base and thereby select the remaining solutions for the comparison.

The process of the Comparison Base definition is organized as follows. At the top of the screen the message appears:

SELECT Efficient Solutions for Comparison

and simultaneously the initial Comparison Base is displayed. The Comparison Base is displayed as a table where each row corresponds to a single efficient solution while the columns correspond to several objective functions. In each row you can read the identification number of the efficient solution and objective values for several criteria. There is available a reverse-image pointer which allows you to select a solution by pointing out its identification number. The pointer is controlled by using the <UP> and <DOWN> arrows. If you have pressed the <DEL> key then the pointed out solution is removed from the Comparison Base and the corresponding row is deleted from the table on the screen. In such a way you can eliminate from the Comparison Base the solutions which you are not interested in during the comparison. You may finish the process of the Comparison Base definition at any moment by pressing the <ESC> key.

We are interested in comparison of all four efficient solutions. So, you should press the <ESC> key without using the <DEL> key. However, do not be afraid to use the <DEL> key. The Comparison Base is only temporal for a single execution of the COMPARE command. All the solutions remain still available in the Solution Base. You can next press twice the <ESC> key in order to return control to the Main Menu and repeat the COMPARE command with the full Comparison Base.

After setting up the Comparison Base by pressing the <ESC> key you can analyse simultaneously the four selected solutions in terms of the objective values and location decisions. The several COMPARE screens are controlled by the <PGDN> or <PGUP> keys which display screen by screen forward or backward, respectively. In order to get the so-called Locations screen you have to press the <PGUP> key or triple press the <PGDN> key. This screen is presented in

Fig. 20. You may notice that the first solution which minimizes the investment cost is based on only one new health–care center located at Bush. Each other solution use two new centers what explains their significantly higher investment costs. They are based on the following locations: Ice and Oasis, Fiord and Oasis, Bush and Fiord, respectively. After performing the comparison you have to press the <ESC> key to return control to the Main Menu.

4.6 Interactive analysis

Having computed the utopia vector we can start the interactive search for a satisfying efficient solution. As we have already mentioned DINAS utilizes aspiration and reservation levels to control the interactive analysis. More precisely, you specify acceptable values for several objectives as the aspiration levels and necessary values as the reservation levels. All the operations connected with editing the aspiration and reservation levels as well as with computation of a new efficient solution are included in the EFFICIENT command.

After selecting the EFFICIENT command you are asked for aspiration and reservation levels editing. The message:

EDIT Aspiration/Reservation Levels

appears at the top of the screen whereas two tables are displayed at the centre (see Fig. 21). The left table contains the objective values for the Current Solution (central column) in comparison with the utopia (left column) and nadir (right column) vectors. At this moment the fourth efficient solution is the Current Solution. The right table is a small spreadsheet for aspiration and reservation levels edition. You can select several fields and edit the corresponding coefficients. A twelve–character (reverse image) field pointer is controlled by the <ENTER> key which move the pointer entry by entry. Moreover, you can use the <UP> or <DOWN> arrows for a direct vertical movement and, similarly, the <CTRL>/<LEFT> or <CTRL>/<RIGHT> keys for a direct horizontal movement. Try to move the pointer. At the beginning of the interactive analysis the aspirations and reservation levels are initialized as equal to the utopia and nadir vectors, respectively.

You can finish the edition phase at any moment by pressing the <ESC> key. The system will check then the introduced coefficients. To be accepted by the system the edited coefficients have to satisfy the following relations:

- for each minimized objective (i.e., for Invest and Dist):

  - the aspiration and reservation levels must be no less than the corresponding utopia value and no greater than the corresponding nadir coefficient;
  - the aspiration level must be no greater than the corresponding reservation level;

- for each maximized objective (i.e., for Satisf and Prox):

  - the aspiration and reservation levels must be no greater than the corresponding utopia value and no less than the corresponding nadir coefficient;
  - the aspiration level must be no less than the corresponding reservation level.

In case of detecting some inconsistencies or errors in the coefficients you will be obliged to correct them.

At the beginning of the interactive analysis the so–called neutral solution is usually computed. For this purpose you should accept the utopia vector as the aspiration levels and the nadir vector as the reservation levels, by pressing the <ESC> key. Then you will be asked

37

whether you will be interested in calculation of a new efficient solution with respect to the edited aspiration and reservation levels:

<div align="center">Do you wish to optimize? (y/n)</div>

This question may seem to be unreasonable since usually you are interested in calculation of a new solution. However, a change of aspiration and reservation levels can be also very useful while performing some solutions comparisons and in such a situation you can use the EFFICIENT command only for the edition phase.

When you have decided to compute a new efficient solution the solver is invoked. Similarly as in the PAY-OFF command, the optimization process is reported by messages:

<div align="center">WAIT   Iterations:#   Solutions:#</div>

and you can suspend computations at any moment (by pressing any key) and cancel or continue them after a break. After having finished the computations the new efficient solution is displayed in the left table as the Current Solution (central column) and the solution identification number appears at the top of the screen. From this moment you have available the so–called SUMMARY screens (by pressing the <PGUP> or <PGDN> key) for examination of the Current Solution in comparison with the previous one. There are four SUMMARY screens:

- Values;
- A/R Bars;
- U/N Bars;
- Locations.

At the top of each screen a header with the solution identification number and the screen name is displayed:

<div align="center">Efficient Solution No 5</div>

The Values screen (see Fig. 22) provides you with numerical information about the objective values of the Current Solution. There is presented a table built of six columns. Each row of the table corresponds to one objective function. In several columns you can read the Utopia, Aspiration, Current, Previous, Reservation and Nadir values for the corresponding objective. From this table you may read that the investment cost for the neutral solution is rather high (Invest=386) whereas the other objectives get middling values (Satisf=276,, Dist=2.26, Prox=6457).

The A/R Bars screen (see Fig. 23) provides you with graphical presentation of the current objective values with respect to the given aspiration and reservation levels. Namely, for each objective separately the difference between the aspiration and reservation levels is taken as a unit, and the percentage degradation of the current objective value from the aspiration level is then calculated. The results are presented in form of the horizontal bars with accuracy of 1%.

More precisely, the aspiration and reservation levels as the basis of the analysis are fixed on the screen. Independently of the optimization type (minimization or maximization) the aspiration level is fixed on the left and the reservation level on the right. For each objective a dim bar shows the whole domain from the utopia value to the nadir value whereas the brighter segment covers the gap between the utopia value and the current value. So, the right side of the bright bar points out the current value. Moreover you are also provided with the objective value of the previous solution by a special sign below the bar. The value of the

<div align="center">38</div>

⊞⊞ Aspiration/Reservation Levels

Utopia/Current/Nadir

	Utopia	Current	Nadir
Invest	186	398	413
Satisf	368	187	100
Dist	2.03e+00	2.12387e+00	2.61e+00
Prox	8854	8.85469e+03	4976

Aspiration/Reservation

	Aspiration	Reservation
Invest	186	413
Satisf	368	100
Dist	2.03144e+00	2.61462e+00
Prox	8.85469e+03	4.97645e+03

▓ ▓ ⬛ ⬛ ⬛ Field Edit ⬛ ⬛ ⬛ ⬛ ⬛ Field Movement ⬛ End of EDIT

Figure 21: Aspiration/Reservation levels editing

Efficient Solution No 5
Values

Current/Previous

	Utopia	Aspiration	Current	Previous	Reservation	Nadir
Invest	186	186	386	398	413	413
Satisf	368	368	276	187	100	100
Dist	2.03e+00	2.03e+00	2.26056e+00	2.12387e+00	2.61e+00	2.61e+00
Prox	8854	8854	6.45690e+03	8.85469e+03	4976	4976

⬛ ⬛ A/R Bars, U/N Bars, Locations, Values   ⬛ Menu

Figure 22: Values screen for the neutral solution

previous solution is pointed out by the top of the hat "^" (see Invest in Fig. 23) or by the right side of the small square "■" (see e.g., Satisf in Fig. 23).

The U/N Bars screen (see Fig. 24) provides you with a graphical presentation of the current objective values with respect to the utopia and nadir values. This screen is very similar to the A/R Bars. The main difference depend on using of the different scale for the bars. Namely in U/N Bars, the difference between the utopia and nadir values is taken as a unit and the percentage degradation of the current objective value from the utopia value is then calculated. Similarly as in A/R Bars the results are presented in form of the horizontal bars with accuracy of 1% and the same scheme for the current and previous values illustration is used. In our case the utopia and nadir values were taken as the aspiration and reservation levels, respectively, and thereby both the bars screens have the same look–like. However, in general it is not true (see Fig. 26).

The Locations screen (see Fig. 25) provides you with the location decisions on which the Current Solution is based. There is displayed a very simple table built of two columns. The first column is associated with the Current Solution whereas the second one represents the previous solution. Each row of the table corresponds to one potential node. You can read from the table whether a potential node is active in the solution (denoted by Yes) or is not active (denoted by No). From the Locations screen you may read that the neutral solution is based on location of two new health–care centers at Bush and at Ice.

Apart from the solution connected with the minimization of the investment cost all the other solution are based on location of two new health–care centers what implies a high investment cost. Therefore we try to find an efficient solution with small investment cost (one new center) and relatively good values of the other objectives. For this purpose we suggest you to define the aspiration and reservation levels as it is given in Table 10.

	Invest	Satisf	Dist	Prox
aspiration	186	300	2.08	8500
reservation	250	200	2.50	7000

Table 10: Aspiration/reservation levels for solution no 6

In effect, you get the sixth efficient solution based on location of one new health–care center at Oasis. The investment cost is small (Invest=201), the satisfaction level has middling value (Satisf=192) while the average distance is very large (Dist=2.58) and the overall proximity is even less than the corresponding coefficient of the nadir vector (Prox=4933). Note that the system automatically corrects the nadir vector by putting the new worst value as the proper coefficient.

To avoid too small values of the overall proximity in the next solution we modify the reservation level for this objective putting 8000 as the new value. After repeating the computation we get the seventh efficient solution based on the sole new health–care center located at Ice. Due to the very convenient form of solution presentation in DINAS we can easy examine performances (in terms of objective values) of the new solution in comparison with the previous one (see Fig. 26). The overall proximity, the average distance and the investment cost are slightly better (Prox=5287, Dist=2.53 and Invest=200) while the overall satisfaction level is a few percent worse (Satisf=176).

After analysis of two last efficient solutions we make a supposition that it is necessary to relax requirements on the satisfaction level for making possibility to find an efficient

40
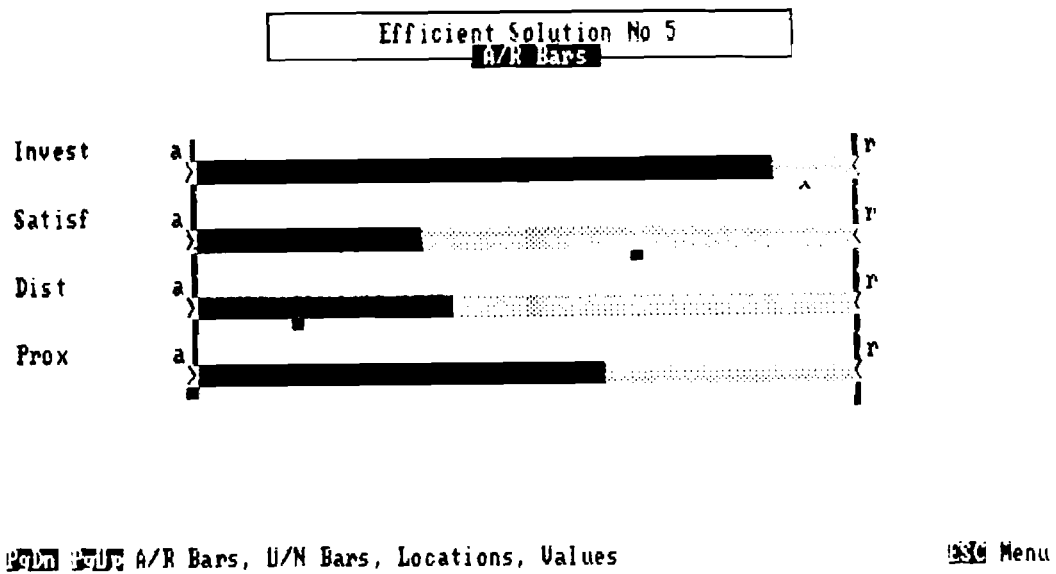
Figure 23: A/R Bars screen for the neutral solution
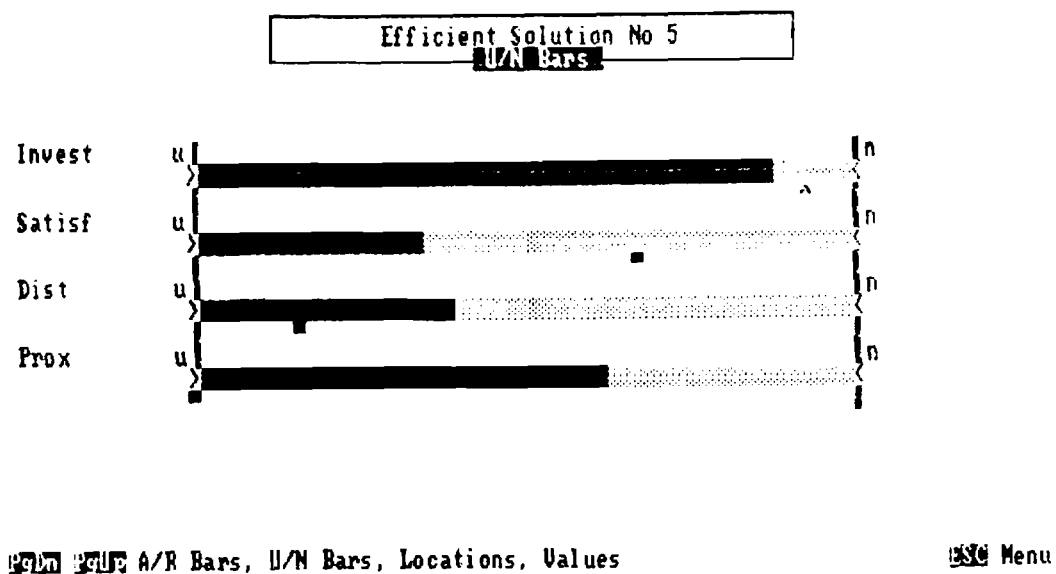
Figure 24: U/R Bars screen for the neutral solution

```
┌─────────────────────────────────────┐
│       Efficient Solution No 5        │
│            Locations                 │
└─────────────────────────────────────┘



        ┌─Current/Previous──────┐
        │           Current  Previous │
        │ Bush      Yes      Yes      │
        │ Fiord     No       Yes      │
        │ Ice       Yes      No       │
        │ Oasis     No       No       │
        └─────────────────────────────┘
```

F10 F1 A/R Bars, U/N Bars, Locations, Values   Esc Menu

Figure 25: Locations screen for the neutral solution

```
┌─────────────────────────────────────┐
│       Efficient Solution No 7        │
│             A/R Bars                 │
└─────────────────────────────────────┘
```

Invest
Satisf
Dist
Prox
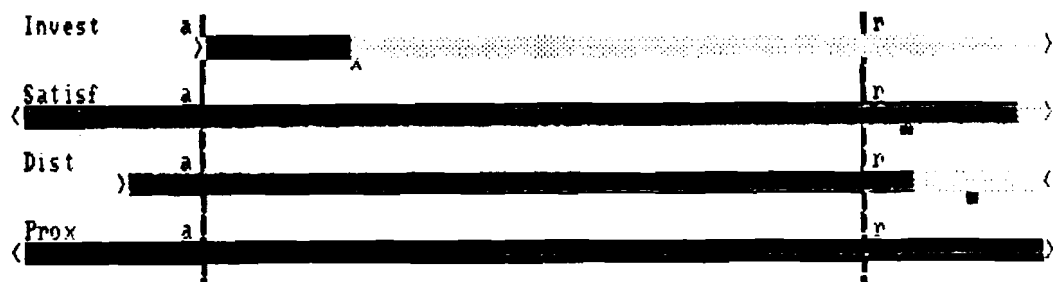
F10 F1 A/R Bars, U/N Bars, Locations, Values   Esc Menu

Figure 26: A/R Bars screen for the seventh solution

solution with good values of the average distance and the overall proximity under small the investment cost. So, we change the reservation level associated with the function Satisf on 100. The system confirms our supposition. We get the eighth efficient solution based on the sole new health-care center located at Fiord. The solution guarantees quite large overall proximity (Prox=7691) and relatively small average distance (Dist=2.38) under small investment cost (Invest=212). On the other hand, the satisfaction level has a value even less than the corresponding coefficient of the nadir vector (Satisf=87). Despite of the latter the solutions seems to be very interesting among the other efficient solutions based on location of a sole health-care center.

Further search for a satisfying efficient solution based on only one new health-care center have finished without success. Namely, for different values of the aspiration and reservation levels the same efficient solutions have been generated. We suggest you to remove such solutions from the Solution Base immediately after the generation. For this purpose you can use the DELETE command from the SOLUTION branch. During the execution of the DELETE command the identification number of the Current Solution is displayed and you are asked to confirm your decision or cancel it. The corresponding message takes the form:

            Do you wish to delete Efficient Solution No 9   (y/n)?

If you have confirmed the command then the Current Solution is deleted from the Solution Base whereas the previous solution is activated as the Current Solution and presented with the SUMMARY screens.

To complete the analysis you should try to examine another efficient solutions. For this purpose we suggest you to relax requirements on the investment cost. Among others, while using the aspiration and reservation levels given in Table 11 we get the eleventh efficient solution (the ninth and tenth solutions were deleted as duplications of the previous ones. It is based on the same location of new centers as the third solution (Fiord and Oasis) and thereby it gives the same investment cost (Invest=413) and satisfaction level (Satisf=279). However, the average distance and the overall proximity differs slightly (Dist=2.04 and Prox=8791).

	Invest	Satisf	Dist	Prox
aspiration	200	300	2.10	8800
reservation	400	200	2.50	8400

Table 11: Aspiration/reservation levels for solution no 11

Finally, you may examine all the generated efficient solutions using the COMPARE command. The solutions are listed in Figures 27 and 28. A careful analysis of these solutions leads us to the following conclusion. The investment cost cannot be regarded as a typical objective function since its values depend rather on the number of new health-care centers than on their locations. It only partitions all the efficient solutions into two groups: solutions based on a sole new health-care center and solutions based on location of two new centers. Therefore it is necessary to look for a good solution based on a sole new center which can be expanded to a better solution by adding the second new center. In our opinion, the first new health-care center should be located at Fiord (Solution 8). It is the only one efficient solution (based on a sole new center) which gives acceptable values of the average distance and the overall proximity (see Fig. 29). This solution gives also the worst value of the satisfaction level. However, further development of this solution by adding the new health-care center at Oasis

43

```
┌─────────────────────────────────────┐
│  Comparison of Efficient Solutions   │
│              ██Values██               │
└─────────────────────────────────────┘
```

	Invest	Satisf	Dist	Prox
Sol. 1	186	100	2.61e+00	4976
Sol. 2	401	360	2.17e+00	6.38e+03
Sol. 3	413	279	2.03e+00	8792
Sol. 4	398	187	2.12e+00	8854
Sol. 5	386	276	2.26e+00	6.46e+03
Sol. 6	201	192	2.58e+00	4.93e+03
Sol. 7	200	176	2.53e+00	5287
Sol. 8	212	87	2.38e+00	7.69e+03
Sol. 11	413	279	2.04e+00	8790

██ ██ A/R Bars, U/N Bars, Locations, Values   ██ Menu

Figure 27: Values comparison

```
┌─────────────────────────────────────┐
│  Comparison of Efficient Solutions   │
│             ██Locations██             │
└─────────────────────────────────────┘
```

	Sol.1	Sol.2	Sol.3	Sol.4	Sol.5	Sol.6	Sol.7	Sol.8	Sol.11
Bush	Yes	No	No	Yes	Yes	No	No	No	No
Fiord	No	No	Yes	Yes	No	No	No	Yes	Yes
Ice	No	Yes	No	No	Yes	No	Yes	No	No
Oasis	No	Yes	Yes	No	No	Yes	No	No	Yes

██ ██ A/R Bars, U/N Bars, Locations, Values   ██ Menu

Figure 28: Locations comparison
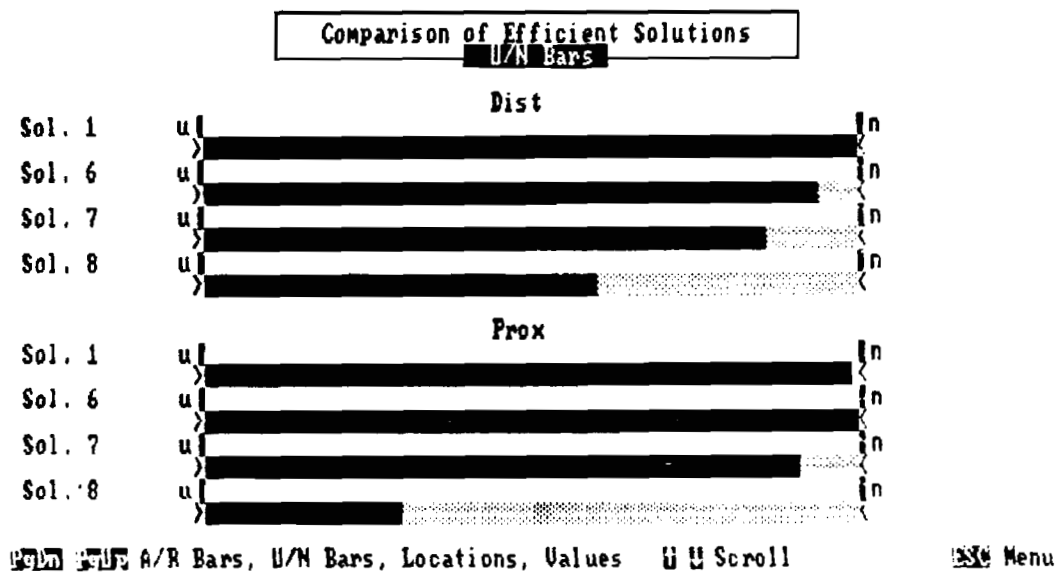
Figure 29: U/N Bars for the solutions based on a sole new center
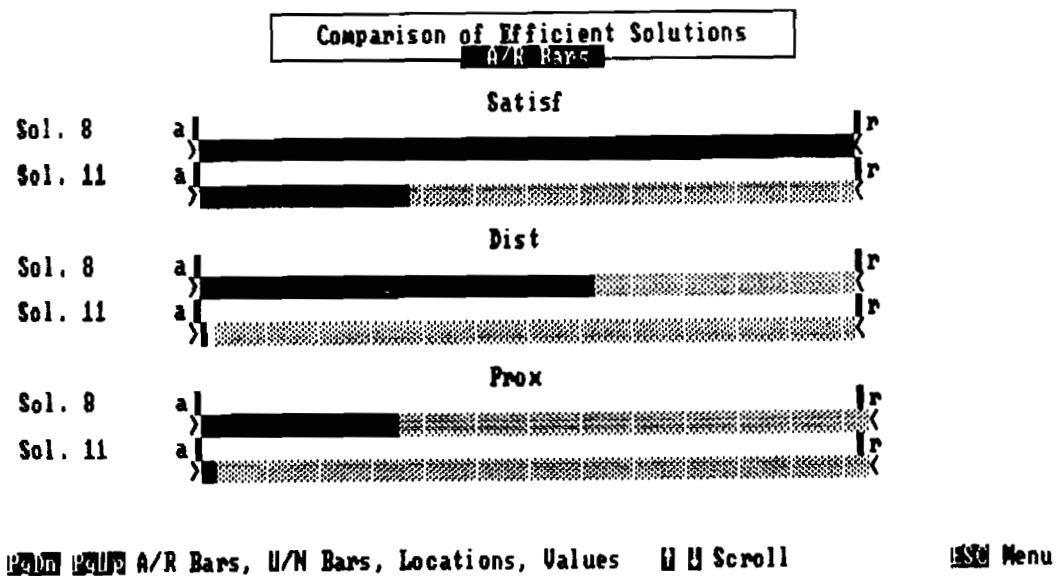
Figure 30: A/R Bars for two final solutions

45

(Solution 11) leads to a quite high value of the satisfaction level and makes further significant improvements with respect to the average distance and the overall proximity (see Fig. 30). Both the proposed solutions have the highest investment costs in the corresponding groups of solutions but variation of this objective among solutions of the same group is so small that it cannot be considered as a serious weakness.

Using the BROWSE command you can examine in details the selected solutions with the Network Editor. It turns out that in the eighth efficient solution the health–care center Hill is assigned to areas: Acer, Picea, Litwor, Betula and Erica. The health–care center Pond services areas: Bobrek, Arnika, Robur, Larix and a small part of Ribes. The new health–care center Fiord services only areas Pinus, Rumex and the main part of Ribes. Capacity of the new center Fiord is completely used whereas in the old centers we have noticed some small free capacities. It suggests that the old health–care centers have nonoptimal location with respect to the considered objective functions. The eleventh efficient solution confirms this observation. The additional new health–care center at Oasis takes the area Acer and the main part of Erica from the region of Hill and the area Bobrek from the region of Pond. So, in this solution both the new health–care centers use the whole their capacities whereas the old centers use only 50–70% of their capacities. In effect, all the health–care centers have well balanced charges.

Having performed the analysis you are usually interested in printing the selected solutions. For this purpose you should also use the BROWSE command. While executing the BROWSE command and selecting the PRINT NETWORK command from the Editor Menu the report on the Current Solution will be generated. In order to get the report on another efficient solution you have to use the PREVIOUS or NEXT command to change the Current Solution. The efficient solutions within the Solution Base are ordered according to the increasing identification numbers. The Next command causes that the next one after the Current Solution becomes a new Current Solution. On the other hand, the PREVIOUS command makes the solution that precedes the Current Solution to be a new Current Solution.

To leave the system you should select the QUIT command. DINAS requires a confirmation of your decision to leave the system and makes an opportunity to cancel it. Namely, you have to answer the question:

<div align="center">Do you wish to leave the system (y/n)?</div>

If you press the <Y> key then the control will be returned to the DOS operating system.

5 The Interactive System

5.1 Main Menu

To perform interactive analysis of the multiobjective problem with DINAS you need not to be familiar with neither computer techniques nor mathematical programming. DINAS is a menu–driven system with very simply commands. It is also equipped with the HELP file.

DINAS is started simply by typing command DINAS. The system cover is then visible on the display and there is a short pause while DOS finds and loads the execution program. When the loading procedure has already finished the blinking message:

<div align="center">Press any key to continue!</div>

appears at the bottom of the display. Pressing <ENTER> or any other key, you will see the Main Menu screen with the system banner. From this moment the HELP file is still available (by pressing function key <F1>).

Operations available in the Main Menu are partitioned into three groups and corresponding three branches of the menu (see Table 12): PROCESS, SOLUTION and ANALYSIS.

Process	Solution	Analysis
Problem	Summary	Compare
Convert	Browse	Previous
Pay–Off	Save	Next
Efficient	Delete	Last
Quit		Restore

Table 12: Main Menu Commands

The PROCESS branch contains basic operations connected with processing the multiobjective problem and generation of several efficient solutions. There are included problem definition operations such as calling the Network Editor for input or modification of the problem (PROBLEM) and converting of the edited problem with error checking (CONVERT). Further, in this branch the basic optimization operations are available: computation of the pay–off matrix with the utopia and nadir vectors (PAY-OFF) and generation of efficient solutions depending on the edited aspiration and reservation levels (EFFICIENT). As the last command in this branch is placed the QUIT operation which allows you to finish work with the system.

DINAS stores the efficient solutions in a special Solution Base. All the efficient solutions generated (or input from a file) during a session get consecutive numbers and are automatically put into the Solution Base. However at most nine efficient solution can be stored in the Solution Base. When the tenth solution is put into the base the oldest solution is automatically dropped from the base. On the other hand any efficient solution can be saved on a separate file and restored during the same or a subsequent session with the problem.

DINAS is armed with many operations which help to manage the Solution Base. There are two kinds of operations connected with the Solution Base: operations on a single efficient solution, and operations on the whole Solution Base. Operations addressed to a single solution are connected with the Current Solution. The newest generated efficient solution is automatically assumed to be the Current Solution but any efficient solution from the Solution Base can be manually assigned as the Current Solution.

The SOLUTION branch contains additional operations connected with the Current Solution. You can examine in details the Current Solution using the Network Editor (BROWSE) or analyse only short characteristics such as objective values and selected locations (SUMMARY). Values of the objective functions are presented in three ways: as a standard table, as bars in the aspiration/reservation scale and as bars in the utopia/nadir scale. The bars show percentage level of each objective value with respect to the corresponding scale. You may also save the Current Solution on a separate file in order to use it during next runs of the system with the same problem (SAVE). There is also available a special command to delete the Current Solution from the Solution Base if you find it as quite useless (DELETE).

The ANALYSIS branch collects commands connected with operations on the Solution Base. The main command COMPARE allows you to perform a comparison between all the efficient solutions included in the Solution Base or in some subset of the base. In the comparison only short characteristics of the solutions are used, i.e., objective values in the form of tables and bars as well as tables of selected locations. Moreover, some commands included in this branch

47

(PREVIOUS, NEXT and LAST) allow you to select any efficient solution from the Solution Base as the Current Solution. There exist also an opportunity to restore some efficient solution (saved earlier on a separate file) to the Solution Base (RESTORE).

Command selection is performed with using a reverse image pointer which is controlled by the arrow keys. Namely, using the <LEFT> or <RIGHT> arrow you select a proper menu branch, and using the <UP> or <DOWN> arrow you select a proper item within the branch. Note that the pointer position within a branch is automatically restored during the next selection of the same branch. For execution of the selected command you have to press <ENTER>. After a command has been executed you need, usually, to press the <ESC> key in order to return control to the Main Menu.

Troubleshooting:

1. The Main Menu screen does not appear.
   Make sure that all the system files are available in the default directory.

2. After pressing the <F1> the following message:
        No help file - dinas.hlp press any key to continue
   appears in the help window.
   Make sure that the file DINAS.HLP is available in the default directory.

3. You cannot move the pointer across the Main Menu. Pressing any arrow key makes only the error noise.
   The <NUMLOCK> toggle is likely on. Make sure that <NUMLOCK> is off.

5.2 PROCESS branch

5.2.1 PROBLEM and CONVERT commands

Before the multiobjective analysis is launched, a file must be constructed describing the problem to be analysed. This file is called the network file. It is a special binary file generated by the Network Editor. The Network Editor is called by execution of the PROBLEM command.

Thus the PROBLEM command is usually selected as the initial step. In such a situation the Network Editor is called with an empty network file. The Editor Menu and the corresponding banner will appear on the display. Using the editor commands (see Chapter 6 for details) you will be able then to create a new network file (a new problem) or load and edit some existing one.

The network file created and saved during the execution of the PROBLEM command is not automatically assigned to the Interactive System. You may edit many various network files during a single editor calling. To assign a specific network file to the system you have to execute the CONVERT command. The execution of the CONVERT command makes the specified problem (network file) available for the system.

After selecting the CONVERT command you will be asked for a specification of the problem name. For this purpose a special 38-character field is displayed preceded by the message:

                    GIVE Problem Name:

You can then edit the name according to the general field editing rules (see Appendix A). Next the specified problem data will be converted with error checking. Any recognized data error will be reported on the display. In case of a successful conversion the problem statistics

will be reported, i.e., the table containing: name of the problem, numbers of objectives, arcs, fixed nodes, potential nodes and selections will be displayed.

If you have prepared a network file during some previous session and do not change the problem then you can, obviously, initialize the analysis by direct execution of the CONVERT command without using the PROBLEM command.

You can execute the PROBLEM and CONVERT commands many times during the same DINAS session. However, if some problem is actually assigned to the system then effects of the commands executions will differ slightly in comparison with the initial ones. While executing the CONVERT command the current problem statistics will be displayed and you will be asked for confirmation that the current problem have to be abandoned, i.e., the following question will appears:

<p style="text-align:center">Do you wish to abandon Current Problem (y/n)?</p>

Depending on your answer the command execution will be canceled or the standard converting procedure will be continued.

While executing the PROBLEM command the actually assigned problem is automatically loaded into the editor and therefore the message:

<p style="text-align:center">Reading Network</p>

appears before displaying the Editor Menu. It is assumed that you are interested in data examination or making some changes in the problem under analysis. Nevertheless, if you want you can load another problem using the editor commands.

Multiple usage of PROBLEM and CONVERT commands during a single DINAS session can be very useful for more complex multiobjective analyses. However, to avoid troubles you must then observe the following rules:

- do not save the problem if you have not modified the problem;
- execute CONVERT command if you have modified the problem.

Troubleshooting:

1. After executing of the PROBLEM command the Network Editor is not activated.
   The Network Editor cannot be loaded. Make sure that all the system files are in the default directory. Make sure that there are 640 KB RAM available in your PC.

2. While executing of the CONVERT command the following message appears:
   Some Problems with NETWORK FILE
   PRESS ANY KEY TO CONTINUE !
   The specified network file does not exist or is not available. Make sure that you use the proper name of the network file. Make sure that the network file is in the default directory or use the proper path.

3. While executing of the CONVERT command the following message appears:
   Some Problems with WORKING FILE
   PRESS ANY KEY TO CONTINUE !
   A working file for the Solution Base cannot be opened in the default directory. Make sure that there is a possibility to open a new file in the default directory (the disk is not write-protected, the door is closed, etc.).

4. While executing of the CONVERT command the following message appears:

   DISK FULL !!!

   PRESS ANY KEY TO CONTINUE !

   There is no sufficient space for the Solution Base on the default disk. Delete some useless (network and solution) files or put them on another disk (see Appendix D).

5. While executing of the CONVERT command the following message appears:

   DATA ERROR !

   error description

   Do you wish to continue ? (y/n)

   An error in the network file found (see Section 5.2.2 for details). If you press the <Y> key the conversion will be continued, if possible, to recognize another errors. If you press the <N> key the conversion will be terminated prematurely. In both the cases no problem will be assigned to the Interactive System.

6. While executing of the CONVERT command the following message appears:

   EXECUTION INTERRUPTED !

   Do you wish to continue ? (y/n)

   You have pressed some key and in result the command execution is suspended. You can cancel the command execution by pressing the <N> key or continue it by pressing the <Y> key.

5.2.2 Data errors

There are many various restrictions on the problem data. They can be partitioned into three groups: size limits, restriction on the network structure, restriction on several data coefficients. Some of the restrictions (especially from the last group) are supported by the Network Editor in such a way that you cannot input a wrong coefficient. However many of the restrictions cannot be verified before the problem definition is finished. Therefore during the execution of the CONVERT command all the problem data are carefully examined with respect to the restrictions. In this section you will find detail description of the data restrictions and corresponding error messages issued by the CONVERT command.

For the basic version of the DINAS system the following size limits are valid:

number of active objectives	- 7
number of arcs	- 300
number of fixed nodes	- 100
number of potential nodes	- 15
number of selections	- 8

However the given numbers define only maximal size of the problem with respect to a single quantity. We do not guarantee a possibility to solve the problem with all the quantities equal to their maximal sizes simultaneously. Namely, the system allocates dynamically necessary data structures and there exist an internal limit on the total size of the data structures. There are two restrictions on the network structure:

- the network cannot contains any simple loop;
- the network cannot contain any arc which joins directly two potential nodes.

50

Both the restriction are supported by the Network Editor (see Chapter 6) in such a way that you cannot input a wrong arc.

The several data coefficients have to fulfill the following requirements:

- the balances should be real numbers and the sum of all the balances have to be equal to 0;
- the objective coefficients should be real numbers;
- the arc capacities should be nonnegative real numbers;
- the potential node capacities should be positive real numbers;
- the selection bounds should be nonnegative integer numbers and for a given selection its lower bond cannot exceed its upper bound.

A quantity p is accepted by DINAS as a proper real number if it satisfies the following inequality:

$$-1.0e30 \leq r \leq 1.0e30.$$

Troubleshooting:

1. While executing of the CONVERT command a DATA ERROR message appears like these:
   ```
   Too many OBJECTIVES !
   Too many ARCS !
   Too many FIXED NODES !
   Too many POTENTIAL NODES !
   Too many SELECTIONS !
   ```
   The current number of objectives, arcs, fixed nodes, potential nodes or selections, respectively, exceeds the corresponding size limit. Verify whether your problem really need such a large number of given objects. If there is no possibility to rebuilt the model, it cannot be solved with this version of the system.

2. While executing of the CONVERT command a DATA ERROR message appears like these:
   ```
   There are NO OBJECTIVES !
   There are NO ARCS !
   There are NO FIXED NODES !
   ```
   An incomplete problem formulation. Correct your problem.

3. While executing of the CONVERT command a DATA ERROR message appears like these:
   ```
   Arc name INVALID CAPACITY !
   Node name INVALID CAPACITY !
   ```
   An invalid capacity for the given arc or potential node. Correct the corresponding data (remember that the capacities for arcs must be nonnegative and capacities for potential nodes must positive).

4. While executing of the CONVERT command a DATA ERROR message appears like these:
   ```
   Arc name INVALID COEFFICIENT !
   Node name INVALID COEFFICIENT !
   ```
   An invalid cost coefficient for the given arc or potential node. Correct the corresponding data.

5. While executing of the CONVERT command a DATA ERROR message appears like this:
   ```
   Node name INVALID BALANCE !
   ```
   An invalid balance for the given fixed node. Correct the corresponding data.

6. While executing of the CONVERT command a DATA ERROR message appears like this:
   Selection *name* INVALID BOUNDS !
   Invalid lower and/or upper bounds for the given selection. Correct the corresponding data (remember that the lower bound cannot exceed the upper bound).

7. While executing of the CONVERT command DATA ERROR messages of type (3) to (6) permanently appear for all the data.
   Probably you use a version of the system which takes advantage of the Numeric Data Processor whereas your computer is not armed with such a hardware. Change the version of the system.

8. While executing of the CONVERT command a DATA ERROR message appears like this:
   Arc *name* INVALID CONNECTION !
   An illegal arc which connects two potential nodes. Correct the network structure. In order to define a connection of two potential nodes you can use an artificial fixed node.

9. While executing of the CONVERT command a DATA ERROR message appears like this:
   Problem NOT BALANCED !
   The sum of all the balances is not equal to zero. Verify all the balances whether they are correct. If your problem is unbalanced in fact you can redefine it as balanced one by introducing an artificial fixed node.

10. While executing of the CONVERT command a DATA ERROR message appears like this:
    INSUFFICIENT MEMORY !
    The problem is too large to solve with this version of the system. Try to decrease the size of the problem, especially numbers of objectives and potential nodes.

5.2.3   PAY-OFF command

When the problem has been defined and converted you must execute the PAY-OFF command as the first step of the multiobjective analysis . It performs optimization of each objective function separately. In effect, you get the so-called pay–off matrix. The pay–off matrix is a well–known device in MCDM. It is displayed as a table containing values of all the objective functions (columns) obtained while solving several single–objective problems (rows) and thereby it helps to understand the conflicts between different objectives (see Fig 19).

The execution of the PAY-OFF command provides also you with two reference vectors: the utopia vector and the nadir vector. They are displayed as a two–column table below the pay–off matrix (see Fig. 19). The utopia vector represents the best values of each objective considered separately, and the nadir vector express the worst values of each objective noticed during optimization of another objective function. The utopia vector is, usually, not attainable, i.e., there are no feasible solutions with such objective values.

Coefficients of the nadir vector cannot be considered as the worst values of the objectives over the whole efficient (Pareto–optimal) set. They usually estimate these values but they express only the worst values of each objective noticed during optimization of another objective function. In further analysis these estimations can be sometimes overstep.

Due to a special regularization technique used while computating the pay–off matrix (see Chapter 3) each generated single–objective optimal solution is also an efficient solution to the multiobjective problem. So, after the calculation of the pay–off matrix you have already available in the Solution Base a number of efficient solutions connected with several rows of the pay–off matrix.

The pay–off matrix calculation is, usually, the most time–consuming operation of the multiobjective analysis. Therefore DINAS automatically saves the computed pay–off matrix on the network file. However, the corresponding efficient solutions are not saved. So, if you restart the analysis of the problem (without any changes in formulation) the PAY-OFF command causes only restoration of the pay–off matrix without generation any efficient solution in the Solution Base. Editing of the problem (exactly: using the SAVE command in the Network Editor) cancels the pay–off record on the network file.

While performing the optimization the computation process is reported by the messages:

<div align="center">WAIT   Iterations: #   Solutions: #</div>

where the numbers represent the number of simplex steps having performed and the number of feasible solutions having examined, respectively. You can suspend the computations at any moment (by pressing <ENTER> or any other key) and cancel them or continue after a break.

Troubleshooting:

1. While executing of the PAY-OFF command the following message appears:
   Problem NOT AVAILABLE !
   SELECT CONVERT COMMAND !
   There is no problem assigned to the Interactive System. Press the <ESC> key to return control to the Main Menu and execute the CONVERT command.

2. While executing of the PAY-OFF command a message appears in the pay–off table, like this:
   INFEASIBLE PROBLEM !
   UNBOUNDED PROBLEM !
   During the optimization process the corresponding single–objective problem proved to be infeasible or unbounded respectively. You have to correct the problem formulation. Press the <ESC> key to return control to the Main Menu.

3. While executing of the PAY-OFF command the following message appears:
   EXECUTION INTERRUPTED !
   Do you wish to continue ? (y/n)
   You have pressed some key and in result the command execution is suspended. You can cancel the command execution by pressing the <N> key or continue it by pressing the <Y> key.

4. While executing of the PAY-OFF command the following message appears in the pay–off table:
   USER's BREAK !
   You have canceled the command execution (see point (3)). Press the <ESC> key to return control to the Main Menu.

5. While executing of the PAY-OFF command the following message appears in the pay–off table:
   RESTORING PROBLEMS !
   The system came across some problems while restoring the pay–off record from the network file. Press the <ESC> key to return control to the Main Menu and execute the PAY-OFF command again. The pay–off matrix will be then computed.

6. While executing of the PAY-OFF command the following message appears in the pay-off table:

NUMERICAL PROBLEMS !

The system came across some numerical problems and cannot overcome them. So, your problem cannot be solved.

5.2.4 EFFICIENT command

Having executed the PAY-OFF command you can start the interactive search for a satisfying efficient solution. DINAS utilizes aspiration and reservation levels to control the interactive analysis. More precisely, you specify acceptable values for several objectives as the aspiration levels, and necessary values as the reservation levels. All the operations connected with editing the aspiration and reservation levels as well as with computation of a new efficient solution are performed within the EFFICIENT command.

After selecting the EFFICIENT command you are asked for aspiration and reservation levels editing. The message:

EDIT Aspiration/reservation Levels

appears at the top of the screen whereas two tables are displayed at the centre (see Fig. 21). The left table contains the objective values for the Current Solution (central column) in comparison with the utopia (left column) and nadir (right column) vectors. The right table is a small spreadsheet for aspiration and reservation levels edition. You can select several fields and edit the corresponding coefficients. A twelve-character (reverse image) field pointer is controlled by the <ENTER> key which move the pointer entry by entry. Moreover, you can use the <UP> or <DOWN> arrows for a direct vertical movement and, similarly, the <CTRL>/<LEFT> or <CTRL>/<RIGHT> keys for a direct horizontal movement. At the beginning of the interactive analysis the aspirations and reservation levels are initialized as equal to the utopia and nadir vectors, respectively.

You can finish the edition phase at any moment by pressing the <ESC> key. The system will check then the introduced coefficients. To be accepted by the system the edited coefficients have to satisfy the following relations:

- for each minimized objective :

  - the aspiration and reservation levels must be no less than the corresponding utopia value and no greater than the corresponding nadir coefficient;
  - the aspiration level must be no greater than the corresponding reservation level;

- for each maximized objective :

  - the aspiration and reservation levels must be no greater than the corresponding utopia value and no less than the corresponding nadir coefficient;
  - the aspiration level must be no less than the corresponding reservation level.

In case of detecting some inconsistencies or errors in the coefficients you will be obliged to correct them.

After successful finishing of the editing phase you will be asked whether you will be interested in calculation of a new efficient solution with respect to the edited aspiration and reservation levels:

```
Do you wish to optimize? (y/n)
```

This question may seem to be unreasonable since usually you will be interested in calculation of a new solution. However, a change of aspiration and reservation levels can be also very useful while performing some solutions comparisons and in such a situation you can use the EFFICIENT command only for the editing phase.

When you have decided to compute a new efficient solution the solver is invoked.

Similarly as in the PAY-OFF command, the optimization process is reported by messages:

```
WAIT    Iterations: #   Solutions: #
```

and you can suspend computations at any moment (by pressing any key) and cancel or continue them after a break. After having finished computations the new efficient solution is displayed in the left table as the Current Solution (central column) and the solution identification number appears at the top of the screen. From this moment you have available four SUMMARY screens (by pressing the <PGUP> or <PGDN> key) for examination of the Current Solution in comparison with the previous one. After solution examination you leave the EFFICIENT command (by pressing the <ESC> key) to select another command from the SOLUTION or ANALYSIS branch, or to repeat the EFFICIENT command. You have to leave the EFFICIENT command even if you want to repeat it.

Troubleshooting:

1. While executing of the EFFICIENT command the following message appears:
   ```
   Problem NOT AVAILABLE !
   SELECT CONVERT COMMAND !
   ```
   There is no problem assigned to the Interactive System. Press the <ESC> key to return control to the Main Menu and execute the CONVERT command.

2. While executing of the EFFICIENT command the following message appears:
   ```
   Utopia & Nadir Vectors are NOT AVAILABLE !
   SELECT PAY-OFF COMMAND !
   ```
   The PAY-OFF command has to be executed before first using of the EFFICIENT command. Press the <ESC> key to return control to the Main Menu and execute the PAY-OFF command.

3. While executing of the EFFICIENT command the following message appears:
   ```
   There is ONLY ONE OBJECTIVE !
   SELECT PAY-OFF COMMAND !
   ```
   Your problem is a single–objective one. You will get an optimal solution by using the PAY-OFF command. Press the <ESC> key to return control to the Main Menu and execute the PAY-OFF command.

4. After editing of the aspiration and reservation levels the following message appears:
   ```
   Illegal Aspiration/Reservation Levels !
   PRESS ANY KEY TO CONTINUE !
   ```
   The edited aspiration and/or reservation levels do not satisfy necessary inequalities. The names of the objectives with illegal quantities are displayed in the reverse form. Press <ENTER> or any other key and edit the aspiration and reservation levels again.

5. While computing of a new efficient solution the following message appears:
   EXECUTION INTERRUPTED !
   Do you wish to continue ?   (y/n)
   You have pressed some key and in result the command execution is suspended. You can cancel the command execution by pressing the <N> key or continue it by pressing the <Y> key.

6. While computing of a new efficient solution the following message appears:
   USER's BREAK !
   You have canceled the command execution (see point (5)). Press the <ESC> key to return control to the Main Menu.

7. While computing of a new efficient solution the following message appears:
   NUMERICAL PROBLEMS !
   The system came across some numerical problems and cannot overcome them. So, your problem cannot be solved.

5.2.5 QUIT command

The QUIT command allows you to leave the DINAS system and return control to the DOS Operating System. Leaving the DINAS system makes the Solution Base be lost. Therefore before execution of the QUIT command you must be sure that you have saved all the solutions which are intended to be used in a further analysis. To prevent you from accidental loss of the efficient solutions while executing the QUIT command, DINAS requires a confirmation of your decision to leave the system and makes an opportunity to cancel it. Namely, you have to answer the question:

Do you wish to leave the system (y/n)?

If you have pressed the <N> key then the control will return to the DINAS Main Menu.

5.3 SOLUTION branch

5.3.1 SUMMARY command

The SUMMARY command provides you with the most important but compressed characteristics of the Current Solution. It allows you to analyse in terms of the objective values and location decisions the Current Solution in comparison with the previous one. Execution of the SUMMARY command makes available four screens:

- Values;
- A/R Bars;
- U/N Bars;
- Locations.

At the top of each screen a header with the solution identification number and the screen name is displayed.

The Values screen (see Fig. 22) provides you with numerical information about the objective values of the Current Solution. There is presented a table built of six columns. Each row of the table corresponds to one objective function. In several columns you can read the Utopia, Aspiration, Current, Previous, Reservation and Nadir values for the corresponding objective.

56

The A/R Bars screen (see Fig. 23 or 26) provides you with graphical presentation of the current objective values with respect to the given aspiration and reservation levels. Namely, for each objective separately the difference between the aspiration and reservation levels is taken as a unit and the percentage degradation of the current objective value from the aspiration level is then calculated. The results are presented in form of the horizontal bars with accuracy of 1%.

More precisely, the aspiration and reservation levels as the basis of the analysis are fixed on the screen. Independently of the optimization type (minimization or maximization) the aspiration level is fixed on the left and the reservation level on the right. For each objective a dim bar shows the whole domain from the utopia value to the nadir value whereas the brighter segment covers the gap between the utopia value and the current value. So, the right side of the bright bar points out the current value. Moreover you are also provided with the objective value of the previous solution by a special sign below the bar. The value of the previous solution is pointed out by the top of the hat (^) or by the right side of the small square (■).

You can define various aspiration and reservation levels during the execution of the EFFICIENT command. For a narrow distance between the aspiration and reservation levels in a comparison with the whole utopia/nadir domain you can get only part of the bar on the screen. To make an opportunity to recognize such a situation the bars are bordered by the signs > on the left side and < on the right side. If a bar has cut on the screen then you will perceive the sign < on the left side of the screen or the sign > on the right one.

The U/N Bars screen (see Fig. 24) provides you with a graphical presentation of the current objective values with respect to the utopia and nadir values. This screen is very similar to the A/R Bars. The main difference depend on using of the different scale for the bars. Namely in U/N Bars, the difference between the utopia and nadir values is taken as a unit and the percentage degradation of the current objective value from the utopia value is then calculated. Similarly as in A/R Bars the results are presented in form of the horizontal bars with accuracy of 1% and the same scheme for the current and previous values illustration is used. In U/N Bars the utopia and nadir values are fixed on the screen. Thus the whole domain and thereby the whole bars are always visible.

The Locations screen (see Fig. 25) provides you with the location decisions on which the Current Solution is based. There is displayed a very simple table built of two columns. The first column is associated with the Current Solution whereas the second one represents the previous solution. Each row of the table corresponds to one potential node. You can read from the table whether a potential node is active in the solution (denoted by Yes) or is not active (denoted by No).

The SUMMARY screens are controlled by the <PGDN> or <PGUP> keys which display screen by screen forward or backward, respectively. To return control to the Main Menu you have to press the <ESC> key.

Apart from the direct selection in the Main Menu, the SUMMARY command is also executed by many other system commands. Namely, each command which implies a change of the Current Solution is finished with the activation of the SUMMARY screens for the new Current Solution.

Troubleshooting:

1. While executing of the SUMMARY command the following message appears:
       There are NO SOLUTIONS !

```
SELECT ANOTHER COMMAND !
```
The Solution Base is empty. Press the <ESC> key to return control to the Main Menu and execute another command (e.g., the EFFICIENT command for solution generation).

5.3.2 BROWSE command

The BROWSE command allows you to examine in details the Current Solution using the Network Editor. The execution of this command causes calling of the Network Editor in the view mode. The network file under consideration with linked Current Solution information is then automatically loaded into the editor. You can examine flows along several arcs and through several potential nodes, as well as activity of the potential nodes and objective values. There are no any automatic schemes of examination. You have to decide which characteristics or which part of the network you want to examine . Simply you can browse the Current Solution.

During the execution of the BROWSE command some editor file operations are not available as unreasonable. Namely, you cannot load any network file as well as you cannot save the problem. The execution of the PRINT command generates then the solution report instead of the standard network report (see 6.3 for details).

Troubleshooting:

1. While executing of the BROWSE command the following message appears:
   ```
   There are NO SOLUTIONS !
   SELECT ANOTHER COMMAND !
   ```
   The Solution Base is empty. Press the <ESC> key to return control to the Main Menu and execute another command (e.g., the EFFICIENT command for solution generation).

2. After executing of the BROWSE command the Network Editor is not activated.
   The Network Editor cannot be loaded. Make sure that all the system files are in the default directory. Make sure that there are 640 KB RAM available in your PC.

3. While executing of the BROWSE command the following message appears:
   ```
   Some problems with NETWORK FILE !
   PRESS ANY KEY TO CONTINUE !
   ```
   The network file was changed during the analysis and solutions from the Solution Base can be improper for the current problem. You should restart the analysis with the CONVERT and PAY-OFF commands. Press any key to return control to the Main Menu.

4. While executing of the BROWSE command the following message appears:
   ```
   Some Problems with WORKING FILE
   PRESS ANY KEY TO CONTINUE !
   ```
   A working file with the Solution Base cannot be found in the default directory. Make sure that you have not changed a diskette during the work and the door is closed. Press any key to return control to the Main Menu.

5.3.3 SAVE command

The SAVE command generates a special Solution File for the Current Solution. This file can be used later during the same DINAS session or even during one of subsequent sessions for

restoration of the efficient solution. Thus the SAVE command allows you to make the Current Solution be save for further analysis. You can, certainly, save any efficient solution from the Solution Base having made it previously the current one with commands from the ANALYSIS branch (see Section 5.4.2).

There are two reasons for using of the SAVE command. The first one is connected with conducting a time–consuming analysis which cannot be finished during a single session. You should save then all the interesting efficient solutions before breaking off the analysis and leaving the DINAS system. The second reason is associated with performing a complex analysis where there are many (greater than nine) interesting solutions. The Solution Base is then too small and to prevent from loss you must save some solutions on separate files.

To avoid mistakes, while executing of the SAVE command the identification number of the Current Solution is displayed and you are asked to confirm your decision or cancel it. The corresponding message takes the form:

<p align="center">Do you wish to save Efficient Solution No # (y/n)?</p>

Next, if you have decided to save the solution you are asked for a name for the solution file. For this purpose a special eight–character field is displayed preceded by the message:

<p align="center">GIVE Solution File Name:</p>

You can then edit the name according to the general field editing rules (see Appendix A). At the beginning the field is initialized with the name SOLUTION. During subsequent executions in the field appears the latest used name of the solution file (in SAVE or RESTORE commands). During saving the solution the following message appears:

<p align="center">WAIT Saving Efficient Solution No # as <i>filename</i></p>

where *filename* represents the name of the solution file.

Warning: To avoid accidental loss of solution files you have to use different names for different efficient solutions.

The solution file is generated in the default directory as a binary file with the given name and extension EFF. For instance having given the name SOLUTION the system will generate the solution file SOLUTION.EFF.

To avoid various troubles with the saved files you should observe the following rules:

- after the session copy all the important solution files from the default directory;
- after the session delete from the default directory all the solution files which are useless;
- before the session copy all the necessary solution files to the default directory.

Troubleshooting:

1. While executing of the SAVE command the following message appears:
   There are NO SOLUTIONS !
   SELECT ANOTHER COMMAND !
   The Solution Base is empty. Press the <ESC> key to return control to the Main Menu and execute another command (e.g., the EFFICIENT command for solution generation).

2. While executing of the SAVE command the following message appears:
   Some problems with FILE: *name*
   The specified solution file cannot be opened in the default directory. Make sure that there is a possibility to open a new file in the default directory (the disk is not write–protected, the door is closed, etc.).

3. While executing of the SAVE command the following message appears:

        DISK FULL ! ! !
        PRESS ANY KEY TO CONTINUE !

   There is no sufficient space for the solution file on the default disk. Delete some useless (network and solution) files or put them on another disk (see Appendix D).

4. While executing of the SAVE command the following message appears:

        Some Problems with WORKING FILE
        PRESS ANY KEY TO CONTINUE !

   A working file with the Solution Base cannot be found in the default directory. Make sure that you have not changed a diskette during the work and the door is closed. Press any key to return control to the Main Menu.

5.3.4   DELETE command

The DELETE command is connected with the Current Solution but it help you to manage the Solution Base. In the Solution Base can be stored at most nine solutions and while the tenth solution is putting into the base the oldest solution is automatically deleted. To avoid loss of the interesting efficient solution you can delete manually another solution before the generation of a new efficient solution. The DELETE command delete the Current Solution from the Solution Base. It is recommended to delete not promising or duplicated efficient solution immediately after the generation when it is the Current Solution. Nevertheless you can delete any solution from the Solution Base having used previously some commands from the ANALYSIS branch (see Section 5.4.2) for activation this solution as the Current Solution.

   To prevent you from an accidental lost of the important efficient solution, while executing of the DELETE command the identification number of the Current Solution is displayed and you are asked to confirm your decision or cancel it. The corresponding message takes the form:

        Do you wish to delete Efficient Solution No # (y/n)?

If you have confirmed the command then the Current Solution is deleted from the Solution Base whereas the previous solution is activated as the current one and presented with the SUMMARY screens. If there is no previous solution the last solution will be selected as the Current Solution. For availability of the DELETE command the Solution Base must contain at least two solutions.

   Deleting of the efficient solution from the Solution Base does not erase the corresponding solution file if the solution has been previously saved (see Section 5.3.3). So, you can restore later such a solution from the solution file to the Solution Base (see Section 5.4.3). However, while restoring the solution get a new identification number.

Troubleshooting:

1. While executing of the DELETE command the following message appears:

        There are NO SOLUTIONS !
        SELECT ANOTHER COMMAND !

   The Solution Base is empty. Press the <ESC> key to return control to the Main Menu and execute another command (e.g., the EFFICIENT command for solution generation).

2. While executing of the DELETE command the following message appears:
   ```
   There is ONLY ONE SOLUTION !
   SELECT ANOTHER COMMAND !
   ```
   The Solution Base contains only one solution and it cannot be deleted. Press the <ESC> key to return control to the Main Menu and execute another command (e.g., the EFFICIENT command for solution generation).

5.4 ANALYSIS branch

5.4.1 COMPARE command

The COMPARE command is the main command of the ANALYSIS branch. It allows you to compare any set of the efficient solution included in the Solution Base with respect to all the characteristics supported by the SUMMARY screens. So, with the COMPARE command you can get objective values, aspiration/reservation bars, utopia/nadir bars and location activities for all the selected solutions simultaneously.

At the beginning of the COMPARE command execution you have to select solutions included into the comparison. For this purpose a special (temporal) Comparison Base is used. The Comparison Base is initialized as containing all the efficient solutions from the Solution Base. You can remove some solutions from the Comparison Base and thereby select the remaining solutions for the comparison.

The process of the Comparison Base definition is organized as follows. At the top of the screen the message appears:

<p align="center">SELECT Efficient Solutions for Comparison</p>

and simultaneously the initial Comparison Base is displayed. The Comparison Base is displayed as a table where each row corresponds to a single efficient solution while the columns correspond to several objective functions. In each row you can read the identification number of the efficient solution and objective values for several criteria. There is available a reverse-image pointer which allows you to select a solution by pointing out its identification number. The pointer is controlled by using the <UP> and <DOWN> arrows. If you have pressed the <DEL> key then the pointed out solution is removed from the Comparison Base and the corresponding row is deleted from the table on the screen. In such a way you can eliminate from the Comparison Base the solutions which you are not interested in during the comparison. You may finish the process of the Comparison Base definition at any moment by pressing the <ESC> key.

Remark: Do not be afraid to use the <DEL> key. The Comparison Base is only temporal for a single execution of the COMPARE command. All the solutions remain still available in the Solution Base.

For making a comparison at least two items in the Comparison Base are needed. Therefore the Comparison Base definition is automatically finished prematurely if only two efficient solutions remain in the base. The COMPARE command is not available if there is less than two efficient solutions within the Solution Base.

After setting up the Comparison Base you can analyse simultaneously all the selected solutions in terms of the objective values and location decisions. Similarly as during the execution of the SUMMARY command, there are available four screens:

- Values,
- A/R Bars,

<p align="center">61</p>

- U/N Bars,
- Locations.

At the top of each screen a header with the screen name is displayed.

The Values screen (see Fig. 27) provides you with numerical information about the objective values of several efficient solutions within the Comparison Base. There is presented a table where each row corresponds to a single efficient solution and the columns correspond to several objective functions. So, paying attention on a column you can compare the objective values of the specific criterion for given efficient solutions (rows).

The A/R Bars screen (see Fig. 30) provides you with a graphical comparison of the efficient solutions achievements with respect to the given aspiration and reservation levels. Namely, for each objective separately the group of aspiration/reservation bars corresponding to several Comparison Base items is presented. For detail description of a single aspiration/reservation bar structure see Section 5.3.1.

Similarly, the U/N Bars screen (see Fig. 29) provides you with a graphical comparison of the efficient solutions achievements with respect to the utopia and nadir values. Namely, for each objective separately the group of utopia/nadir bars corresponding to several Comparison Base items is presented. For detail description of a single aspiration/reservation bar structure see Section 5.3.1.

At both the bars screens the name of the objective is displayed over the bars group and each bar is marked (on the left) by the solution identification number. Usually, all the objective groups of bars cannot be displayed simultaneously due to lack of place on the screen. You can then scroll the screen using the <UP> or <DOWN> arrows. At the screen is displayed as many objective groups as possible (depending on the Comparison Base size) and using the narrow arrows you scroll one objective group up or down, respectively.

The Locations screen (see Fig. 20 or 28) provides you with comparison of the location decisions on which several efficient solutions are based. There is displayed a special table where each row corresponds to one potential node and the columns correspond to several items of the Comparison Base. So, paying attention on a row you may compare decisions connected with a specific potential node for given efficient solutions (columns).

Similarly as the standard SUMMARY screens, the COMPARE screens are controlled by the <PGDN> or <PGUP> keys which display screen by screen forward or backward, respectively. In order to return control to the Main Menu you have to press the <ESC> key.

Troubleshooting:

1. While executing of the COMPARE command the following message appears:
   There are NO SOLUTIONS !
   SELECT ANOTHER COMMAND !
   The Solution Base is empty. Press the <ESC> key to return control to the Main Menu and execute another command (e.g., the EFFICIENT command for solution generation).

2. While executing of the COMPARE command the following message appears:
   There is ONLY ONE SOLUTION !
   SELECT ANOTHER COMMAND !
   The Solution Base contains only one solution and the comparison cannot be performed. Press the <ESC> key to return control to the Main Menu and execute another command (e.g., the SUMMARY command for solution examination).

5.4.2 NEXT, PREVIOUS and LAST commands

The commands grouped in the SOLUTION branch can operate only on the Current Solution. The NEXT, PREVIOUS and LAST commands allows you to select any efficient solution from the Solution Base as the Current Solution and thereby to use the SOLUTION branch commands on that solution.

The efficient solution within the Solution Base are ordered according to the increasing identification numbers. The NEXT command causes that the next one after the Current Solution becomes a new Current Solution. While executing the PREVIOUS command the solution that precedes the Current Solution in the Solution Base becomes a new Current Solution. The LAST command makes the last solution in the Solution Base being a new Current Solution. While executing any of the three commands the new Current Solution is presented using the SUMMARY screens (see Section 5.3.1 for details). So, in order to return control to the Main Menu you have to press the <ESC> key.

Troubleshooting:

1. While executing of the NEXT, PREVIOUS or LAST command the following message appears:

   There are NO SOLUTIONS !
   SELECT ANOTHER COMMAND !

   The Solution Base is empty. Press the <ESC> key to return control to the Main Menu and execute another command (e.g., the EFFICIENT command for solution generation).

2. While executing of the NEXT command the following message appears:

   There is NO NEXT SOLUTION !
   SELECT ANOTHER COMMAND !

   The last solution is the Current Solution. Press the <ESC> key to return control to the Main Menu.

3. While executing of the PREVIOUS command the following message appears:

   There is NO PREVIOUS SOLUTION !
   SELECT ANOTHER COMMAND !

   The oldest solution in the Solution Base is the Current Solution. Press the <ESC> key to return control to the Main Menu.

5.4.3 RESTORE command

The RESTORE command allows you to insert an efficient solution from a solution file to the Solution Base. The solution file have to be previously prepared by the SAVE command (during the same or some earlier session with the problem). Thus the RESTORE command together with the SAVE command extend capabilities of the DINAS system making an opportunity for partitioning the analysis process into a few sessions as well as they allows you to conduct an analysis with greater number of efficient solutions than the Solution Base capacity (more than nine).

During the execution of the RESTORE command you are asked for a name of the solution file to be inserted. For this purpose a special eight-character field is displayed preceded by the message:

GIVE Solution File Name:

You can then edit the name according to the general field editing rules (see Appendix A for details).

You finish the edition by pressing the <ENTER> key whereas pressing the <ESC> key allows you to cancel the RESTORE command. If the system has found the proper solution file then the following message appears:

WAIT   Restoring *filename*   as Efficient Solution No #

and there is a short pause while the solution file is input and checked. If the restored solution file has found as a proper one then the inserted solution becomes the Current Solution and it is presented with the SUMMARY screens (see Section 5.3.1 for details). So, in order to leave the command you have to press the <ESC> key.

To avoid troubles while executing the RESTORE command you should observe the following rules:

- before the session copy all the necessary solution files to the default directory;
- make sure that the solution files correspond to the problem under analysis, i.e., the problem has not be changed after the solution files generation.

Troubleshooting:

1. While executing of the RESTORE command the following message appears:
   Problem NOT AVAILABLE !
   SELECT CONVERT COMMAND !
   There is no problem assigned to the Interactive System. Press the <ESC> key to return control to the Main Menu and execute the CONVERT command.

2. While executing of the RESTORE command the following message appears:
   Utopia & Nadir Vectors are NOT AVAILABLE !
   SELECT PAY-OFF COMMAND !
   The PAY-OFF command has to be executed before first using of the RESTORE command. Press the <ESC> key to return control to the Main Menu and execute the PAY-OFF command.

3. While executing of the RESTORE command the following message appears:
   Some problems with FILE: *name*
   PRESS ANY KEY TO CONTINUE !
   The specified solution file cannot be found in the default directory. Make sure that you have specified a proper file name and it is in the default directory.

4. While executing of the RESTORE command the following message appears:
   Illegal SOLUTION FILE !
   PRESS ANY KEY TO CONTINUE !
   The specified solution file does not contain a solution which corresponds to the problem under consideration. Simply, it is not a solution file or it is a solution file to another problem. After pressing any key you can edit the name of the solution file to be restored. You can cancel the command execution by pressing the <ESC> key while editing the name.

6 Network Editor

6.1 The Editor Menu

DINAS is armed with the built-in Network Editor EDINET. EDINET is a full–screen editor which allows you to create a network file for the problem using IBM PC's keyboard. Two modes of using the editor are supported: the edit and the view mode. The edit mode allows you to display and edit data of the problem. In the view mode the data can be only examined but cannot be edited. This mode is used for an examination of the current efficient solution. The modes are activated due to selecting of appropriate commands from the Main Menu: PROBLEM for the edit mode and BROWSE for the view mode.

Using the EDINET editor is simple as it can be: when you have selected the PROBLEM or BROWSE command, the editor is activated automatically. The Editor Menu and the corresponding banner appears on the display.

FILE	PRINT NETWORK	EDIT NETWORK
Load		List nodes
Save		Network
Quit		Selections
		Objectives

Table 13: The Editor Menu

Table 13 shows the commands available in the Editor Menu. A command is selected while moving the reverse image pointer through the menu by use of arrow keys, and executed by pressing the <ENTER> key. The HELP file is available at any time by pressing the <F1> function key.

The commands are partitioned into three branches: FILE, PRINT NETWORK and EDIT NETWORK. The FILE branch collects commands associated with file operations and leaving the editor (see Figure 5). The PRINT NETWORK branch consists of a single command which generates various reports. The EDIT NETWORK branch collects the editor commands which enable the creation and modification of the network file (see Figure 6).

Troubleshooting:

1. After pressing the <F1> key the message
    No help file - editor.hlp press any key to continue
   appears in the help window. Make sure that the file EDITOR.HLP is available in the default directory.

6.2 FILE branch

6.2.1 LOAD command

The LOAD command is used to select a network file to be edited, printed and saved. The LOAD command will issue the request for a network file name. A special field for the name is displayed preceded by the short message:

    File:

and you may respond with any legal file name, e.g., `Filename.ext`, editing the name according to the general field editing rules (see Section 5).

If you enter a file name without period and extension, the extension NET is automatically assumed and appended to the name.

If the specified file does not exist or cannot be opened, the following message is displayed:

<div align="center">

`Some problems with input file - PRESS enter`

</div>

After pressing the `<ENTER>` key a new file is opened and is started as the current network file if it was not opened before.

If the `EDINET` editor is called by the `BROWSE` command (in the view mode), the `LOAD` command is not attainable to you; the current network file processed in the system is automatically loaded and assumed to be current in the editor.

If you work with a network file and you are going to load another file, then you are asked whether the current network file may be overridden.

Remarks: The network file name may be preceded by a path what allows you to edit files from various directories.

The `LOAD` command is not available while working in the view mode.

Troubleshooting:

1. The message

   `Some problems with input file - PRESS enter`

   is issued during the execution of the `LOAD` command since the specified network file cannot be loaded.

   The accident may occur for the following reasons

   - you want to create a new network file;
   - you made a mistake specifying an incorrect file name;
   - the drive is not ready for reading.

   In the first case simply press `<ENTER>` to open the new network file. In the second case specify the file once again using its correct name, and press `<ENTER>`. In the third case you have to make the drive ready for reading and press `<ENTER>`.

2. The message

   `Can't read network file ! Press any key.`

   is issued during the execution of the `LOAD` command. It may happen when a fatal disk read error takes place. Use another source disk to input the network file.

6.2.2 SAVE command

The `SAVE` command is used to save the current network file on a disk. The editing process is performed entirely in memory, and any associated disk file is not affected. Saving of the edited file on a disk is done explicitly with the `SAVE` command. After selecting the `SAVE` command you are asked for a name of the network file. For this purpose a special field appears preceded by the message:

`File:`

You can then edit the name according to the general field editing rules (see Section 5 for details). The field is initialized with the recently used name of the network file during the LOAD or SAVE command execution. Thus if you want to save the recently loaded file without any change of the name you can simply press <ENTER> to confirm the file name.

Warning: The SAVE command does not produces a BAK file. Therefore you should change the file name during the execution of the SAVE command, if you are interested in saving both the network files: the original one and the modified one.

Warning: During the execution of the PAY-OFF command from the DINAS Main Menu, the computed pay off matrix and the utopia and nadir vectors are automatically saved on the current network file. They can be used in next runs without renewed computation provided that the file has not been saved by the editor SAVE command. Using of the SAVE command destroys the pay–off record on the network file.

Remark: The SAVE command is not available while working in the view mode.

Troubleshooting:

1. The message

        Some problems with output file - PRESS enter

    is issued during the execution of the SAVE command since the specified network file cannot be saved. It happens when the drive is not ready for writing. Thus make the drive ready and press <ENTER> to finish the execution of the SAVE command.

2. The message

        Can't write network file! Press any key.

    is issued during the execution of the SAVE command. It happens when either the disk space is exhausted and the network file cannot be saved as whole or a fatal disk write error takes place. To avoid these troubles change the target disk and press <ENTER>.

6.2.3 QUIT command

The QUIT command is used to leave the editor and return control to the Main Menu. The QUIT command does not save automatically the current network file. In order to save the edited data on a disk you have to use the SAVE command. To prevent you for accidental loss of the data, if a network file has been edited (since it was loaded) you are asked whether you want to save it before leaving the editor. Namely, the following question appears:

        Abandon current network file ? (y/n)

If you have pressed the <Y> key then the control will return to the DINAS Main Menu. Pressing another key allows you to remain within the editor.

6.3 PRINT NETWORK branch

6.3.1 PRINT NETWORK command

The PRINT NETWORK command controls the generation of two kinds of reports: the network report or the solution report. The report kind is strictly connected with the editor mode. If the editor is called in the edit mode (PROBLEM command) then the network report is generated whereas the solution report is generated in the view mode (BROWSE command). Both the reports take the form of a set of tables. After the command activation, the following message is displayed:

```
Press ENTER to select printer or type file name
```

It allows you to specify whether the tables have to be printed directly or stored on a designated file. The report file is a standard text file and thereby it will be able to be displayed (typed) or printed with the standard DOS commands after leaving the DINAS system. The file name have to be complied with DOS requirements.

During printing the report a message appears:

```
Press any key to break printing
```

which inform you about an opportunity to interrupt printing at any time. If you press a key then the report generation is suspended and the following command is displayed:

```
Press ENTER to resume, ESC to stop printing
```

Then, if <ENTER> is pressed, printing will be continued, but if you press the <ESC> key then the command will be canceled and the Editor Menu will be reactivated.

6.3.2   The network report

The network report consists of 5 tables: OBJECTIVES, ARCS, FIXED NODES, POTENTIAL NODES and SELECTIONS. Each table is preceded by a brief header identifying the system (DINAS), problem (file name) and table. The header is directly followed by a pattern of a single record of the table. An example of each table is given below. The contents of the tables are described in the notes that follow each example.

The OBJECTIVES table:

```
DINAS
PROBLEM    demo.net
OBJECTIVE
   NAME      TYPE     ACTIVITY
   Invest    MIN      YES
   Satisf    MAX      YES
   Dist      MIN      YES
   Prox      MAX      NO
```

Contents: A list of the objectives with their types and activities.
Name: The name of the objective function.
Type: MIN if the objective function is minimized and MAX if it is maximized.
Activity: YES if the objective is active and NO otherwise.

The ARCS table:

```
DINAS
PROBLEM    demo.net
ARC
NAME        FROM  -  TO        OBJECTIVE
CAPACITY                        NAME     COEFFICIENT
BURO        Bush  -  Robur
50                             Invest   0
                               Satisf   0
                               Dist     0.01825
                               Prox     5.21
BAR         Bush  -  Arnika
60                             Invest   0
                               Satisf   0
                               Dist     0.01125
                               Prox     13.72
```

Contents:	A list of the network arcs with their capacities and objective coefficients.
Name:	The name of the arc.
Capacity:	The arc capacity.
From:	The name of the predecessor node of the arc.
To:	The name of the successor node of the arc.
Objective:	A list of the objectives with their coefficients corresponding to the arc.
Name:	The name of the objective.
Coefficient:	The objective coefficient corresponding to the arc.

The FIXED NODES table:

```
DINAS
PROBLEM    demo.net
FIXED NODES
    NAME        BALANCE        NAME        BALANCE
    Acer        -16            Arnika      -20.5
    Betula      -13            Bobrek      -22
    Tie         240
```

Contents:	A list of the fixed nodes and their balances, in alphabetic order.
Name:	The name of the node.
Balance:	The balance amount for the corresponding node.

The POTENTIAL NODES table:

```
DINAS
PROBLEM   demo.net
POTENTIAL NODES
                        SELECTIONS       OBJECTIVE
NAME      CAPACITY                       NAME    COEFFICIENT

Bush      50        South   Forest       Invest      126
                                         Satisf      100
                                         Dist          0
                                         Prox          0
Fiord     60        North                Invest      220
                                         Satisf       87
                                         Dist          0
                                         Prox          0
```

Contents:	A list of the potential nodes with their capacities, selections which contain the node, and objective coefficients.
Name:	The name of the node.
Capacity:	The node capacity.
Selection:	The names of (no more then two) selections including this node.
Objective:	A list of the objectives with their coefficients corresponding to the node.
Name:	The name of the objective.
Coefficient:	The objective coefficient corresponding to the node.

The SELECTIONS table:

```
DINAS
PROBLEM     demo.net
SELECTIONS
    NAME          BOUND        NODES
              LOWER UPPER
    North         0    1       Fiord   Ice
    South         1    2       Bush    Oasis
```

Contents:	The alphabetically ordered list of selections with their lists of included potential nodes and lower and upper bounds on numbers of the nodes to be selected.
Name:	The name of the selection.
Lower:	The lower bound on number of the nodes to be selected.
Upper:	The upper bound on number of the nodes to be selected.
Nodes:	A list of the potential nodes which belong to the selection.

6.3.3 The solution report

The solution report differs from the network report only in the tables OBJECTIVES, ARCS and POTENTIAL NODES. In these tables there are some additional entries which represent the current efficient solution. An example of each of the extended tables is given below.

70

The OBJECTIVES table:

```
DINAS
PROBLEM   demo.net
OBJECTIVE
  NAME      TYPE    ACTIVITY    VALUE
  Invest    MIN      YES        386
  Satisf    MAX      YES        276
  Dist      MIN      YES        2.26056e+00
  Prox      MAX      YES        6.45690e+03
```

Additional entries:

Value: The optimal (efficient) value of the corresponding objective function.

The ARCS table:

```
DINAS
PROBLEM   demo.net
ARC
NAME          FROM  -  TO        OBJECTIVE
CAPACITY      FLOW                NAME     COEFFICIENT
BURO          Bush  -  Robur
50                 2.05000e+01    Invest   0
                                  Satisf   0
                                  Dist     0.01825
                                  Prox     5.21
BAR           Bush  -  Arnika
60                 0              Invest   0
                                  Satisf   0
                                  Dist     0.01125
                                  Prox     13.72
```

Additional entries:

Flow: The optimal (efficient) flow along the arc.

The POTENTIAL NODES table:

```
DINAS
PROBLEM   demo.net
POTENTIAL NODES
ACTIVITY   FLOW          SELECTIONS        OBJECTIVE
NAME       CAPACITY                        NAME    COEFFICIENT
YES        47.86
Bush       50         South   Forest       Invest   126
                                           Satisf   100
                                           Dist     0
                                           Prox     0
NO         0
Fiord      60         North                Invest   220
                                           Satisf   87
                                           Dist     0
                                           Prox     0
```

71

Additional entries:

Activity: YES if the node has been located and NO otherwise.

Flow: The optimal (efficient) flow through the node.

6.4 EDIT NETWORK branch

The DINAS interactive procedure works with the network file containing whole the information defining the problem and the EDIT NETWORK branch of the Editor Menu enables to prepare this file. The main data of the problem can be divided into two groups:

- logical data defining the structure of a transportation network (nodes, arcs, selections);
- numerical data describing the nodes and arcs of the network (balances, capacities, objective coefficients).

The general concept of the Network Editor is to edit the data while defining the logical structure of the network. More precisely, the essence of the EDINET concept is a dynamic movement from some current node to its neighboring nodes, and vice versa, according to the network structure. The input data are inserted by a special mechanism of windows, while visiting several nodes. At any time only one of the windows representing different kinds of the data is active. The corresponding part of the data can be then inserted. While working with the editor you can activate several windows.

The EDIT NETWORK branch consists of he following commands: LIST NODES, NETWORK, SELECTIONS and OBJECTIVES. Each of these commands is executed explicitly by selecting the appropriate position in the EDIT NETWORK submenu and pressing the <ENTER> key. However, in order to prevent you from frequent returns to the menu during the editing process, a special implicit execution technique is also available. Namely, each of these commands can be activated during execution of another command by pressing the <ALT> key together with the first letter of the command name, i.e., by pressing <ALT>/<L>, <ALT>/<N>, <ALT>/<S> or <ALT>/<O>, respectively.

6.4.1 LIST NODES command

After activating the LIST NODES command a special window appears. An example of such a window is presented in Figure 16.

The message at the top of the window provides you with the window name and the name of the current network file. While starting with a new network file the window is empty. If not, the window includes all the network nodes (in the alphabetic order), which has been inserted so far. At any time a certain node of the nodes list is pointed out. The names of the potential nodes are highlighted (blue) and the pointed out node is blinking. Using arrow keys you can move the pointer along the list to select a node. The list is vertically scrolled, if it is too long to be presented directly.

There are two ways to finish the LIST NODES command. By pressing the <ESC> key you simply leave the command and return control to the Editor Menu (in case of a direct execution) or to the place where the command was executed (by the <ALT>/<L> key). You can also finish the command by activating the EDIT windows (see Section 6.5) with a selected node. For this purpose you press <ENTER> what confirms the node selection given by the pointer or simply you type a name of the node (new or existing).

6.4.2 NETWORK command

The NETWORK command issues a special window which helps you to recognize the network structure. An example of the NETWORK window is presented in Figure 15. The window name and the name of the network file are given at the top of the window.

The NETWORK window presents a graphic scheme of the network that is actually edited. The basic concept of the scheme is to give a local view on the structure of the network. The scheme consists of several (alphabetically ordered) central nodes connected to their predecessors (on the left hand side) and their successors (on the right hand side). As a rule, the pointer points out the central node at the top of the window. However, you can change the pointed out central node. After pressing the <DOWN> arrow, the next (in alphabetic order) central node is pointed out; the central nodes with their predecessors and successors are scrolled up and, in result, the next central node will occupy the first position. Similarly, to point out the preceding central node you have to press the <UP> arrow, then the central nodes are scrolled down and the preceding central node is shifted to the pointed out position.

You can also move the pointer to a predecessor or successor of the pointed out central node. To point out a predecessor of the central node you have to use the <LEFT> arrow. Then the first predecessor is pointed out and using the <DOWN> or <UP> arrows you can select another predecessor. Use the <RIGHT> arrow to return to the pointed out central node. You can also change the selected predecessor into the pointed out central node using the <ENTER> key. Similarly, you can point out a successor of the central node by pressing the <RIGHT> arrow. Then you can select any successor using the <DOWN> or <UP> arrows. Use the <LEFT> arrow to return to the pointed out central node or press <ENTER> to change the selected successor into the pointed out central node.

Similarly as in the LIST NODES command here are two ways to finish the NETWORK command. By pressing the <ESC> key you simply leave the command and return control to the Editor Menu (in case of the direct execution) or to the place where the command was executed (by the <ALT>/<N> key). You can also finish the command by activating the EDIT windows (see Section 6.5) with a selected node. For this purpose you press <ENTER> what confirms the node selection given by the pointer (the pointed out central node).

Remark: Move the pointer to the central position before leaving the command (by pressing the <ENTER> key).

6.4.3 SELECTIONS command

After executing of the SELECTIONS command a special window is displayed. An example of the SELECTIONS window is given in Figure 17.

The selections which have been met during the editing process are listed in this window. On the right hand side of each selection name a list of the potential nodes belonging to the selection is given. The top position of the selections list is pointed out. You can move each selection into the pointed out position by scrolling the list with the <DOWN> or <UP> arrows.

Sometimes the selections list is found empty (e.g., if the current network file has been just opened or if no selections have been inserted until now). Then the following massage is issued:

<center>No selections - press a key</center>

After pressing any key you will leave the command.

If you press <ENTER>, a special window for edit bounds of the pointed out selection appears. An example of the BOUNDS window is given in Figure 18.

<center>73</center>

The name of the pointed out selection is displayed at the top of the window. One of two fields corresponding to the LOWER and UPPER bounds is highlighted while editing. You can insert an integer number into the highlighted field and press the <ENTER> key or <DOWN> or <UP> arrows. Then the other field will be highlighted and you can edit the second bound. In order to leave the BOUNDS window you have to press the <ESC> key. Then, the SELECTIONS window appears again.

If the bounds have been inserted and the UPPER bound proves to be less than the LOWER bound then the following error message is displayed:

```
Can't be LOWER > UPPER  -  press any key
```

After pressing a key you have to edit bounds again to avoid this error. The editor also protests if you are going to insert a negative value as a bound.

Pressing the <ESC> key lets you leave the SELECTIONS command and return to the point where it was called.

6.4.4 OBJECTIVES command

Objective functions are defined by use of the OBJECTIVES command. Activating this command will issue the OBJECTIVES window. An illustration of such a window is given in Figure 7. While starting with a new file, the window is blank apart from the pattern line at the top. In order to define an objective you have to fill in the window form three items:

OBJECTIVE: The objective name.

TYPE: MIN if the objective is minimized and MAX if it is maximized.

ACTIVITY: YES if the objective is active and NO otherwise.

If you actually edit the OBJECTIVE or TYPE field, you can move the cursor to the next field (TYPE or ACTIVITY, respectively) using the <ENTER> key. If you press <ENTER> after the ACTIVITY is selected, the cursor moves to the next objective. Use <DOWN> or <UP> arrow to move the cursor along the objective list. To edit TYPE and ACTIVITY you have to select one of two options given in the edited field using the <LEFT> or <RIGHT> arrows: MIN or MAX and YES or NO, respectively.

If the editor works in the view mode the contents of the OBJECTIVES window is extended. Namely, on the right hand side of each objective record the optimal (efficient) value of the objective is given.

In order to leave the OBJECTIVES command you have to press the <ESC> key. Then the control will return to the point where the command was called.

6.5 EDIT windows

6.5.1 NODE windows

In order to start the network edit you have to call the LIST NODES or NETWORK command and leave it by activating the EDIT windows. Thus you have to press <ENTER> or type a node name (in case of the LIST NODES command).

Suppose at first that you have typed a node name. After the first character of the name is entered, the window presented in Figure 8 appears. The character is placed in the name field and you can continue the name edit. When the name is completed press <ENTER> or <ESC>.

74

Now you meet one of two options of the program performance: the name is new or the name has been inserted before. The new node name case is described below. The second option will be explained in Section 6.5.2.

While performing the first option, the window as in Figure 9 is displayed. You are informed that the node is not defined yet and you have to decide whether the node have to be fixed or potential. Select option "fixed" or "potential" moving cursor with the <LEFT> or <RIGHT> arrows and press <ENTER> or <ESC>. Then the new node is defined and dependently on the selected option the FIXED or POTENTIAL node window appears.

If the FIXED node option has been selected, the window illustrated in Figure 12 is presented on the screen. The inserted node name is found at the top. The message in the second line inform you that the node is fixed. The third line contains the balance field. Using the <DOWN> or <UP> arrows you can select the "name" or "balance" field and edit it.

If you have selected the potential node option, the window that is shown in Figure 10a is displayed. The entered node name is placed at the top. The "potential" type declaration is found in the second line. The third line contains the capacity field. You can edit the capacity and press <ENTER>. Then the first selection field appears. You can edit a selection name and press <ENTER> or only press <ENTER> leaving the field blank (or not changed, in general). Then the second selection field appears and you can do the same. Finally, the block of the objectives is displayed. You can edit several objective coefficients using the <DOWN> and <UP> arrows to change the field to be edited. An example of the complete potential node window is given in Figure 10b. You can use the <DOWN> or <UP> arrow to select any field and edit it again in order to change or correct the data.

Remark: Notice, that you can change the previously edited name. If you change a name into one of another node names, the message will be issued

                Already exists such a node - Press any key

since all the node names have to be different. Thus you can change the previously edited name only into a name which is actually not used.

If the editor works in the view mode then the information contained inside of the potential node window is extended. At the left-top corner of the window a special character appears if the potential node occupying this window has been selected (located). Moreover, under the capacity line the optimal value of the flow through the node is given.

If you have finished the editing process of the current (fixed or potential) node then you have to press the <ESC> key in order to activate the CURRENT/FROM/TO screen.

6.5.2 CURRENT/FROM/TO screen

The CURRENT/FROM/TO screen (see Figure 11) consists of three windows: CURRENT NODE in the middle of the screen, NODE FROM on the left hand side and NODE TO on the right hand side. This screen is displayed when a new node has been defined. It appears also if you have left the LIST NODES or NETWORK command pressing <ENTER> or typing a node name inserted before. The pointed out (in the <ENTER> case) or called (by the name) node is assumed to be current and occupies the CURRENT NODE window. Thus the CURRENT NODE window is simply the FIXED or POTENTIAL node window (see Figure 12 and 10b). The window represents a defined node, called current.

The NODE FROM window contains names of the nodes that precede the current node in the network, and names of the corresponding arcs (if they were introduced). Similarly, the NODE TO window contains names of the nodes and arcs which directly succeed the current

node in the network. These windows may be empty if no predecessor or no successor to the current node have been inserted. Inside of each of the windows you can move the cursor along the node list using the <DOWN> or <UP> arrow. If a list is too long it is vertically scrolled.

You can activate any of these three windows using appropriate keys. If the CURRENT NODE window is active then you can activate the NODE FROM or NODE TO window using the <CTRL>/<LEFT> or <CTRL>/<RIGHT> arrow, respectively. On the other hand, if one of the side windows is active, you can activate the CURRENT NODE window pressing <ESC>.

If you want to make a node belonging to the NODE FROM or NODE TO list to be current then, at first, you have to activate the corresponding window. Next, using the <DOWN> or <UP> arrows you have to select the node and press <ALT>/<C>. In result, the selected node becomes current and is automatically inserted into the CURRENT NODE window. Moreover, its predecessors and successors enter the NODE FROM and NODE TO windows, respectively.

In order to return to the Editor Menu you have to activate the CURRENT NODE window and then press the <ESC> key.

6.5.3 Predecessors and successors editing

In order to edit predecessors or successors to the current node you have to call the CURRENT/FROM/TO screen and then activate one of the side windows (see Section 6.5.2). Suppose, the NODE FROM window has been activated. Then you can select one of the predecessors to the current node or type a node name (in particular, a new name). Thus the framework described in Section 6.5.1 comes to light again. If you select or type the name of an existing predecessor, the window containing the whole information corresponding to this node will be issued. But if you type a new predecessor name, the definition of the node will be processed. As a result of the both cases a (fixed or potential) NODE window corresponding to this predecessor will be displayed and you will be able to edit or examine the data in the window. After the edit (or examination) is finished you have to press the <ESC> key. Then you are asked to respond to the short question (see Figure 12)

ARC?

which appears at the bottom of the window. If you wish to visit the corresponding ARC window you should press the <ENTER> key. By pressing the <ESC> key you cause reactivating of the NODE FROM list of predecessors.

You can also visit the ARC window immediately while visiting the NODE FROM list. To attain it you have to select a predecessor from the list and then press <CTRL>/<RIGHT> arrow. Then you can see the ARC window with contents corresponding to the arc leading from the selected predecessor to the current node. If you press <CTRL>/<RIGHT> arrow again, the NODE FROM list will be reactivated.

Any successor with their associated arc can be edited similarly, but by use of the NODE TO windows.

Troubleshooting

1. You cannot introduce a predecessor (or successor) name since the message
       Can't define a cyclic arc PRESS any key
   is issued while introducing.
   The network cannot contain any simple loop. To introduce this predecessor (or successor) you must either change its name or change the current node name so as these

names will be different.

If you really want to introduce the loop Nnode–Mnode you may define an artificial fixed node Nloop with the zero balance and the pair of the arcs: Nnode–Nloop, Nloop–Nnode. The loop is equivalent to the pair. The data corresponding to the loop characterize one of the arcs, but the other arc is characterized by the unbounded (sufficiently large) capacity and the vanishing objective coefficients.

2. You cannot introduce a predecessor (or successor) name since the message

    Can't define arc from potential to potential PRESS any key

  is issued while introducing.

  The network cannot contain any arc which joins two potential nodes directly.

  To introduce the arc Npot–Mpot (joining two potential nodes) you have to define an intermediate fixed node Nint with the zero balance and these arcs: Npot–Nint and Nint–Mpot. The data corresponding to the arc Npot–Mpot characterize one of these arc but the other arc is characterized by the unbounded (sufficiently large) capacity and the vanishing objective coefficients. The couple of the arcs defined this way is equivalent to the arc Npot–Mpot.

6.5.4 ARC window

As it was mentioned in Section 6.5.3 the ARC window can be activated while visiting NODE FROM/TO lists or while editing the actual predecessor (using <ENTER>). The window is designed to edit or examine the data corresponding to the arc that leads from the predecessor to the current node (see Figure 13).

The top line at the ARC window contains the predecessor and current node names and this line cannot be edited. The next line is assigned to the name of the arc. The name is optional and need not to be inserted. The arc capacity can be entered in the third line. The next two lines are free. If the editor works in the view mode then you can find the value of the optimal flow along the arc in the first of the free lines. At the end, the block for objective coefficients editing appears. You can edit several coefficients as well as the arc name and capacity using the <DOWN> or <UP> arrow and the <ENTER> key to select the field to be edited.

In order to close the ARC window you have to press the <ESC> key. You can also return directly to a NODE FROM/TO list by pressing <CTRL>/<RIGHT> arrow.

6.6 DELETE command

The editor allows you to delete a node, arc, selection or objective if they are superfluous or unwanted. The DELETE command is executed by activating an appropriate window, pointing out the name of the removed object and pressing <ALT>/<D>. A brief description of these operations is given below.

- Delete an objective:

    1. activate the OBJECTIVES window;
    2. point out the name of the objective to be deleted;
    3. press <ALT>/<D>.

  Warning: The whole information concerning the deleted objective, including the coefficients defined within each POTENTIAL NODE or ARC window, is lost. Therefore for temporal deactivation of the objective function you should use the ACTIVITY column in the OBJECTIVES window instead of the DELETE command.

- Delete a selection:

  1. activate the SELECTIONS window;
  2. point out the name of the selection to be deleted;
  3. press <ALT>/<D>.

  Remark: The name of the selection is also deleted from each POTENTIAL NODE window associated with the deleted selection.

- Delete a node:

  1. load the node to be deleted into the CURRENT NODE window and activate this window;
  2. point out the name of the node;
  3. press <ALT>/<D>.

  Remark: All the arcs that are incident to the deleted node are deleted with this command automatically.

- Delete an arc:

  1. load one of the arc endpoints into the CURRENT NODE window;
  2. the remainder endpoint is either predecessor or successor to the current node; activate the appropriate NODE FROM or NODE TO window and select this endpoint from the node list included inside of the window;
  3. press <ALT>/<D>.

  After pressing <ALT>/<D> you are asked whether you really want to delete the indicated object (objective, selection, node or arc). Namely, you have to answer a question like this:

  Do you really....

  You press then <Y> to confirm or <N> otherwise.

  Warning: No provision exists to restore a deleted object, so be careful while using the DELETE command.

7 References

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A Field editing

While working with DINAS you are frequently asked for some parameters specification. Especially, during the problem input with the network editor you have to give many names and numbers. In the whole DINAS system, i.e. in both the interactive system and the network editor the process of parameters input runs according to the same scheme. Namely, a special field or a group of fields organized in a special window is displayed and you can input parameters by editing these fields.

The size of the field depends on a specific parameter and it limits the maximal length of a name or number. Moreover depending on a specific parameter some characters (some keys) are non accepted as quite improper. For instance, while editing a number there is no possibility to type a letter expect of e or E (which can precede a decimal exponent). The <SPACE> bar is not accepted neither in numbers nor in names.

The process of a single field editing is controlled by a one–character cursor with the following keys: <LEFT> and <RIGHT> arrows, <BACKSPACE>, <DEL> and <INS>. The <LEFT> or <RIGHT> arrow moves the cursor one space left or right, respectively. The <DEL> key causes that the pointed character disappears, and the rest of the field moves to the left one space. Similarly, while using the <BACKSPACE> key the character preceding the cursor disappears, and the rest of the field moves to the left one space. There are available two editing modes: the insert mode and the overwrite mode. While editing in the overwrite mode the input character appears exactly at the cursor position replacing any previous character at this position. While editing in the insert mode the input character also appears exactly at the cursor position but the rest of the field (including the previous character from the cursor position) moves to the right one space. If there is no possibility to move the rest of the field to the right (since the field is full) the input is not accepted. Each field is opened with initialized the insert mode. The <INS> key is a toggle switch that allows you to change the editing mode.

There are a few ways to finish editing and close the field. By pressing the <ENTER> key you close the field and open the next field in case of a multiple fields window (see, e.g., aspiration/reservation edit in Section 5.2.4 or node definition in Section 6.6.1) or you cause the command execution in case of a single field (see e.g. RESTORE command in Section 5.4.3 or LOAD command in Section 6.2.1). By pressing the <ESC> key you close not only the edited field but also the whole window of the fields (see, e.g., the ARC window in Section 6.6.4 or aspiration/reservation edit in Section 5.2.4). Moreover the command or the phase of the command connected with the window is also finished. This possibility can be used, sometimes, to cancel the command (see e.g. RESTORE command in Section 5.4.3). While editing some window of fields you can also finish editing of a single field by pressing a specific movement key which closes the field and open another field in the window. The movement keys are always specified in the help line. Usually, the <UP> and <DOWN> arrows are movements keys, and sometimes the <CTRL>/<LEFT> and <CTRL>/<RIGHT> arrows are also movement keys.

In case of numbers editing, after closing the field the number is automatically verified. Any improper string is signaled by the message

error

which appears in the field. Moreover, while editing aspiration and reservation levels after closing the field, the number is presented in such a form as it has been taken by the system.

<u>Troubleshooting</u>:

1. You cannot input any character. Pressing any character key makes only the error noise.
   You work in the insert mode with a full field. Use the <DEL> or <BACKSPACE> key to
   make some space or activate the overwrite mode by the <INS> toggle key.

B Short reference

B.1 The Interactive System

- MENU BRANCHES

PROCESS	commands connected with processing of the multiobjective transshipment–location problem and generation of several efficient solutions (PROBLEM, CONVERT, PAY–OFF, EFFICIENT, QUIT).
SOLUTION	commands connected with the Current Solution (SUMMARY, BROWSE, SAVE, DELETE).
ANALYSIS	commands connected with operations on the Solution Base which collects up to nine efficient solutions (COMPARE, PREVIOUS, NEXT, LAST, RESTORE).

- PROCESS COMMANDS

PROBLEM	edit or input of a problem with the Network Editor. If the network file for the problem has been prepared before DINAS starts, PROCESS can be initialized directly using the CONVERT command.
CONVERT	convert the network file with error checking.
PAY–OFF	compute the pay–off matrix and the utopia and nadir vectors.
EFFICIENT	compute an efficient solution depending on introduced aspiration and reservation levels:

    1.edit aspiration and reservation levels;

    2.DINAS computes a new efficient solution depending on the aspiration and reservation levels;

    3.the solution is put into the Solution Base and is presented as the Current Solution with special tables and bars.

    The Current Solution is presented similarly as while using the SUMMARY command.

QUIT	leave the DINAS system.

- SOLUTION COMMANDS

SUMMARY	present short characteristics of the Current Solution such as:

    table of selected locations,

    table of objective values,

    bars in the aspiration/reservation scale,

    bars in the utopia/nadir scale.

    The tables characterize the current and previous efficient solutions. The bars show a percentage level of each objective value with respect to the corresponding scale.
Change the kind of characteristic using the <PGDN> or <PGUP> key.

BROWSE	examine or print the Current Solution with the Network Editor.
SAVE	save out the Current Solution on a separate file for using in next runs.

DELETE   delete the Current Solution from the Solution Base.

- ANALYSIS COMMANDS

COMPARE   perform comparison of all the efficient solutions from the Solution Base
                or of some subset of them. (A solution can be temporarily deleted from
                the comparison using the <DEL> key.)
                The following characteristics are used for the comparison:

                    table of selected locations,

                    table of objective values,

                    bars in the aspiration/reservation scale,

                    bars in the utopia/nadir scale.

                The tables and bars characterize all the efficient solutions selected from
                the Solution Base. The bars are given for each objective and show a
                percentage level of the objective value with respect to the correspond-
                ing scale. Use the <PGDN> or <PGUP> key to change the kind of the
                current characteristic. Scroll bars for different objectives using the
                <UP> or <DOWN> arrows.

PREVIOUS   take the previous efficient solution as the Current Solution.

NEXT   take the next efficient solution as the Current Solution.

LAST   take the last efficient solution as the Current Solution.

RESTORE   restore some efficient solution (saved earlier with the SAVE command)
                to the Solution Base.

B.2   The Network Editor

- MENU COMMANDS

LOAD   select a file to be used to edit.
                        If the file name is typed without any extension the extension
                        .NET is automatically appended to the name.

SAVE   write the edited file out without creating a .BAK file.

QUIT   leave the Network Editor and return to the Main Menu.

PRINT NETWORK   print the entire data file and the solution included in the file.

LIST NODES   display a list of nodes (may be empty at the start).
                        Type or select a node name to activate the edit mode. Then
                        the CURRENT NODE window including the selected (or typ-
                        ed) node is activated.

NETWORK   display a scheme of the transportation network. Select a node
                        to activate the edit mode. Then the CURRENT NODE win-
                        dow is activated with the selected node as the current node.

SELECTIONS   list the nodes belonging to several selections. Use <ENTER> to
                        display the BOUNDS window corresponding to the pointed
                        out selection.

OBJECTIVES   define, modify or examine objectives.

- WINDOWS

CURRENT NODE	the node selected (or typed) with the LIST NODES or NETWORK command becomes the current node. Then it can be defined and its data can be edited or examined.
NODE FROM (list of predecessors)	list names of nodes and the corresponding arcs which precede the current node. Select a node or type a node name.
NODE FROM (a selected predecessor)	edit or examine data of the selected (or typed) node. If the <ESC> key is used after the edit is finished, the question ARC? appears. Press <Y> if an inspection of the corresponding arc is needed, or <N> otherwise.
NODE TO (list of successors)	list names of nodes and the corresponding arcs which succeed the current node. Select a node or type a node name.
NODE TO (a selected successor)	edit or examine data of the selected (or typed) node. If the <ESC> key is used after the edit is finished, the question ARC? appears. Press <Y> if an inspection of the corresponding arc is needed, or <N> otherwise.
BOUNDS	edit or examine lower and upper bounds on a number of potential nodes which can be used in the given selection.

- ALT COMMANDS

ALT C change the actual node from/to into the current node.

ALT D delete an objective, selection, node or arc using the OBJECTIVES, SELECTIONS, CURRENT NODE or NODE FROM/TO command, respectively.

ALT L execute the LIST NODES command.

ALT N execute the NETWORK command.

ALT O execute the OBJECTIVES command.

ALT S execute the SELECTIONS command.

- CTRL COMMANDS

CTRL LEFT ARROW	move from CURRENT NODE to NODE FROM.
CTRL RIGHT ARROW	move from CURRENT NODE to NODE TO.
CTRL RIGHT ARROW	display the ARC window for a node selected from the NODE FROM/TO list, and reversely.

- USING ANOTHER KEYS

ESC	leave the current command/window, e.g., from NODE FROM/TO to CURRENT NODE, from CURRENT NODE to the Editor Menu, and out of HELP.

84

ENTER   command execution or node selection.

ARROWS move the pointer or scroll data.

C   Installation

DINAS runs under Disk Operating System (DOS version 3.00 or higher) on an IBM–PC XT/AT or compatible and requires 640 K RAM. Using of a color display with EGA or CGA card is recommended but DINAS can also work with a monochrome display and can use Hercules card. A hard disk is recommended but not necessary. One double–sided double–density floppy disk drive is sufficient to run DINAS.

The system can be installed in two versions: with taking advantages of the Numeric Data Processor chip, or without using the NDP chip. However, for solving large real–life problems the version with the NDP chip is strongly recommended.

A printer is useful but not necessary since all the reports can be routed directly to a printer or to a disk file for printing at a later time.

The DINAS system is distributed on one double–sided double density diskette. The distribution diskette contains the following files:

README	introductory information
DINAS.EXE	main executable program of the system
WIND.EXE	editor program
SOLVER.N87	optimizer without using NDP
SOLVER.Y87	optimizer with using NDP
DINAS.HLP	DINAS help file
EDITOR.HLP	editor help file
DEMO.NET	tutorial example

Before launching the system you have to make a working copy of the distribution diskette and then put the original one away. You can also install the system on your hard disk.

In order to install the system you have to perform the following operations:

1. make the destination disk (and/or directory) to be default;
2. copy both the EXE files from the distribution diskette;
3. copy both the HLP files from the distribution diskette;
4. copy the DEMO.NET file from the distribution diskette;
5. depending on your hardware configuration copy the SOLVER.N87 or SOLVER.Y87 file and rename it as SOLVER.EXE.

DINAS is not copy protected and thereby all the files from the distribution diskette can be copied using the DOS command COPY. While working without a hard disk, it is usually a good idea to install DINAS on a diskette which has been previously formatted as the so–called system diskette and thereby holds the COMMAND.COM file (see IBM Disk Operating System manual for details).

After finishing of the installation process the following files have to appear in the default directory:

DINAS.EXE   main executable program of the system

WIND.EXE   editor program

SOLVER.EXE optimizer

DINAS.HLP DINAS help file

EDITOR.HLP editor help file

DEMO.NET   tutorial example

Warning: The working diskette cannot be write protected.

D System files

The DINAS system consists of five system files:

```
DINAS.EXE
SOLVER.EXE
WIND.EXE
DINAS.HLP
EDITOR.HLP
```

- DINAS.EXE loads and runs all the system programs.
- SOLVER.EXE contains the Interactive System.
- WIND.EXE contains the Network Editor.
- DINAS.HLP and EDITOR.HLP are help files to the Interactive System and Network Editor, respectively.

All the other files are created by DINAS as various data files connected with performed analysis.

The network files contain the problems data in a special internal format. They are created by the Network Editor while saving the edited problems. The network file has, usually, the extension .NET. Namely, if the problem is specified without any extension then the extension .NET is automatically assumed. However, you can specify the problem name with another extension. Moreover you can route the network file to another directory or drive using the corresponding path in the name.

The solution files contain data for the several efficient solutions. They are created by the Interactive System while executing of the SAVE command. The solution files have the extension .EFF and they are always created in the default directory.

The output files contain network or solution reports. They are created by the Network Editor while executing of the PRINT NETWORK command. The reports are, usually, routed directly to the printer. However, you have an opportunity to specify an output file instead of the printer. The output file has the extension .PRN provided that you had not specified another one. The name of the output file can be preceded by a path in order to create the file in the corresponding directory.

Remark: We suggest you to depend on the default extensions (i.e., to specify all the names without extensions) in order to avoid mistakes.

DINAS creates also some working files and erases them before finishing the run. Thus you should never see these files in the directory. However, sometimes due to an extraordinary finish of the run such a file can appear in the directory. The working files get unique names of the type XTEMP$$$.$$$. Do not be afraid to delete such a file whenever you find it.

The system files take up 160 K of a disk space leaving about 200 K on a standard double-sided double–density disk. However, you should not treat the working diskette as archives for all the old problems and solutions. Files which are not used in the current analysis should be copied to another disk and deleted from the working one.