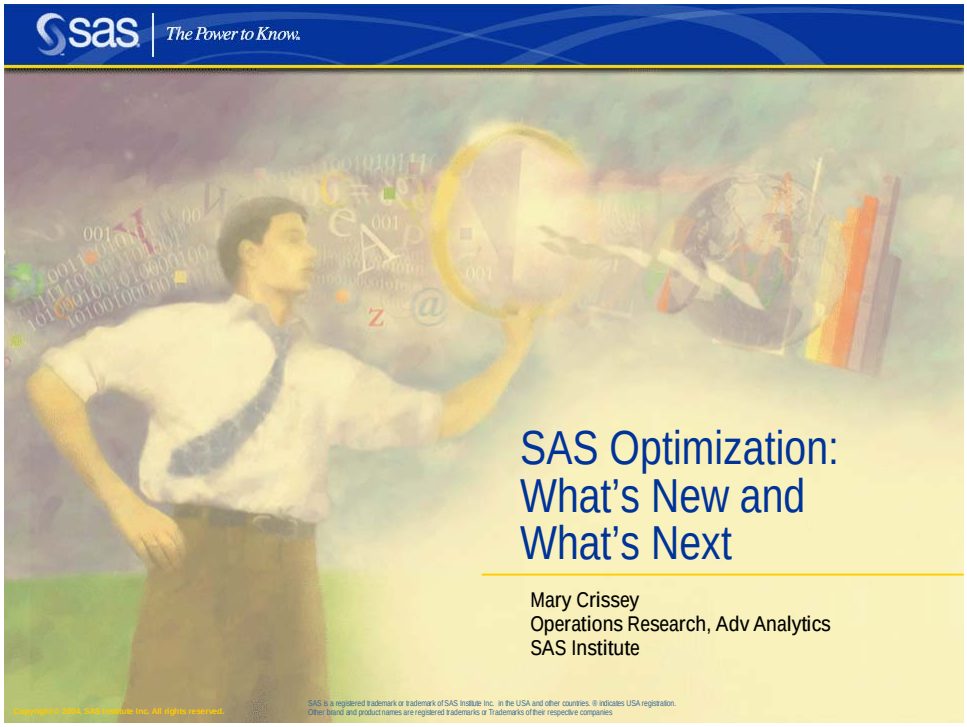
“SAS Optimization: What’s New and What’s Next”

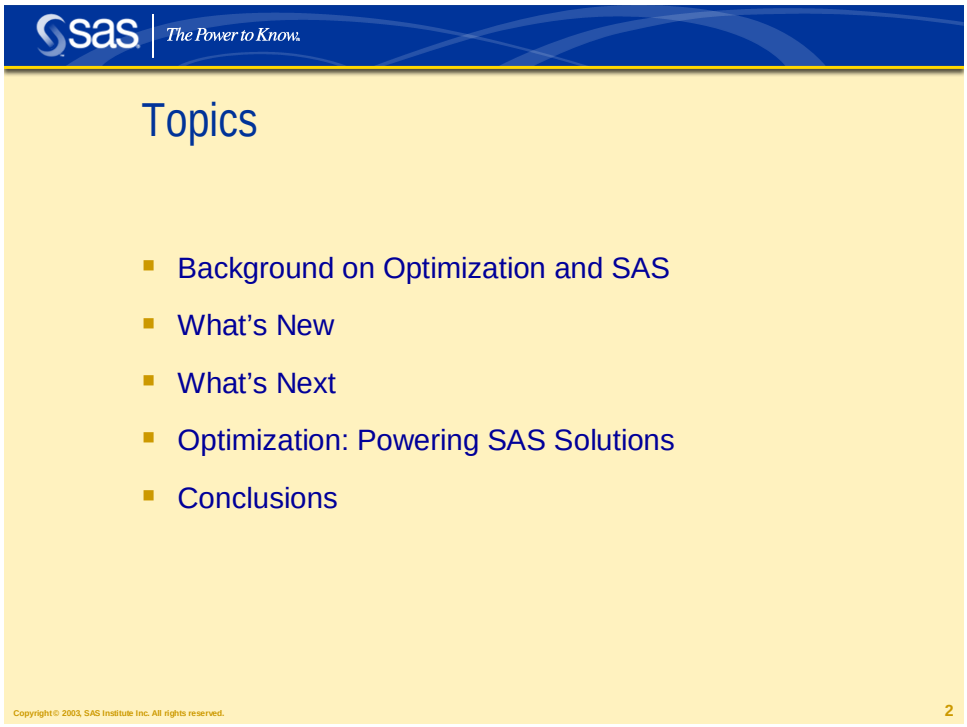
Nov 2004 by the SAS/OR product strategist
Mary Crissey, San Antonio TX mary.crissey@sas.com



This was presented at SUGI 29 by Ed Hughes the SAS/OR Product Manger.

SAS/OR provides a full set of tools that give companies the knowledge to identify and optimize business processes and management challenges. Built on almost 30 years of SAS statistical modeling and business analysis experience, SAS Operations Research and Management Science delivers answers that help companies effectively make strategic business decisions on a variety of issues ranging from resource allocation and inventory planning to distribution, scheduling and routing. Taking advantage of the advances delivered in the SAS 9 Intelligence Platform, SAS/OR uses data from across the organization to do all of this faster, more efficiently and with less risk.

SAS/OR provides full-featured modeling and solution capabilities for the strategic and tactical planner, focusing on optimization, scheduling, simulation, and decision analysis. These capabilities are integrated with and are supported and complemented by SAS' strengths in data access and warehousing, reporting, and analytics including statistical analysis, forecasting, and data mining.



Optimization has been around for quite a long time—in fact, for as long as there's been life, there's been optimization. Foraging for food, survival of the fittest, smart shopping, looking for the quickest route home—all of these are examples of optimization in practice.

How many have ever visited a casino? Did you try to win as much money as you could? If so, you were optimizing—or trying to!

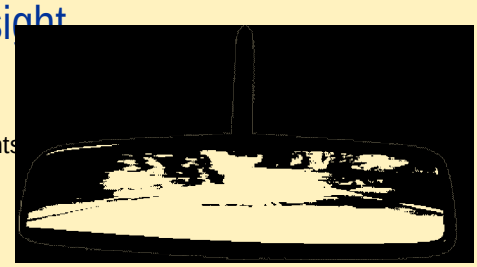
Mathematical optimization, too, has been around for a long time—between 60 and several hundred years, depending upon who you ask—but lately it's become a very hot topic. The reasons are simple—optimization helps you to do more with less, and to get more from what you have. And as we'll see, there are several other benefits as well
.
Today we'll look at optimization's place in SAS, with a special emphasis on new additions and current development work.

What is Optimization?

- Webster: An act, process, or methodology of making something (as a design, system, or decision) as fully perfect, functional, or effective as possible; *specifically* : the mathematical procedures (as finding the maximum of a function) involved in this
- Choosing the available actions producing the best results
- Furthermore: The payoff from amassing business intelligence
- Moving from "What happened," "What's happening," and "What is likely to happen" to "What do we do about it"

Optimization: Moving from Hindsight

- Hindsight
  - Accurate views into past events
  - Valuable basis for planning
  - Not forward-looking



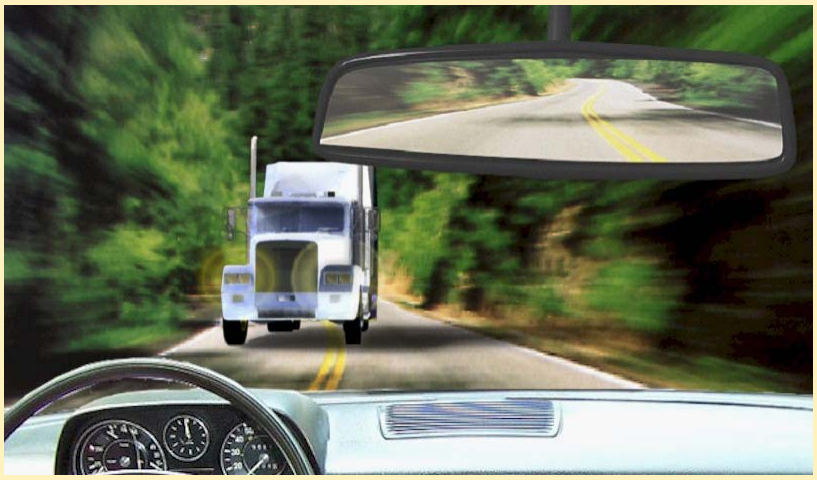
With Business Intelligence and Foresight you have a MUCH more complete picture of your situation. Predictive analytics looks forward based in lessons learned from looking backward. Both are important for good decision-making. As far as the truck metaphor goes, there are lots of examples—competitors, demand shifts, changes in operating conditions or available resources—you name it. Perhaps one truck isn't enough!

But there's something missing, and that's any decision-guidance capabilities.

Think about it…what could you add to this picture that would make you feel better about the truck? How about controls! A means of deciding what to do, and doing it. The truck isn't such a problem IF you can steer out of its way. But you need good information on which way to steer—so that you don't run off the road, or right into yet another truck.

sas | The Power to Know.

…to Action!



Optimization builds on information on the past, present, and future and guides decisions on what to do in light of that information. It takes you from hindsight, to foresight, to action and it helps you support and justify those actions

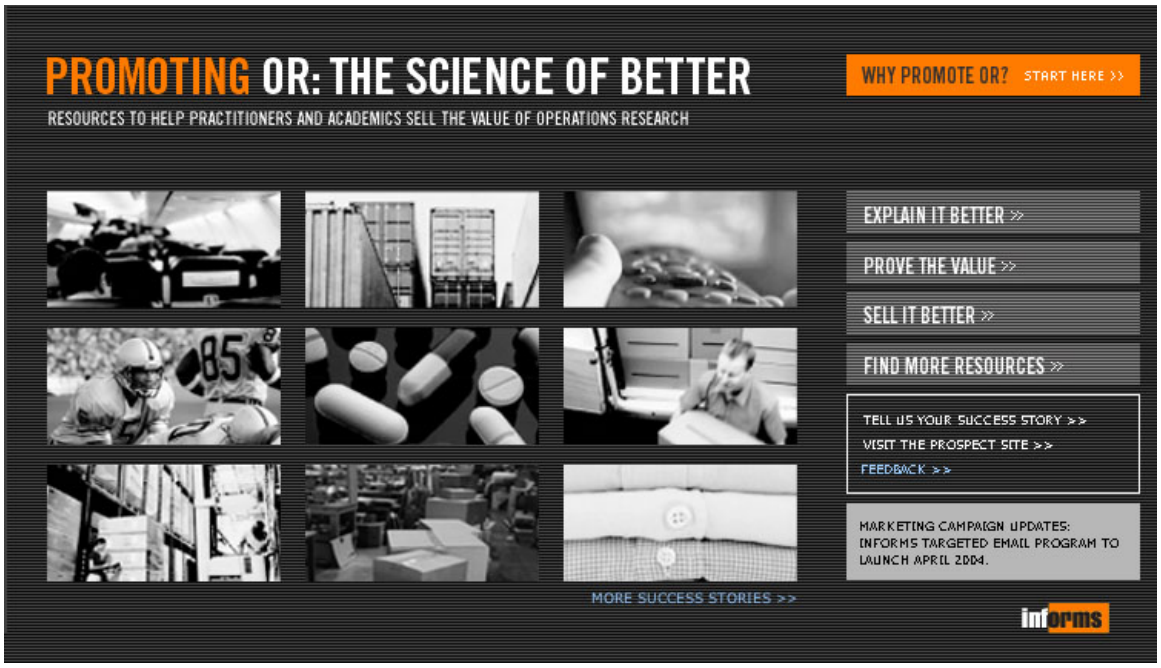
sas | The Power to Know.

Optimization: Why Should You Care? If you deal with any or all of…

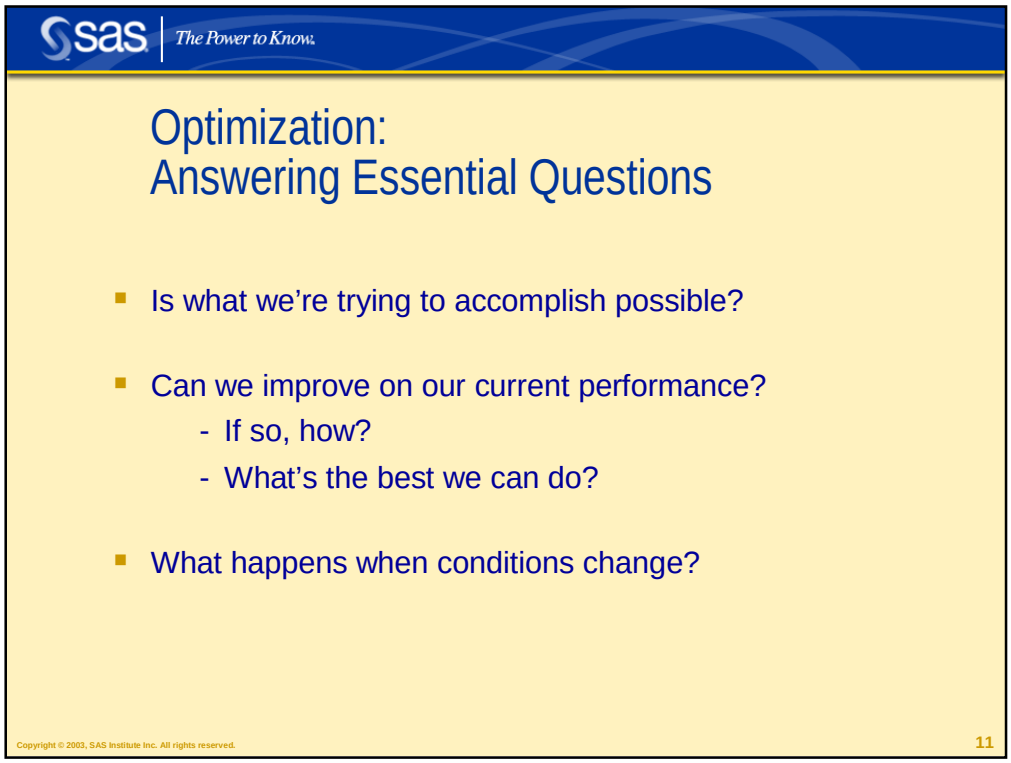
- limited resources…
- customers' needs and expectations…
- business requirements
- government regulations…
- a widening array of available actions…
- competition…

…then you should care about optimization!

For a sampling of the very diverse group of situations in which optimization is providing value take a look at the material posted at www.scienceofbetter.org sponsored by the Institute oF Operations Research and the Management Sciences Society (INFORMS).



When you reduce optimization to its essence, it answers questions that are simple, straightforward, necessary to business operations--and possibly quite difficult to answer



Optimization: Improving the Decision-Making Process by Adding…

- Structure: Know how decisions are motivated
- Consistency: All decisions drive toward same goals
- Repeatability: Make decisions in the same manner over time
- Adaptability: Update, but keep same principles

Optimization Model Building: Important Questions to Ask

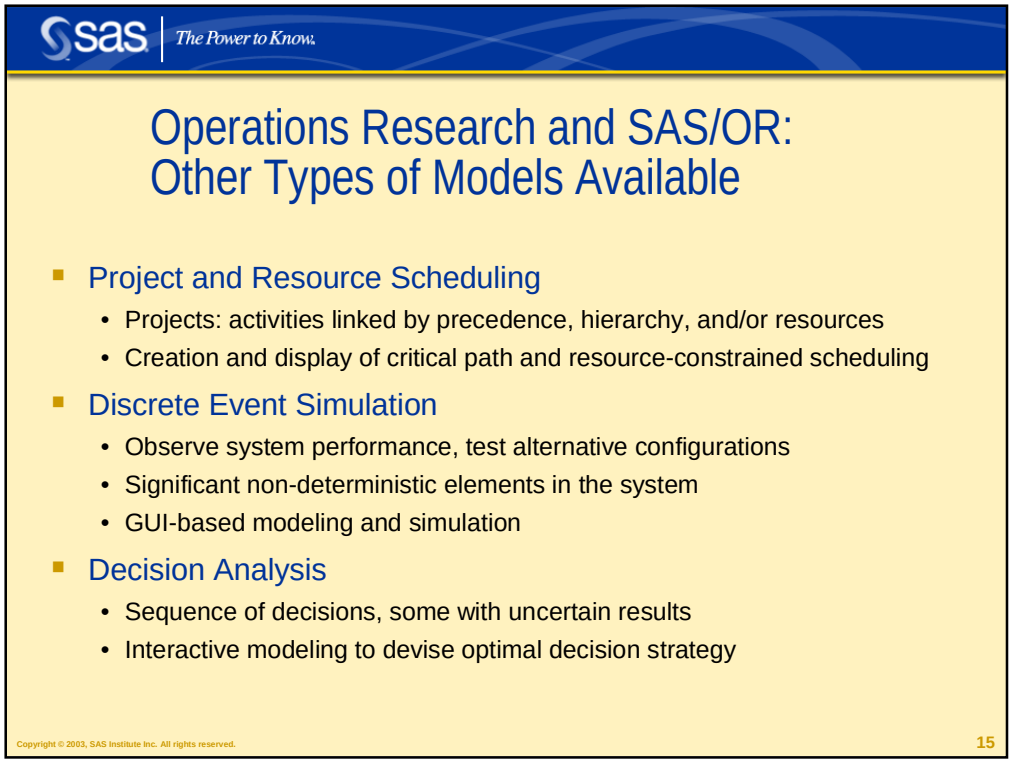
- What are you trying to accomplish?
- How will you measure the degree to which you accomplish this goal?
- What actions are available to you in pursuing this goal?
- How are the available actions related to the measurement of achievement? To each other?
- What other constraints or requirements limit your choice from the set of available actions?

SAS/OR Software: Established Optimization Capabilities

- PROC LP
  - Solves linear programs, mixed-integer programs, and integer programs
- PROC NETFLOW
  - Solves network optimization problems: shortest path, least-cost flow, maximum flow
- PROC NLP
  - Solves general nonlinear programs along with quadratic programs and least-squares problems
- PROC INTPOINT
  - Solves linear programs using an interior point (Primal-Dual Predictor-Corrector) solution method

PROC LP Enhancements

- Significant performance improvements for primal and dual simplex algorithms
- Especially useful for solving large scale linear and mixed integer programming problems
- Invoked automatically; no user intervention needed



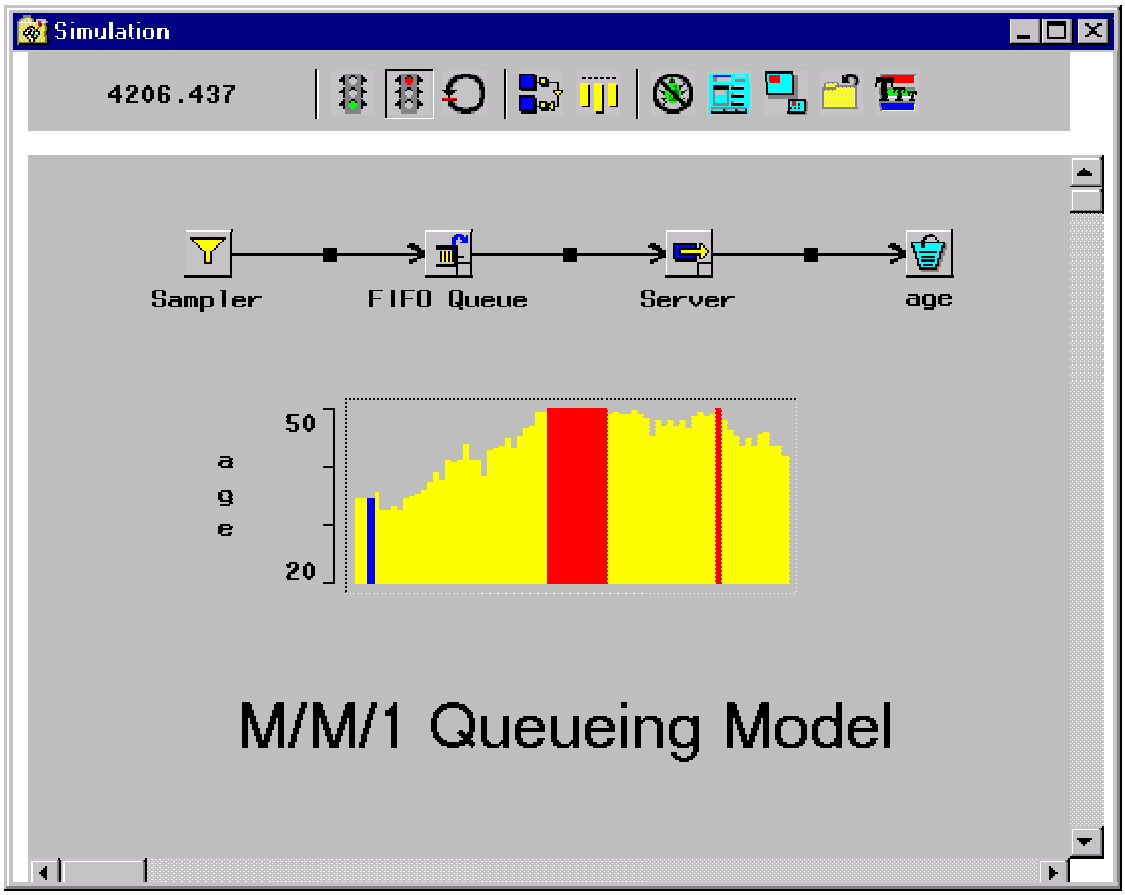
A look at SAS/OR wouldn't be complete without at least a brief mention of its other modeling and capabilities. Just as the discipline of Operations Research is more than just optimization, SAS/OR encompasses much more than its stable of optimization methods.

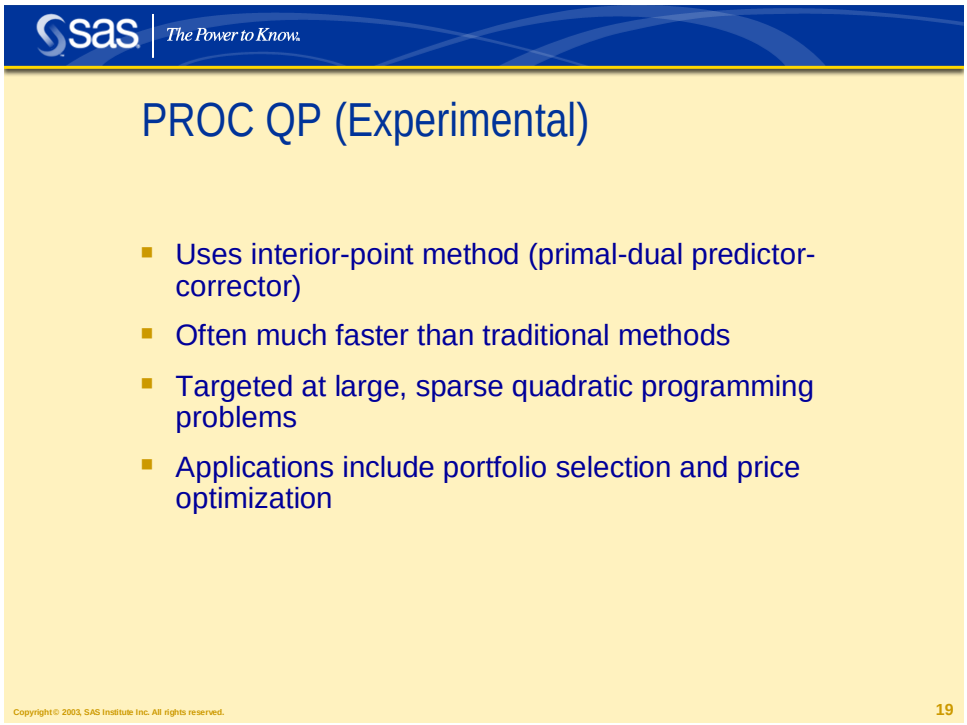
- SAS/OR has excellent project and resource scheduling capabilities.
  - PROC CPM and PROC PM enable you to build and schedule projects in great detail and with great realism.
  - Pure critical path scheduling and resource-constrained scheduling are both available for single and multiple projects. Resource modeling is an especially strong feature, enabling users to model the availability, usage, and substitution of resources in great detail.
  - Tracking of the assignment and availability of resources throughout the project timeline is also provided.
  - Graphical analysis of project schedules is excellent, with both Gantt charts and network diagrams available.

- Discrete event simulation is used to study systems with significant non-deterministic elements, in which probability or chance plays a major role and rigid mathematical relationships do not exist.
  - An example is the problem of having cashiers on hand to serve customers in a store. Arrivals of customers, time with the cashier, and tolerance for long lines are all elements that cannot be pinned down beforehand but which must be simulated.

- QSIM provides great simulation capabilities in a graphical environment.

- Finally, decision analysis studies cases in which you must make a series of decisions and some of the outcomes of your actions are outside your control.
  - An example is a loan officer considering a loan application. If she approves it then the borrower will either pay off the loan or default. The loan officer may decide to order a credit check at additional cost. Ultimately, she must decide whether to approve the loan, based on available information.
  - PROC DTREE models situations like these and determines sequential decision strategies that result in the best expected returns for the decision-maker.

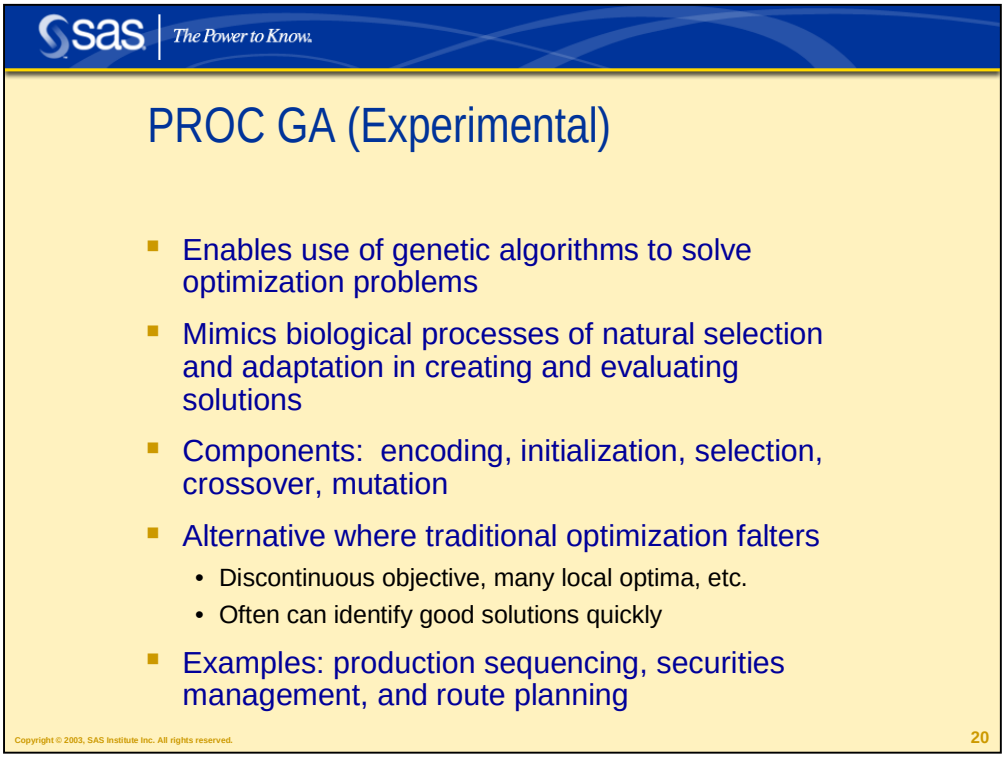




PROC QP
is designed especially to model and solve quadratic optimization problems.

- These problems have linear constraints but have square terms (x2, etc.) in the objective.
- PROC QP is especially adept at working with sparse constraint matrices;
  - this means that the constraints collectively involve a lot of different variables but each individual constraint generally involves very few of them.
  - This is often the case with models built for large, diverse enterprises.

PROC QP, like PROC INTPOINT, uses an interior-point solution method that often finds optimal solutions very quickly. Preliminary tests with PROC QP show performance far in excess of any competing solvers.



PROC GA takes a radically different approach to optimization.

PROC GA uses genetic algorithms,

- embracing the fact that all optimizers are search methods.
- Whereas traditional optimizers search by moving from one single solution to another, PROC GA works with groups—populations, if you will—of solutions.

Just as populations of biological organisms

- change and develop through reproduction, mutation, and selection,
- PROC GA simulates these processes as it alters the population of solutions.
- Using the objective function as a metric, PROC GA encourages the survival and propagation of preferable solutions.
- The population evolves successively over multiple generations
- and converges toward a common solution, in which favorable characteristics of solutions become more prevalent.

The genetic algorithms approach often works well for problems that have “difficult” objective functions, featuring discontinuities or a lot of locally optimal solutions (think of a mountain with many small peaks rather than just one big one).

In such cases it’s often enough to find a good solution quickly rather than slaving away to find the absolute best solution. Genetic algorithms are well suited to this type of work.

Example: Sequence-Dependent Production Scheduling

- A set of jobs must be scheduled on a single machine
- Each job has a processing time and a due date
- Overall goal is to minimize (or avoid) lateness
- But it's not that simple!
  - There is a setup time for each job
  - Setup time depends on what job was run previously
- Traditional optimization is cumbersome
- Traditional scheduling cannot handle this
- Genetic algorithms can find good solutions quickly

Here's an example of a problem that would be quite difficult to solve with traditional optimization but which genetic algorithms handle quite well.

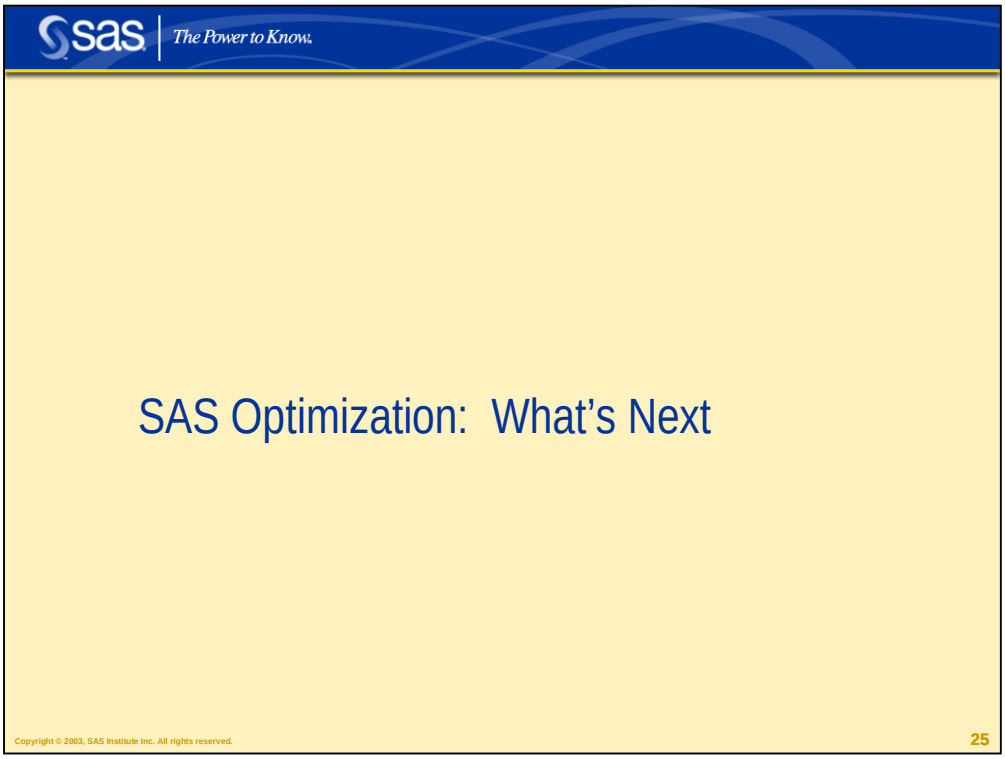
PROC CLP (Experimental)

- Solves Constraint Satisfaction Problems (CSPs) with finite domain constraint programming
  - Concepts: Value assignment, consistency checking, domain reduction, backtracking
- Includes expressive modeling features and powerful search techniques
- Succeeds where conventional optimization modeling is cumbersome or impossible
  - More compact models for problems with many logical or scheduling constraints
- Sequential construction and validation of solutions
- Applications include scheduling and facility location

PROC CLP is the second procedure taking a different approach to optimization. You might say that PROC GA and PROC CLP approach optimization from opposite ends of the spectrum. Whereas PROC GA starts with a population of solutions, PROC CLP builds a single solution by assigning values to each variable in sequence and observing the effects on the permissible values for the as-yet-unassigned variables. In a very real sense, PROC CLP builds solutions piece by piece.

PROC CLP is especially suited to problems in which logical constraints or difficult scheduling constraints are present. An example is a set of events that cannot occur simultaneously; this would be hopelessly complex in an integer program, but for PROC CLP the ALLDIFF statement handles it.

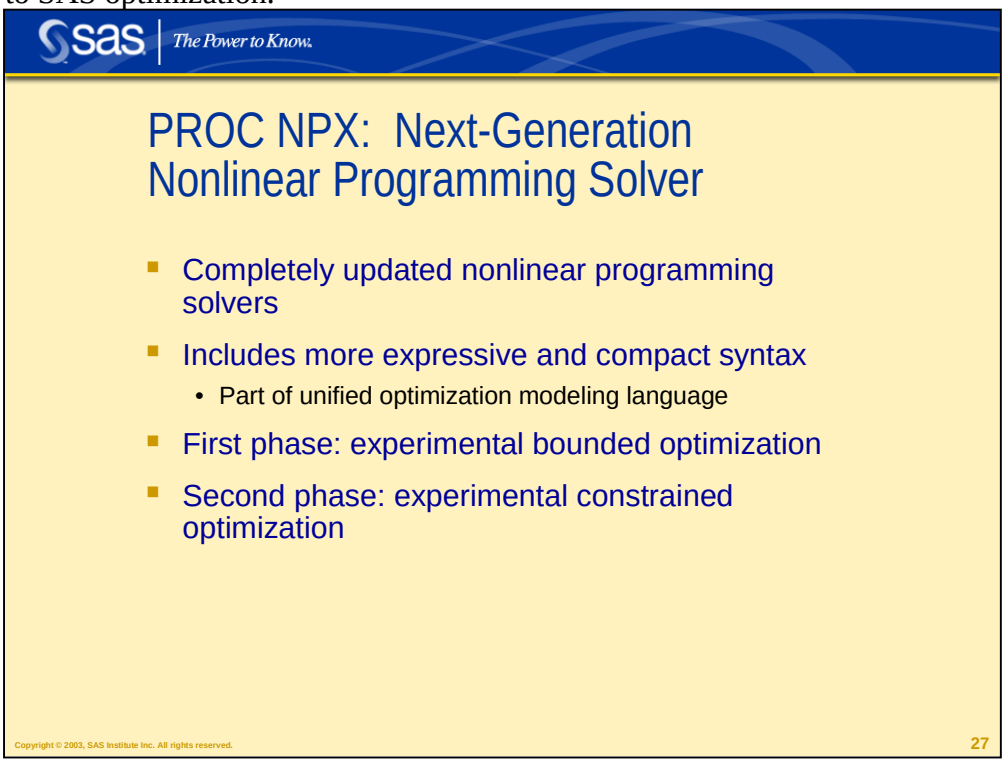
PROC CLP has two modes: general constraint satisfaction and scheduling, which includes some specialized features tailored to describing scheduling problems.



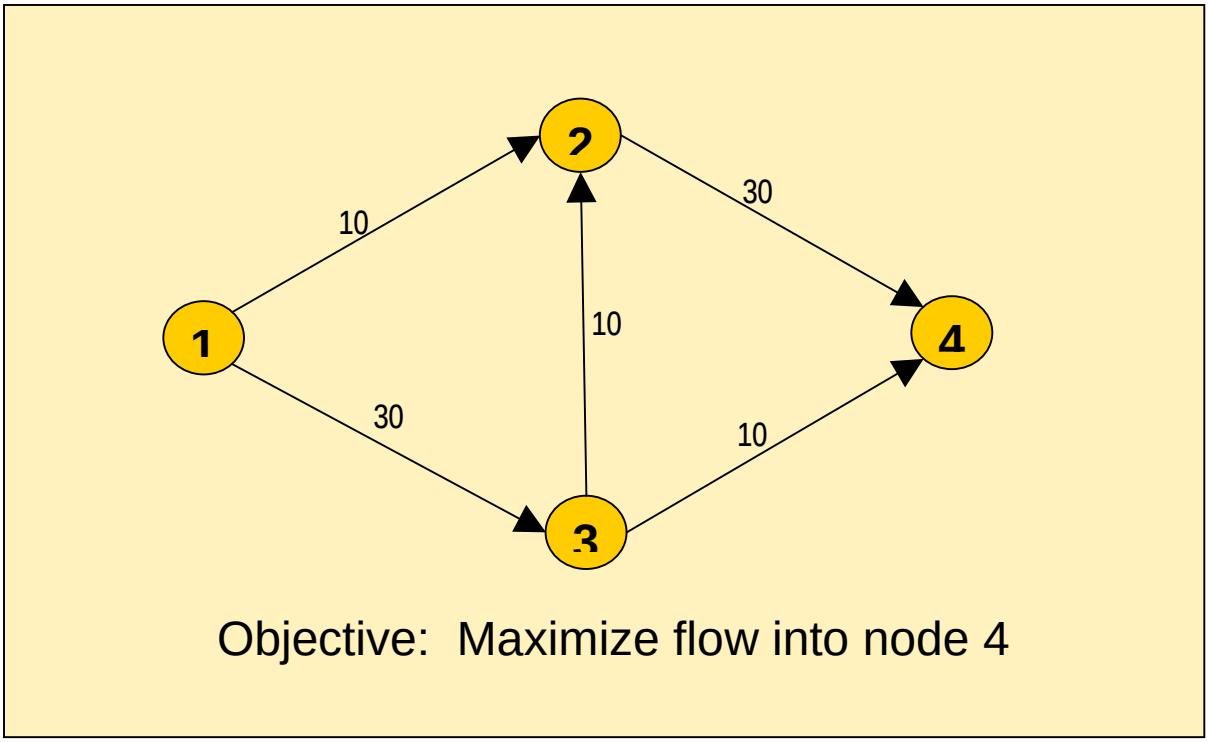
One of the most exciting developments within SAS lately has been the hiring of a large number of outstanding optimization experts.

The optimization staff at SAS is now four times as large as it was only two years ago, and now constitutes one of the largest operations research groups anywhere.

This larger, highly coordinated group is already turning out the first of many improvements to SAS optimization.



Here's a simple network flow optimization problem



Now lets formulate it with PROC NLP and PROC NPX side-by-side.

PROC NLP:

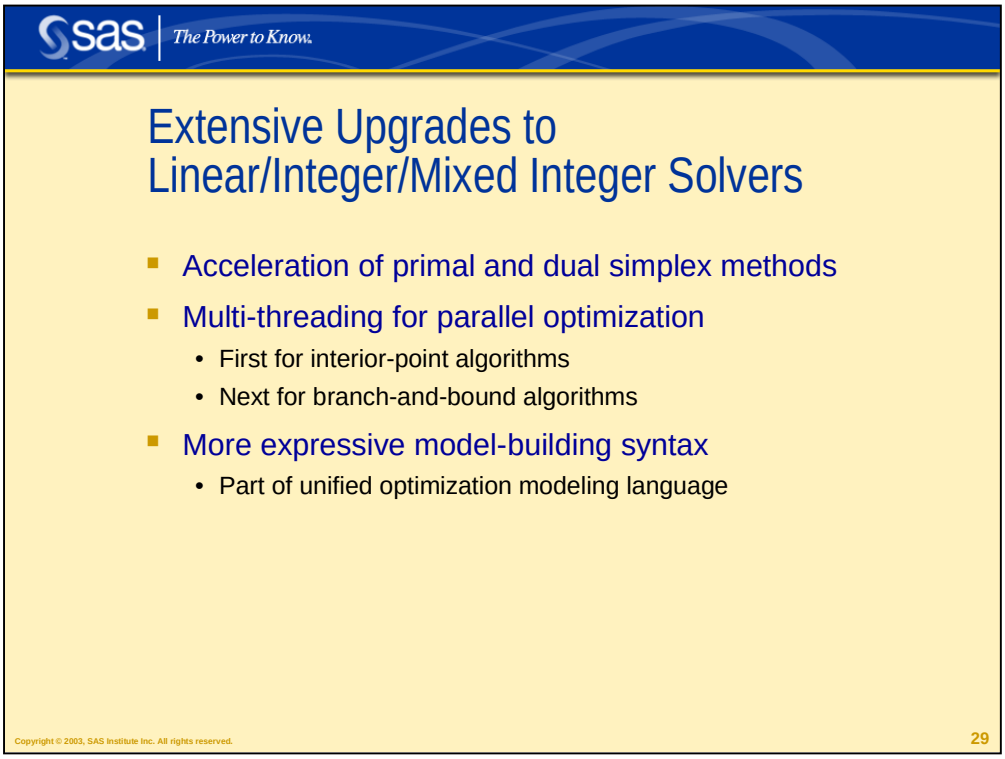
```
proc nlp all initial=0.5;
max y;
parms x12 x13 x32 x24 x34;
bounds          x12 <= 10,
x13 <= 30,
x32 <= 10,
x24 <= 30,
x34 <= 10;
lincon  x13 = x32 + x34,
x12 + x32 = x24,
x24 + x34 = x12 + x13;
y = x24 + x34;
run;
```

PROC NPX:

```
proc npx;
var x12 <= 10 init 0.5;
var x13 <= 30 init 0.5;
var x32 <= 10 init 0.5;
var x24 <= 30 init 0.5;
var x34 <= 10 init 0.5;
con c1: x13 = x32 + x34;
con c2: x12 + x32 = x24;
con c3: x24 + x34 = x12 + x13;
max y = x24 + x34;
solve;
```

You'll notice that in the NPX code the variables, their bounds and initial values, and the constraints are clearly identified in modular blocks.

There's also fewer code lines overall with PROC NPX.

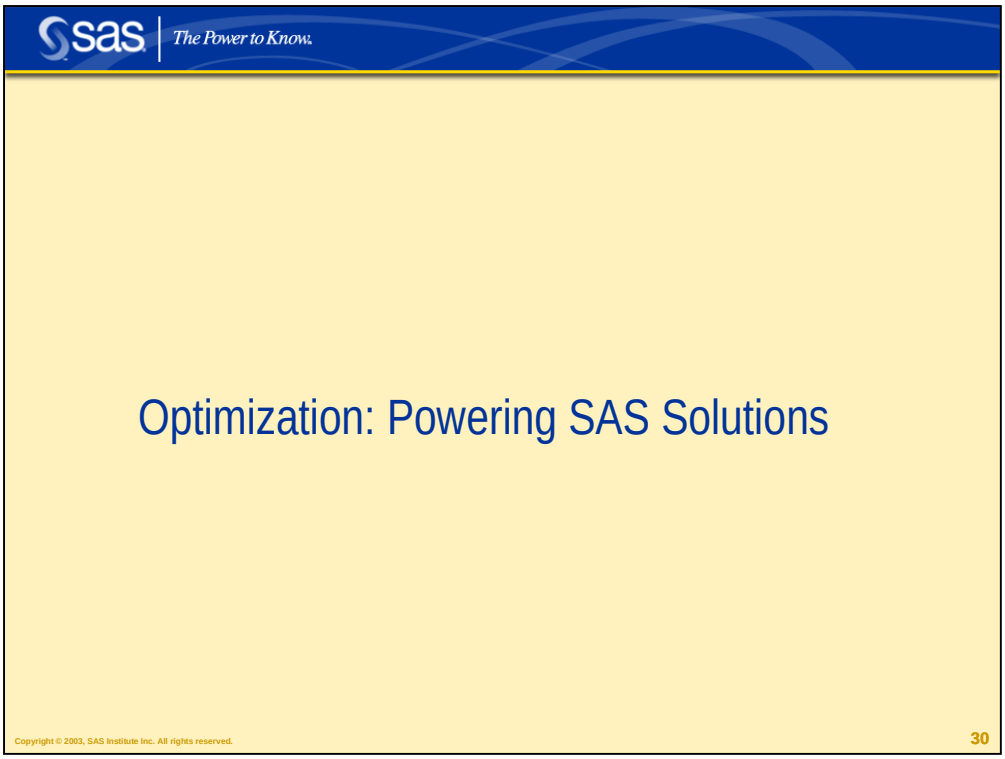


A major work area is linear and mixed-integer optimization,
which accounts for many of the optimization modeling done in SAS.

Since faster optimization is always a moving target,
our R&D staff is hard at work to keep SAS in the forefront.

Another major benefit of this new optimization work is the establishment of a much more unified syntax for modeling optimization problems.

This syntax will enable SAS optimization users
to transition more seamlessly between types of optimization models and the corresponding procedures without confronting new learning curves.



Now let’s look at how optimization is used in current and upcoming SAS solutions.

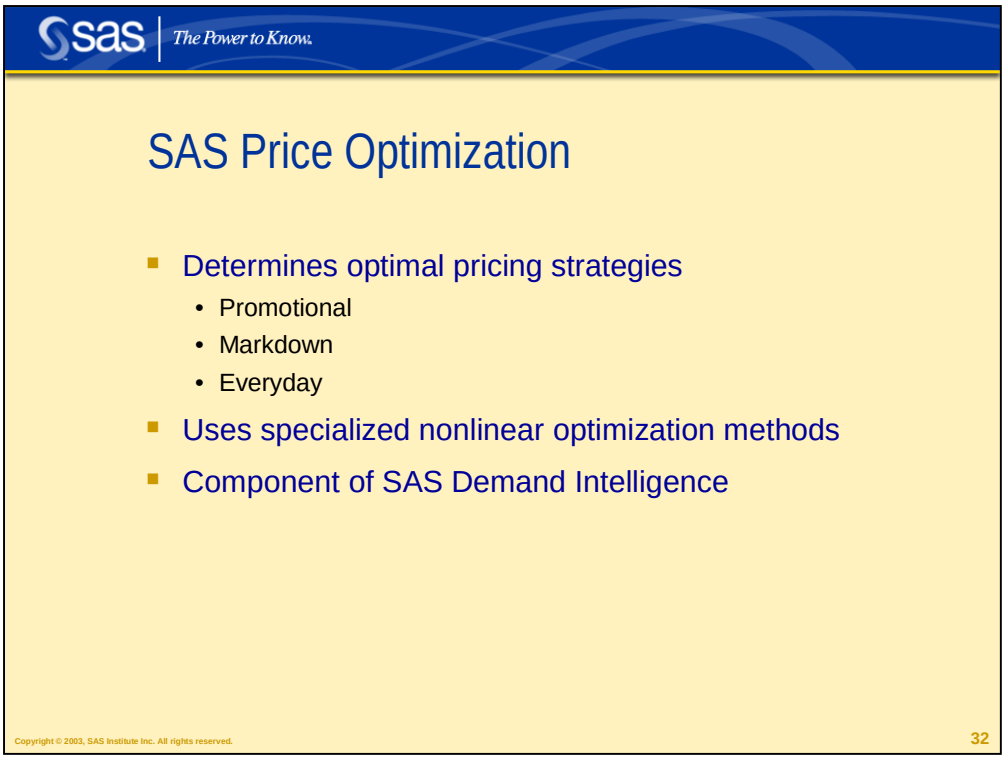
Optimization is a major growth area for SAS as the needs of our customers turn more and more toward the benefits that optimization provides—resource conservation, efficient utilization, and effective, well-justified decision-making.

SAS Inventory Replenishment Planning uses highly specialized optimization Algorithms to set least-cost inventory replenishment policies.

These methods deal with uncertainty on the demand and supply sides of the equation, encompassing variation in both customer demand and supplier lead times.

A variety of business rules and policy types are supported.

SAS Inventory Replenishment Planning is a component of SAS Demand Intelligence.



SAS Price Optimization,
another component of SAS Demand Intelligence,

will use nonlinear optimization methods to determine optimal strategies for promotional, markdown (clearance), and everyday pricing

SAS Supplier Relationship Management has for some time included optimization capabilities as part of the solution offering.

Within SAS Sourcing Strategy,
he supplier ranking module uses a type of optimization
known as *Data Envelopment Analysis* to rate and rank suppliers based on multiple, possibly conflicting, criteria.

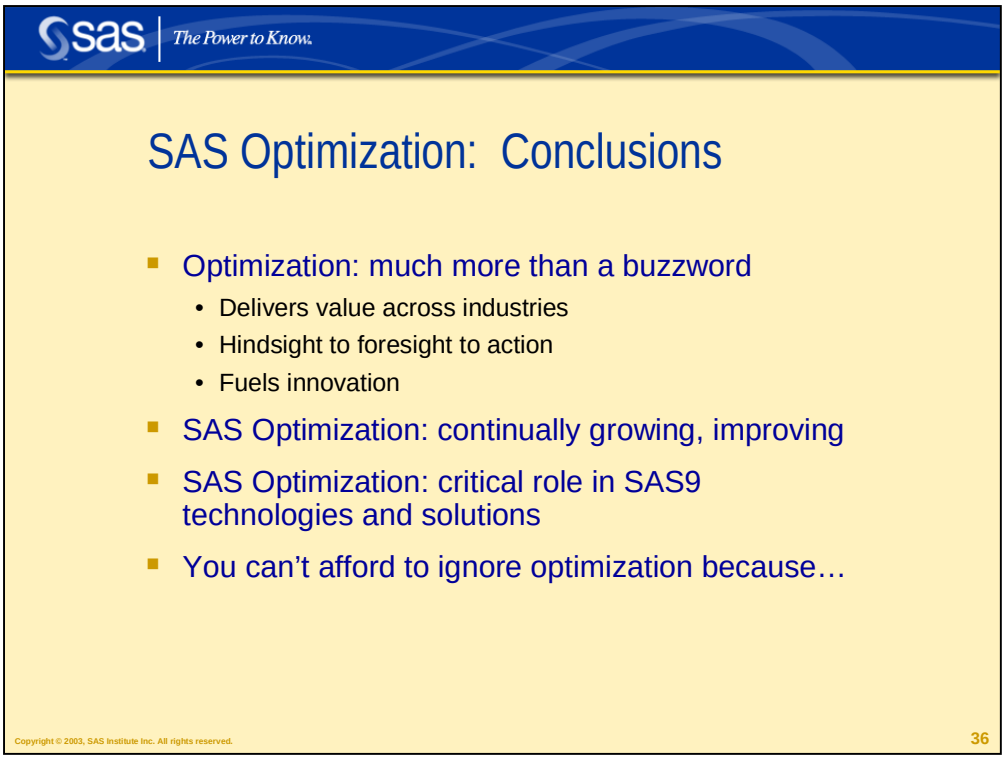
Supply base optimization looks at the question of structuring the supplier portfolio, aiming to achieve an optimal selection of suppliers within the boundaries set by business rules, regulatory requirements, or other relevant restrictions on supplier choice

SAS Marketing Optimization addresses a problem of growing importance to large customer-oriented enterprises:

how to structure promotional efforts so as to produce the greatest positive customer response?

The techniques used by SAS Marketing Optimization enable it to determine highly individualized marketing campaigns that still retain a focus on the “big picture” benefits, and to do so in a highly scalable manner.

This is critical as the reach of promotional campaigns grows ever broader



To sum up: optimization is a hot topic not just because it sounds good, but because it delivers real, tangible benefits.

At SAS, we see more and more of our customers turning to optimization. We're responding both by investing in R&D efforts to keep SAS optimization at the top and by augmenting SAS solutions with optimization capabilities.

In any setting, optimization is critical because it helps you stay on track—to avoid the hazards and achieve the best performance. Remembering back to the "truck" metaphor earlier in the talk…

there's always more than one truck out there to watch! Use SAS optimization to stay on course.