

**DINAS: COMPUTER-ASSISTED SYSTEM FOR MULTI-CRITERIA
TRANSPORTATION AND LOCATION ANALYSES**

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Abstract

DINAS (Dynamic Interactive Network Analysis System) is an interactive system to aid in the solution of various multiobjective transportation problems with facility location. DINAS utilizes an extension of the reference point approach for interactive handling multiple objectives. In this approach the decision-maker forms his requirements in terms of aspiration and reservation levels, i.e., he specifies acceptable and required values for given objectives. A special solver was developed to provide DINAS with solutions to single-objective problems. It is based on the branch and bound scheme with a pioneering implementation of the simplex special ordered network (SON) algorithm with implicit representation of the simple and variable upper bounds (SUB & VUB). DINAS is prepared for IBM-PC XT/AT or compatibles as a menu-driven and easy in usage system equipped with a special network editor which reduces to minimum effort associated with data input for real-life problems.

1. The problem

The distribution-location type problems belong to the class of the most significant real-life decision problems based on mathematical programming. They are usually formalized as the so-called transportation problems with facility location. A network model of the transportation problem with facility location 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 warehouse etc.). For this reason, potential nodes are organized in the so-called selections, i.e., sets

of nodes with the multiple choice requirement. 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 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 flow of the good 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. They will be called cost coefficients independently of their real character. The cost coefficients for potential nodes are, however, understood in a different way than those for arcs. The cost coefficient connected to an arc is treated as the unit cost of the flow along the arc whereas the cost coefficient connected to a potential node is considered as the fixed cost associated with activity (locating) of the node rather than the unit cost.

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

- objectives,
- fixed nodes with their 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.

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 by Ogryczak et al. [4].

2. Overview of the system

DINAS (Dynamic Interactive Network Analysis System) enables a solution to the above problems using an IBM-PC XT/AT or compatibles. It requires 640K RAM and a hard disk or at least one floppy disk. The basic version of the DINAS system can process problems consisted of:

- up to seven objective functions,

- a transportation network with up to one hundred of fixed nodes and three hundred of arcs,
- up to fifteen potential locations.

DINAS consists of three programs prepared in the C programming language:

- an interactive procedure for efficient solutions generation,
- a solver for single-objective problems,
- a network editor for input data and results examination.

For handling multiple objectives DINAS utilizes an extension of the reference point approach proposed by Wierzbicki [6]. The basic concept of the interactive scheme is as follows:

- the DM forms his requirements in terms of aspiration and reservation levels, i.e., he specifies acceptable and required values for given objectives, respectively;
- the DM works with the system in an interactive way so that he can change his aspiration and reservation levels in any direction;
- after editing the aspiration and reservation levels, the system computes a new efficient solution by solving a corresponding single-objective problem;
- 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 analyze performances of the current solution in comparison with the previous ones.

A special TRANSLOC solver has been prepared to provide the multiobjective analysis procedure with 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 a numerical kernel 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 proposed by Glover and Klingman [1] with implicit representation of the simple and variable upper bounds (VUB & SUB) suggested by Schrage [5]. The mathematical background of the TRANSLOC solver was given in details by Ogryczak et al. [3].

DINAS is equipped with the built-in network editor EDINET. It is a full-screen editor specifically designed for input and edit data of the network model of the transportation problems with facility location. The general concept of EDINET 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 numerical data (in fact, attributes to the

nodes and arcs) are inserted by a special mechanism of windows, while visiting several nodes (see Fig. 1). At any time only one of the windows representing different kinds of the data is active. The corresponding part of the data can be inserted then. While working with the editor the DM activates several windows. Apart from the windows with local information some special windows containing a list of nodes and a graphic scheme of the network (see Fig. 2) are available at any moment to ease movement across the network.

The interactive analysis of the multiobjective problem can be performed with DINAS by the DM who is not familiar with neither computer techniques nor mathematical programming. DINAS is a menu-driven system with very simple commands. Operations available in the DINAS interactive procedure are partitioned into three groups and corresponding three branches of the main menu (see Table 1): PROCESS, SOLUTION and ANALYSIS.

Table 1. DINAS Main Menu

PROCESS	SOLUTION	ANALYSIS
Problem	Summary	Compare
Convert	Browse	Previous
Pay-Off	Save	Next
Efficient	Delete	Last
Quit		Restore

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: PAY-OFF and EFFICIENT. As the last command in this branch is placed the QUIT operation which allows the DM to finish work with the system.

The PAY-OFF command must be executed as the first step of the multiobjective analysis. It performs optimization of each objective function separately. In effect, one gets 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.

The execution of the PAY-OFF command provides also the DM with two reference vectors: the utopia vector and the nadir vector. The utopia vector represents the best values of each objective considered

NODE FROM	CURRENT NODE	NODE TO																				
Node Tie Arc TIEB	Name Bush Type potential Capacity 50 Selections South Objectives <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>name</th> <th>coefficient</th> </tr> </thead> <tbody> <tr> <td>Invest</td> <td>186</td> </tr> <tr> <td>Satisf</td> <td>100</td> </tr> <tr> <td>Dist</td> <td>0</td> </tr> <tr> <td>Prox</td> <td>0</td> </tr> </tbody> </table>	name	coefficient	Invest	186	Satisf	100	Dist	0	Prox	0	Name Robur ARC Bush-Robur Name BURB Capacity 50 Objectives <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>name</th> <th>coefficient</th> </tr> </thead> <tbody> <tr> <td>Invest</td> <td>0</td> </tr> <tr> <td>Satisf</td> <td>0</td> </tr> <tr> <td>Dist</td> <td>0.01825</td> </tr> <tr> <td>Prox</td> <td>5.21</td> </tr> </tbody> </table>	name	coefficient	Invest	0	Satisf	0	Dist	0.01825	Prox	5.21
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DEL Current Delete Dist Network Objectives ESC exit
Selections

Figure 1

Structure of the network for problem demo.net

```

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

Bush ----- Erica
Hill -----|
Oasis -----|

Tie ----- Fiord ----- Ribes
                                     Larix
                                     Rumex
                                     Pinus
    
```

F10 move inside the net ENTER select node

CURRENT NODE

 Name **Bush**
 Type potential
 ARC **Bush-Acer**
 Name **BAC**
 Capacity **50**
 Objectives

name	coefficient
Invest	0
Satisf	0
Dist	0.007375
Prox	31.92

Figure 2

separately, and the nadir vector expresses the worst values of each objective noticed during several single-objective optimizations. 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.

Due to a special regularization technique used while computing the pay-off matrix (see [2]) each generated single-objective optimal solution is also an efficient solution to the multiobjective problem. So, after the calculation of the pay-off matrix there is already available 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 problem file.

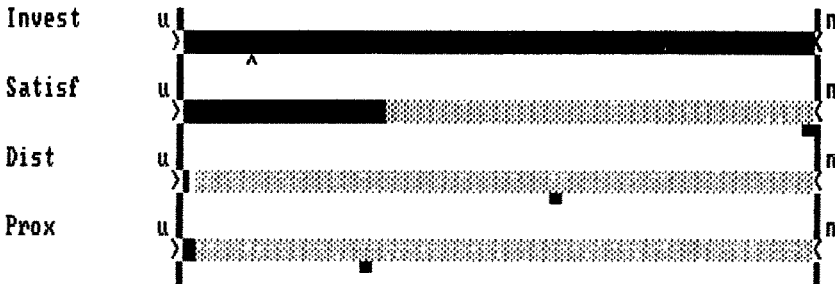
Having executed the PAY-OFF command one can start the interactive search for a satisfying efficient solution. DINAS utilizes aspiration and reservation levels to control the interactive analysis. More precisely, the DM specifies acceptable values for several objectives as the aspiration levels, and necessary 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.

The system searches for a satisfying efficient solution using an achievement scalarizing function as a criterion in the single-objective optimization. Namely, DINAS searches the feasible solution to minimize the following objective function:

$$\text{maximum}_{i=1, \dots, p} u_i(\mathbf{q}, \mathbf{a}, \mathbf{r}) + s/p \sum_{i=1}^p u_i(\mathbf{q}, \mathbf{a}, \mathbf{r})$$

where s is an arbitrarily small number, p denotes number of the objectives, \mathbf{q} represents the objective vector, and u_i is a function which measures the deviation of results from the DM's expectations with respect to the i -th objective depending on a given aspiration level \mathbf{a} and reservation level \mathbf{r} . The function u_i is a strictly monotone function of the objective vector \mathbf{q} with value 0 if $\mathbf{q}=\mathbf{a}$ and value 1 if $\mathbf{q}=\mathbf{r}$. In our system, we use a piece-wise linear function u_i (see [2] for details). The computed solution is always an efficient solution to the original multiobjective model (even if the given aspiration levels are attainable).

Efficient Solution No 9
U/N Bars

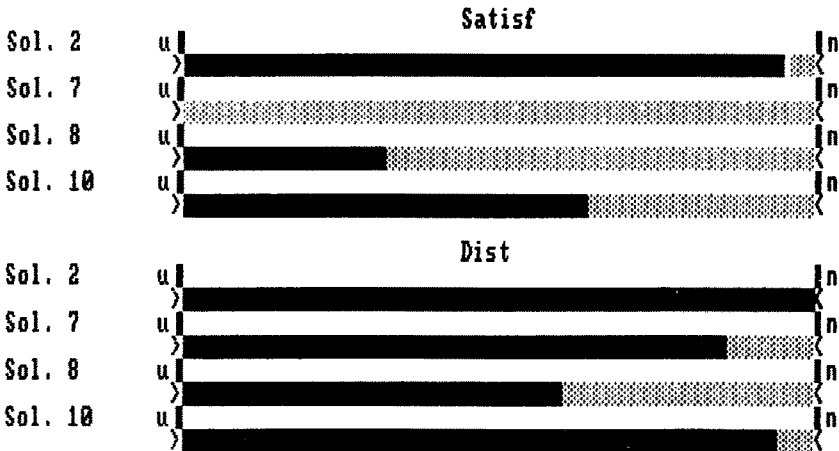


FgDn PgUp A/R Bars, U/N Bars, Locations, Values

ESC Menu

Figure 3

Comparison of Efficient Solutions
U/N Bars



FgDn PgUp A/R Bars, U/N Bars, Locations, Values **FgDn PgDn** Scroll

ESC Menu

Figure 4

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 then the oldest solution is automatically dropped from it. 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 of the main menu contains additional operations connected with the current solution. You can examine in details the current solution using the Network Editor (BROWSE) or analyze 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 (see Fig. 3). One 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 one finds it as quite useless (DELETE).

The ANALYSIS branch of the main menu contains commands connected with operations on the solution base. The main command COMPARE allows the DM 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 (see Fig. 4) as well as tables of selected locations. Moreover, some commands included in this branch (PREVIOUS, NEXT and LAST) allow to select any efficient solution from the solution base as the current solution. One can also restore some efficient solution (saved earlier on a separate file) to the solution base (RESTORE).

3. Final comments

DINAS has been already successfully used while analyzing two real-life problems: routes optimization for building materials transportation and location of new children clinics. The former one was a three-objective transportation problem without facility location. It was originally a two-commodity transportation problem but we managed to model it as a single-commodity one. The latter problem was more complex location-allocation one. It contained 5 objective functions, nearly 300 arcs and nearly 100 nodes including 8 potential ones.

Initial experiences with the DINAS system confirm appropriateness of the used methodology for solving multiobjective transportation problems with facility location. The interactive scheme is very easy and supported by many analysis tools. Thereby, a satisfactory solution can be usually reached in a few interactive steps.

When real-life problems are solved with DINAS on IBM-PC XT/AT microcomputers the single-objective computations take, obviously, much more time than while using some standard optimization tools (like the MPSX/370 package) on a mainframe. However, our experiences with both these approaches allow us to trust that DINAS, in general, will take much less time for performing the whole multiobjective analysis.

4. References

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