SAS/OR SOFTWARE
AS A DECISION SUPPORT TOOL FOR THE PC
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ABSTRACT

SAS/OR Software brought powerful tools for building decision support systems to the PC environment. Specialized optimizers for mathematical programming solve assignment problems, mixed integer programs, network flow models with side constraints, and transportation problems. Project management procedures are provided to plan, control, and monitor projects. Combining SAS/OR tools with other tools of the SAS® System provides everything needed to build effective decision support systems. These decision support systems have the power to solve a wide range of managers' resource allocation and project scheduling problems. Formerly available only on larger systems, these tools have been fully implemented on microcomputers.

INTRODUCTION

Management problems may now be solved using the operations research tools of SAS/OR® Software for microcomputers. The software allows the manager to explore distribution models, production systems, resource allocation problems, and scheduling or project management problems. A problem is modeled in the form of a SAS data set. A SAS/OR procedure is then used to evaluate the model.

SAS/OR procedures are programs that analyze a model called a mathematical program then store the result in a special data set. The procedures for general mathematical programming and network flow programming include ASSIGN, LP, NETFLOW, and TRANS. The procedures for scheduling and project management include CPM, GANTT, and NETDRAW. A data conversion utility, SASMPSX, and a user-friendly project management system shell, PROJMAN, are also included.

The general mathematical programming procedures use model data and specialized algorithms to efficiently optimize a model. PROC LP determines the optimal solution and does postoptimality analysis for general linear, integer, and mixed integer programs. PROC TRANS solves a special type of network problem known as the transportation problem. PROC ASSIGN solves assignment problems, a special type of transportation problem. PROC NETFLOW solves pure network flow and network flow with side constraint problems.

SAS/OR software also has procedures for scheduling and managing the resources for projects. PROC CPM creates schedules that satisfy structural relationships among project activities using only the resources budgeted for a project. PROC NETDRAW draws the project network on full screen, line printer, and high resolution graphics hardcopy devices. PROC GANTT graphically displays the calculated project schedule and its current status also using all these output modes.

MATHMATICAL PROGRAMMING WITH SAS/OR SOFTWARE

SAS/OR procedures solve general linear programs and mixed integer programs. Optimizers exploit special structures in the models including: special ordered sets, imbedded networks, pure networks, transportation networks, and assignment networks. The optimizers integrate with other SAS System components, giving users all the tools needed to build a custom decision support system.

Linear programs solve for values of variables called decision variables. The solution optimizes a function, called the objective function, subject to linear constraints or integer restrictions. A few of the possible applications for these techniques include: product-mix problems, blending problems, cutting stock problems, network flow problems, transportation problems, time staged problems, scheduling problems, capital budgeting and project selection problems, or multiple objective problems.

SAS/OR procedures utilize a methodology called the data flow concept. That is, the model is specified in a SAS data set called the problem data set, the procedure solves the model, then the solution is written into an output SAS data set. Each optimizing procedure also defines special a SAS macro variable whose value records the status of the optimizer upon termination of the procedure.

SAS/OR software simplifies the often difficult task of model specification by providing flexible problem input formats. Linear programming problem data sets may be in dense, sparse, or MPS formats. Dense format is a data set with structural variables, id variable, right-hand-side constant, type identifier, a
constant for right-hand-side sensitivity analysis, or a range variable. Sparse format requires only the nonzero coefficients to be specified in the problem data sets for linear programs, integer programs, and mixed integer problems. Similarly network flow, transportation and assignment problem have formats of their own.

**Linear Programming**

Linear programs, integer programs, mixed integer programs, parametric programming, range analysis, and solution sensitivity reports are all done with PROC LP. The LP procedure will optimize a linear function subject to linear and integer constraints. Linear programs without integer variables employ the two-phased and simplex method while problems with integer variables use the branch and bound technique for optimization.

PROC LP is also used to analyze the sensitivity of the solution to changes in the right-hand-side constants and to changes in the objective function. Sensitivity analysis enables one to examine the size of the change of the right-hand-side or objective vector by an arbitrary change vector for which the basis of the current solution remains optimal. Parametric programming examines how the optimal solution changes when a specified perturbation is made. Range analysis determines the range of right-hand-side or coefficient values for which the basis of the current solution remains optimal.

**Version 6 PROC LP on the PC has enhancements that increase the power and flexibility of the procedure. LP can now solve linear goal-programming problems. Special ordered sets may be specified using the TYPE statement. New memory management techniques let Version 6 users solve larger problems with less memory than the previous Version 5 software.**

**Transportation Problems**

A transportation problem is a special type of linear program, a network flow problem, with each node being either a supply or destination node. Arcs connecting the supply and destination nodes have associated traversal costs. The arcs may have capacities associated with them. The solution to the transportation problem contains the least cost flow through the network that satisfies the demands at the destination nodes.

**Version 6 PROC TRAN has new features including options for dealing with excess supply without the problem being declared infeasible. The TAILNODE option forces excess supply through the network while NOTHRUNET drains away excess supply. The TAILNODE statement replaces the Version 5 ID statement. The HEADNODE statement replaces the Version 5 VAR statement. Since dual variable values are calculated using a new method, Version 6 values may differ from those produced by Version 5.**

**Assignment Problems**

Assignment problems are special transportation problems with unit supply and demand values. The ASSIGN procedure solves assignment problems. ASSIGN finds the minimum or maximum assignment cost of the sink nodes to the source nodes.

ASSIGN in Version 6 has a new option DEC which specifies the scaling factor for input cost data. New memory management gives ASSIGN the power to solve larger problems, with less memory than Version 5 SAS/OR software.

**Network Flow Programming**

Pure network flow problems and network problems with linear side constraints are solved with the NETFLOW procedure. The network is modeled in two data sets: the node data set containing node names with supply and demand data; and the arc data set containing arc traversal costs and arc capacity constraints. Side constraints are specified in the constraint data set using either the sparse or dense data formats that PROC LP accepts. Although network flow problems can be solved using the LP procedure, the NETFLOW procedure is usually more efficient since it exploits the network structure when solving the problem.

The NETFLOW procedure has changed significantly from its Version 5 predecessors NETFLOW and TNETFLOW. Input data formats are now more flexible and less restrictive thus giving the problem generator greater flexibility. Constraint data may now span more than one observation in the input data set. The analyst now has extensive control of the optimization process. Many parts of the optimization algorithm have been changed to improve efficiency. NETFLOW has been redesigned with memory management techniques that enable NETFLOW to solve large scale problems on a microcomputer configured with a modest amount of memory and sufficient disk space.

**PROJECT MANAGEMENT USING SAS/OR SOFTWARE**

SAS/OR software now has three procedures that are useful when planning, monitoring, or controlling projects. The CPM procedure schedules project activities subject to precedence, time, and resource constraints. The
The GANTT procedure displays the schedule as a Gantt chart. The NETDRAW procedure displays the schedule as a network activity diagram. Many procedures in the Base SAS System may also be used for project management: complementing and extending the scheduling and displaying of schedules done with SAS/OR software.

The project management procedures use the same data flow concept as the mathematical programming procedures. Activity, resource, calendar, workday, and holiday data set are used to specify a project description for the CPM procedure. CPM uses these data sets to produce the schedule. The procedure creates two output data sets; one containing schedule data and one with resource usage data. GANTT, NETDRAW, or Base SAS procedures such as CALENDAR use CPM's output as input data for their reporting and graphics functions.

Project Scheduling

The CPM procedure is the core project scheduling component of SAS/OR software. Feasible schedules are determined using activity precedence, time, and resource constraints along with appropriate holiday or calendar specifications. Precedence constraints in the activity data set may be in either an activity-on-arc or an activity-on-node representation.

CPM produces a schedule that is saved in an output data set. No printed output is produced. The schedule data is available for use by other procedures such as the GANTT procedure. The output data set lists the names of each activity, its successors; early start, early finish, late start, and late finish times/dates; as well as the total float and free float for each activity. Other variables may be saved including resource usage variables, actual date information, or ID variables.

Resource availability information is specified in the resource data set. Resource requirements specified in the activity data set are pulled from the available resources to produce a resource constrained schedule. The resources required to complete the schedule may be saved in a separate resource output data set.

PROC CPM has several new features that provide new dimensions in flexibility for the project scheduling procedure. Any number of calendars may be defined for a project. Using the CALENDAR and WORKDAY data sets, work patterns may be modified. Nonstandard relationships may be defined with the new LAG= option. A new statement, the ACTUAL statement, is used to identify variables in the activity data set that contain progress information. PROC CPM allows noncritical activities to be split during resource constrained scheduling.

Gantt Charting

The GANTT procedure graphically displays the scheduled progress of a project's activities. In addition to presenting scheduled progress, GANTT also handles the graphing of actual progress of activities. Important dates such as milestones or deadlines may be drawn on the chart. One may plot the resource constrained schedule on a separate line, a useful technique for monitoring the progress of a project.

Three modes of charting are offered by the PROC GANTT. By default, charts are produced in line printer or character graphics format. This is appropriate when high resolutions output devices are not available or are not desired. Specifying the GRAPHICS option on the PROC GANTT statement produces a high resolutions color GANTT chart suitable for presentations. The user has options to control the appearance and customization of the chart.

The third mode of Gantt charting is the full-screen mode. This is done by specifying the FULLSCREEN option on the PROC GANTT statement. Full screen mode is convenient for large charts that would span several pages. The chart is created and scaled to fit on a single terminal screen. The user may change the scale and scroll around the display. Full screen mode is a new feature with Version 6 SAS/OR software on the microcomputer.

Network Activity Diagrams

A new procedure, NETDRAW, produces network activity diagrams. CPM schedule data sets may be used as input for PROC NETDRAW to draw a project schedule as a network activity diagram. Activities are represented by box shaped nodes and the lines or arcs between the boxes show the relationships between the activities. Any acyclic network may be drawn by providing NETDRAW with the activity names along with their successor activities.

Like PROC GANTT, the NETDRAW procedure produces output in three modes. Line printer graphics is the default. High resolutions color network activity diagrams are drawn if the GRAPHICS option is specified on the NETDRAW statement. Full screen mode is also available if the FULLSCREEN option is specified. Nodes may be moved around to change the layout of the full screen diagram and the changes saved for later use.

Full-screen mode gives the user two basic types of commands. Scrolling commands allow changing of the scale to effectively zoom in and out. After adjusting the scale one may move in any direction through the network activity diagram.
The layout of the diagram may also be changed. Nodes may be moved around on-screen then saved for later use thus giving users full-screen customization capability.

SAS/OR SOFTWARE AND MICROCOMPUTER BASED DSS'S

Decision Support Systems (DSS) may be generally defined as computerized software systems that increase the effectiveness or the efficiency of decision making. Historically DSS's have been developed for single models or single problems. Improved application design combined with robust software tools make it possible to build DSS's that are useful for general purpose decision support applications.

Decision support system development systems must have certain capabilities. Generally accepted requirements for a general purpose DSS development tool include:

- Data base management system
- Data access, entry, and editing tools
- Report writing and document preparation tools
- Graphics generation and management tools
- Project management tools
- Optimization (math programming) tools
- Financial modeling tools
- Statistical analysis tools
- Logic and programming tools
- Mainframe to microcomputer connection

SAS System tools satisfy the entire list of DSS requirements. Tools available on mainframes and minicomputers are now available on microcomputer platforms. New PC SAS/OR software completes the tools required to make the PC SAS System ideal for building decision support systems.

DSS's For Structured Problems

Operations research tools assist in solving many classes of structured problems. Cohen (1986) suggests an approach for solving industrial and business problems using operations research techniques. Cohen's problem solving paradigm is useful for developing prototype decision support systems.

There have been many successful implementations of SAS/OR software for industrial and business problem solving. Because of software availability they have been developed on larger systems in the past. Now, a wide variety of operations research problems may be easily incorporated into microcomputer based DSS applications built with the PC SAS System including:

- Transportation Problems ..... Hudson (1987)
- Network flow problems ..... Therrien (1987)
- Capital budgeting and project selection Gibbley (1985)
- Product Mix problems ..... Eggleston (1984)
- Scheduling Problems ..... Cybrinski (1985)
- Time-staged Problems ..... Walker (1985)
- Blending Problems
- Assignment Problems
- Many other classes of problems

These applications are a few examples of the types of models that have been successfully implemented using SAS/OR software to solve structured problems. Combining SAS/OR software with SAS/AF® software and its new screen control language (SCL) make it possible to build very flexible general purpose decision support systems on the PC. These systems may exploit features not yet available for mainframe systems since PC software is Version 6, the next generation of the SAS System's family of software.

DSS's For Unstructured Problems

Applications to assist in solving unstructured problems may also be built with the SAS System tools. Systems may be designed and built with SAS software to support large, complex, unstructured decision making processes. SAS/OR software and screen control language (SCL) make it possible to build very flexible DSS applications. Group decision support (GDSS) may be done in computer aided deliberation implementations.

Nunamaker (1988) discusses computer aided deliberation, group decision support, and computer aided decision support. Support of unstructured decision processes requires 1) access to a wide range of data, 2) flexible access to qualitative and quantitative decision models, 3) ability to capture and store decision process knowledge, and 4) the capability to support individual as well as group decision support. The SAS system can be used to create many of the applications described in Nunamaker
including electronic brainstorming or even his PLEXSYS, a GDSS system for group planning sessions.

Using techniques similar to those developed by Ogle in SAS (1987) along with the other tools of the PC SAS System, complex GDSS's may be easily built. Ogle's application collects market research data then uses it to dynamically build screens for collecting trade off matrix responses. This approach applies directly to GDSS methodologies such as electronic brainstorming. Powerful data access tools, applications development tools, and the quantitative tools found in SAS/OR software, make the SAS System the tool of choice for developing DSS solutions.

CONCLUSIONS

The PC SAS System now has powerful operations research tools that make it ideal for developing decision support systems. The quantitative techniques in SAS/OR software make it a powerful asset for developing DSS's for structured problems. Applications development tools in the SAS System allow the DSS developer to easily build sophisticated DSS's including group decision support systems, computer aided deliberation systems, or electronic brainstorming systems. SAS Institute's multiple vendor architecture assures DSS developers that systems built for PC platforms using the SAS System will have the same functionality as mainframe or minicomputer systems. Version 6 PC SAS/OR software along with Version 6 SAS/AF software including DCL provide DSS developers with sophisticated features not yet available on larger systems still using Version 5 software.

REFERENCES


