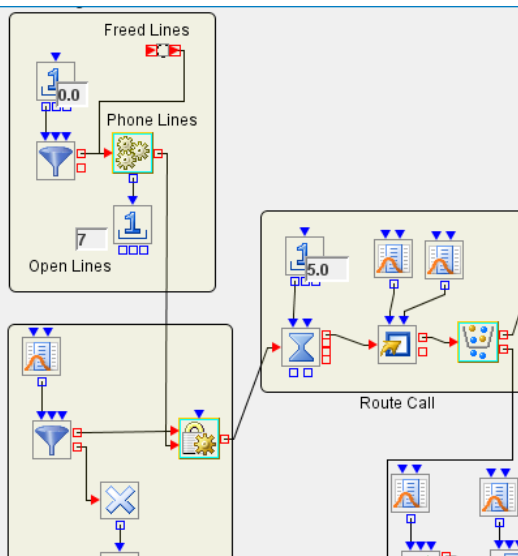


# SAS/OR® Software

Optimize business processes and address management science challenges with enhanced operations research methods



Choosing the actions that produce the best outcomes requires the ability to create, consider and evaluate alternate scenarios. SAS/OR® software helps model, solve and communicate the best solutions to complex planning problems quickly and effectively. The software brings together essential optimization, simulation and scheduling solution capabilities in an integrated and adaptable environment.

Organizations worldwide use SAS/OR software to solve planning problems and address business challenges such as:

- Resource allocation and management.
- Production and inventory planning.
- Product mix and composition.
- Staffing allocation and scheduling.
- Supply chain optimization.
- Capital budgeting, asset allocation and portfolio selection.
- Optimization of service contract agreements.
- Public utility capacity planning.
- Optimal facility site location.
- Workflow productivity improvement.

## What does SAS® SAS/OR® software do?

SAS/OR software provides a powerful array of optimization, simulation and project scheduling techniques to identify the actions that will produce the best results, while operating within resource limitations and other relevant restrictions.

## Why is SAS/OR® important?

Organizations can consider more alternative actions and scenarios, and determine the best allocation of resources and plans for accomplishing goals. Incorporating operations research analytics adds structure and repeatability to decision-making processes, lets you make the most of your analytic and BI investments, and delivers a competitive edge.

## For whom is SAS/OR® designed?

SAS/OR is designed for people in any industry with operations research (or management science) experience who build decision-guidance models by applying operations research techniques to solve real-world problems. Adding well-designed user interfaces can open up these methods for use by people who interact with the problems on a business level.

## Benefits

- **Apply a wide range of operations research methods.** SAS/OR offers the broadest available spectrum of operations research modeling and solution techniques, and includes state-of-the-art methods for mathematical optimization. The depth of detail and realism in SAS/OR software's modeling capabilities, control of optimization, simulation and scheduling processes, and integrated approach to data access and information delivery enable organizations to identify and apply the best responses to complex planning problems.
- **Build models interactively and experiment with data.** SAS/OR lets you build models interactively, modifying constraints or variables and experimenting easily with the effects of changes to underlying data. In mathematical optimization, a specialized modeling language enables you to work transparently and directly with symbolic problem formulations, and an appropriate solution method for the current problem can be automatically

chosen. This allows problems to be formulated and solved intuitively and efficiently regardless of their specific mathematical form.

- **Easily incorporate more data.** With SAS/OR it is easy to indicate where and how input data will be used in a model. Data/model separation is maintained, which is critical when reusing models or model components. Users can select the aspects of the solution to be reported and can control the form in which they are reported.
- **Generate quicker, better answers.** SAS/OR includes analytic and solution methods that are tuned to address large, complex, real-world problems.

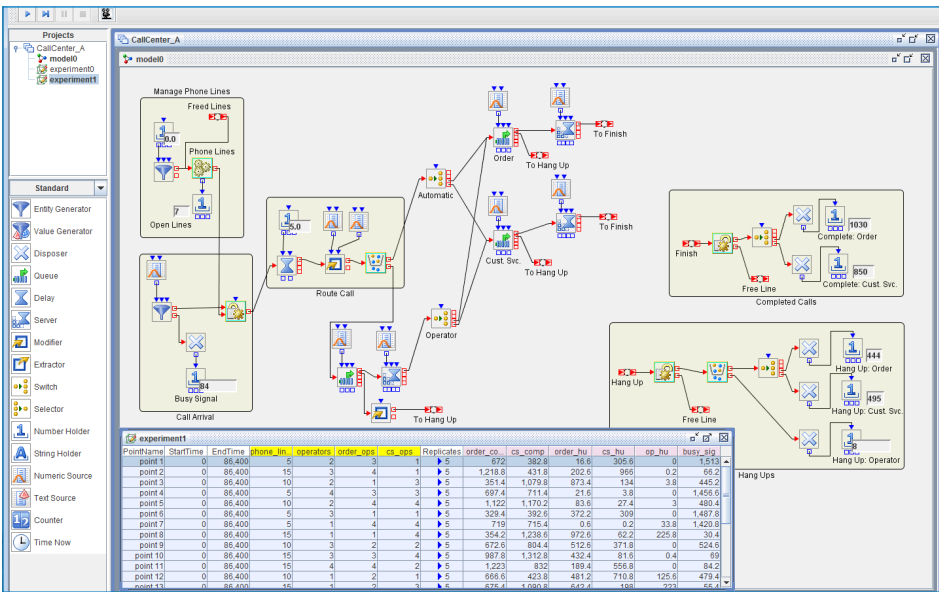
## Product Overview

With SAS/OR software, modelers transform real-world scenarios into mathematical models. When altering models to better reflect the key elements of business problems, they can consider various options, leveraging essential modeling, optimization, simulation and scheduling capabilities from within SAS.

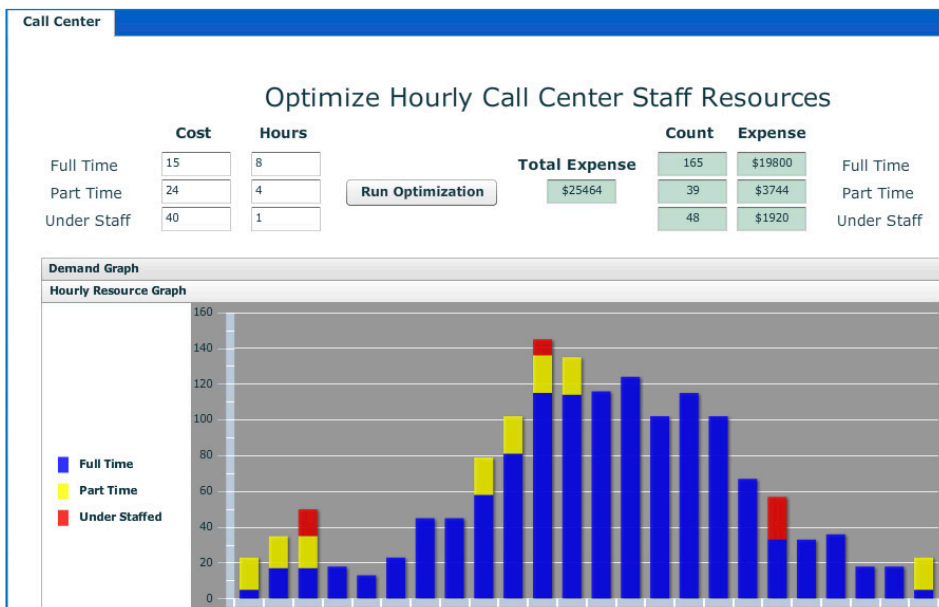
Most SAS/OR capabilities are surfaced within a common language and all use a common data format, which allows analysts to seamlessly utilize data mining, data cleansing, forecasting, experimental design, Monte Carlo simulation or any of the hundreds of statistical functions offered by SAS Analytics, and avoid the hassles of dealing with multiple niche software packages. Operations research is never performed in isolation; it is part of a continuum that begins with data integration, grows by informing decision makers

with descriptive and predictive analytics, and builds on those analyses to deliver proactive decision guidance.

Combining power and accessibility with the SAS foundation of data management, analytical (statistics, forecasting, data mining, etc.) and reporting features, SAS/OR enables you to coordinate directly with critical supporting and follow-on activities as you build, use, maintain and update a wide range of models.



The SAS Simulation Studio graphical interface provides interactive model building and experimental design capabilities.



Sample interface demonstrates the use of SAS/OR to optimize workforce allocation, factoring in shift hours, pay rates and the opportunity cost of unmet demand.

## Mathematical Optimization

SAS/OR contains sophisticated mathematical programming techniques that can help determine the best use of limited resources to achieve desired goals and objectives.

### Algebraic, symbolic optimization modeling language

The OPTMODEL procedure provides a rich optimization modeling language with specialized syntax and constructs that enable problems to be represented directly and efficiently. This makes it easier to review models for initial validation, make subsequent adjustments or run models with new data. This clarity is critical if optimization models are to be distributed for use across many departments or divisions, or if analysts are reassigned and pass planning models to their colleagues to carry on with implementation and/or adaptation for alternate scenarios.

### Linear, integer, mixed integer, nonlinear and quadratic programming

With SAS/OR, you need to learn only one set of statements and commands to build and solve a wide range of optimization models. Optimization models often evolve during the implementation process. As analysts adjust their formulations to address changes in requirements, constraints and/or the objectives can change from linear to nonlinear expressions and vice versa. There's no need to worry about switching modeling environments or employing different syntax to use appropriate solution algorithms.

### Powerful optimization solvers and presolvers

SAS/OR provides a suite of solvers that is streamlined for simplicity and tuned for the best performance when finding optimal solutions. This enables you to tackle even larger enterprise problems and solve them more quickly. Optimization solvers include primal and dual simplex, network simplex, interior point, branch-and-bound, and nonlinear solvers that are especially suited to handle large, sparse problems.

## Decomposition algorithm

The decomposition algorithm (linear and mixed integer linear optimization) exploits a structure often found in optimization models – blocks of constraints, each involving an exclusive set of decision variables. After these blocks have been identified, the algorithm solves the resulting component problems in parallel, coordinating with the solution of the entire problem and ultimately reducing overall solution time significantly.

## Network optimization

The OPTNET procedure provides algorithms for investigating the characteristics of networks and solving network-oriented optimization problems. Input data sets are designed to fit network-structured data. Algorithms include minimum-cost flow, shortest path, traveling salesman problem, connected components, cycle detection, and several others.

## Multistart algorithm helps identify better solutions

Many nonlinear optimization problems can be classified as nonconvex. In such cases, the optimization problem might have many locally optimal solutions that are not globally optimal. To increase the likelihood of identifying a globally optimal solution, the multistart algorithm selects multiple starting points and begins optimization in parallel from each. The best solution found among all starting points is reported.

## Interactive modeling and solution environment

In the OPTMODEL language you can modify your optimization model interactively, dropping or restoring constraints, fixing decision variables at specified values, or altering the underlying data. This enables you to try out different versions of the same model and experiment easily with the effects of changes. You can also define and name multiple models to solve individually or as part of a larger solution strategy. Intermediate solutions can be saved for use in future optimizations. All aspects of intermediate and optimal solutions are fully accessible for examination, analysis and reporting.

## Key Features

### Mathematical optimization

- OPTMODEL procedure:
  - Flexible algebraic syntax for intuitive model formulation.
  - Transparent use of standard SAS functions.
  - Direct access to linear, network, mixed integer, quadratic, nonlinear, and constraint programming solvers.
  - Support for the rapid prototyping of customized optimization algorithms, including named problems and subproblems.
  - Ability to run other SAS code within PROC OPTMODEL with the SUBMIT block.
  - Ability to execute solver invocations in parallel with the COFOR loop.
- Aggressive presolvers to reduce effective problem size.
- Multithreading in underlying technologies for improved optimization performance.
- Linear programming solvers, including primal simplex, dual simplex and network simplex; and interior-point with crossover.
- Parallel branch-and-bound mixed integer programming solver with cutting planes and heuristics.
- Option tuning for mixed integer programming.
- Decomposition algorithm for linear and mixed integer programming.
- General nonlinear optimization solvers, including primal-dual interior point, primal-dual active set, and multistart capability.
- Covariance matrix output available for nonlinear optimization.
- Multiple network diagnostic and optimization algorithms.
- Parallel hybrid global/local search optimization, including multi-objective optimization.
- Constraint programming capabilities with scheduling and resource features.

### Discrete-event simulation

- Versatile, graphical modeling capabilities; create and save custom components.
- Model both static and mobile resources.
- Automated experimental design and input analysis via integration with JMP®.
- Drive models with historical data in SAS data sets or JMP tables.
- Integrate with SAS or JMP for analysis of results.
- Support for large models and large experiments.
- Search facility enables search of all blocks in model.
- Hierarchical modeling: compound blocks and submodel blocks.

### Project and resource scheduling

- Critical path method and resource-constrained scheduling.
- Calendars, work shifts and holidays for determining resource availability and schedules.
- Full support for nonstandard precedence relationships.
- Versatile reporting, customizable Gantt charts and project network diagrams.
- Earned value management analysis for project execution tracking.
- Decision analysis:
  - Create, analyze and interactively modify decision tree models.
  - Calculate value of perfect information (VPI) and value of perfect control (VPC).
- Bill of material (BOM) processing:
  - Read from standard product structure data files and part master files, or combined files.
  - Produce single- or multiple-level bills of material, including indented and summarized BOM.
  - Produce summarized parts, listing items and quantities required to meet the specified plan.

## Global/Local Search Optimization and Constraint Programming

SAS/OR includes two options for those confronting some of the most challenging optimization-related problems. PROC OPTLSO applies multiple global and local search algorithms in parallel to solve optimization problems that include difficult (nonsmooth, discontinuous, nondifferentiable, etc.) functions, and can also solve especially difficult types of problems such as mixed integer nonlinear optimization. Constraint programming with PROC CLP solves constraint satisfaction problems (optionally adding an objective function) using powerful consistency algorithms, tailored for specific classes of constraints, along with a choice of search strategies. Each approach can be useful for problems that are difficult or impossible to formulate or solve with standard optimization methods.

## Discrete-Event Simulation

SAS Simulation Studio features a GUI that requires no programming and provides all the tools needed for building, executing and analyzing discrete-event simulation models. A broad array of modular blocks, each with customization options, enables you to build detailed, realistic simulation models. You can model resources in static or mobile form, further increasing the models' realism. Experimental design (manual and automatic) facilitates what-if experimentation and more extensive exploration of how system controls and operating conditions affect key performance metrics. SAS Simulation Studio can integrate with JMP for experimental design and input analysis, and with JMP and SAS for source data and analysis of simulation results.

## Project and Resource Scheduling

SAS/OR software's project scheduling capabilities give you the flexibility to plan, manage and track project and resource schedules through a single, integrated system. The software handles complicated situations involving multiple project record keeping, resource priorities, project and resource calendars, substitutable resources with skill pools, multiple and nonstandard precedence relationships and activity deadlines. You can create and update single- and multiple-project schedules, incorporating structural, time, and resource constraints. Inputs to the scheduling process include hierarchical project structures, resource requirements, and work shift/calendar/holiday information for activities and resources. Both replenishable and consumable resources are supported, and resources can be assigned in teams as needed. Extensive control over the scheduling process is provided. Output includes detailed project schedules and profiles of resource usage and availability across timelines. Graphics include Gantt charts and network diagrams.

### Earned value management analysis

SAS/OR includes earned value management capabilities that enable you to track, analyze and predict the cost and schedule performance of projects in progress. A set of metrics based on comparing actual versus planned progress and costs detects deviations from the schedule/budget early in the project, providing a factual basis for targeted corrective action.

### Decision analysis

Decision trees help structure sequential decision-making processes under uncertain conditions by enabling you to examine and

compare all possible outcomes. In input data sets you describe the problem structure, the probabilities of various outcomes and the associated payoffs. SAS/OR analyzes the decision problem, incorporates utility functions and attitudes toward risk, and identifies an optimal decision strategy.

### Bill of material processing

Bills of material are used in manufacturing to show the relationships linking parts and materials, subassemblies, assemblies and finished products, and can also be used to explore the roles of multiple levels of subsidiary tasks in major activities. SAS/OR performs bill of material processing, reading product and component structure data and composing the information into single-level, multiple-level and indented bills of material. Summarized reports show quantities of all items needed to fill orders for finished goods. These capabilities can work in conjunction with SAS/OR software's project scheduling features to determine the impact of parts availability on production and delivery schedules.

### TO LEARN MORE »

SAS/QC takes advantage of the SAS®9 engine, part of the SAS Platform. Many SAS procedures have been enhanced so code launched from SAS 9 can run in SAS Viya™, the SAS Platform's new distributed, in-memory engine. For more information, visit [sas.com/platform](http://sas.com/platform).

To learn more about SAS/OR, download white papers, view screenshots and see other related material, please visit [sas.com/or-software](http://sas.com/or-software).

To contact your local SAS office, please visit: [sas.com/offices](http://sas.com/offices)

