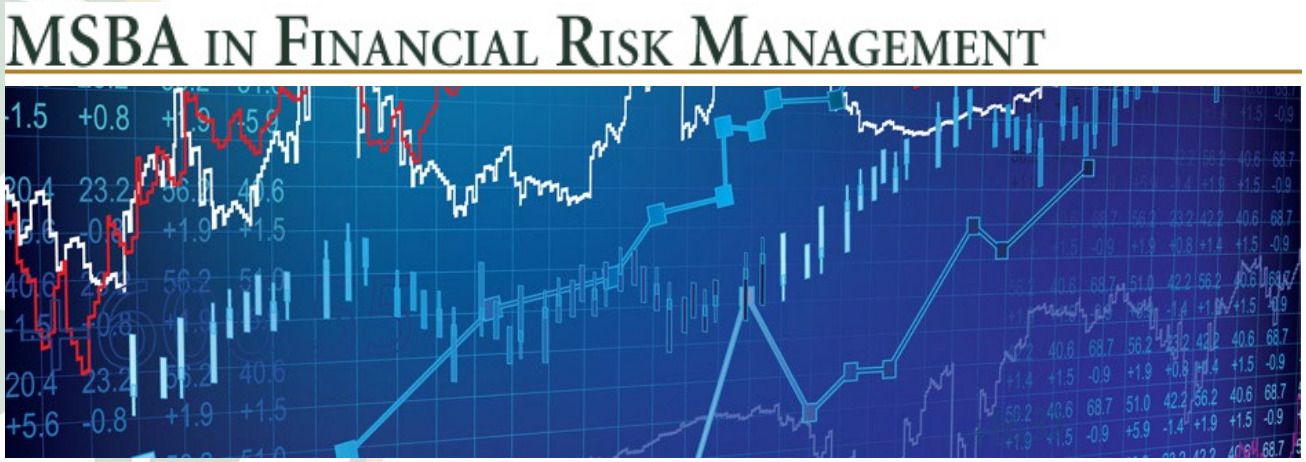
Financial Risk Management



Stochastic Optimization with Crystal Ball

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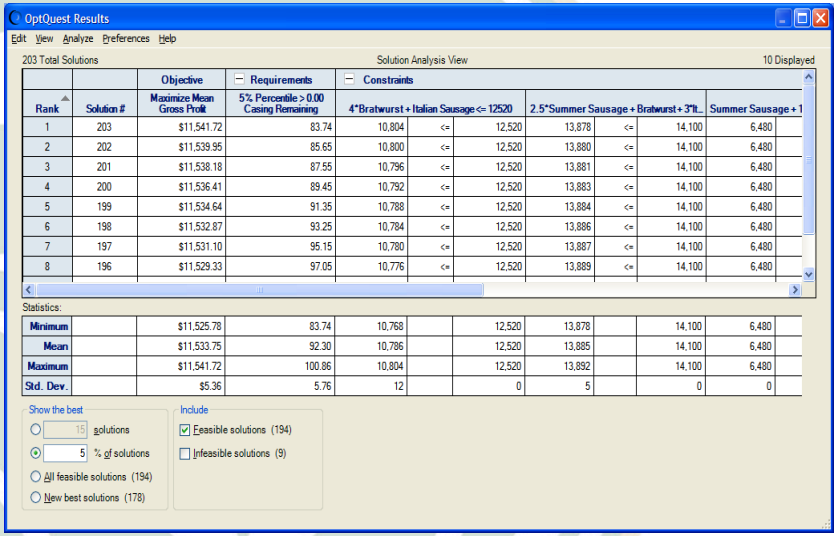
CRYSTAL BALL

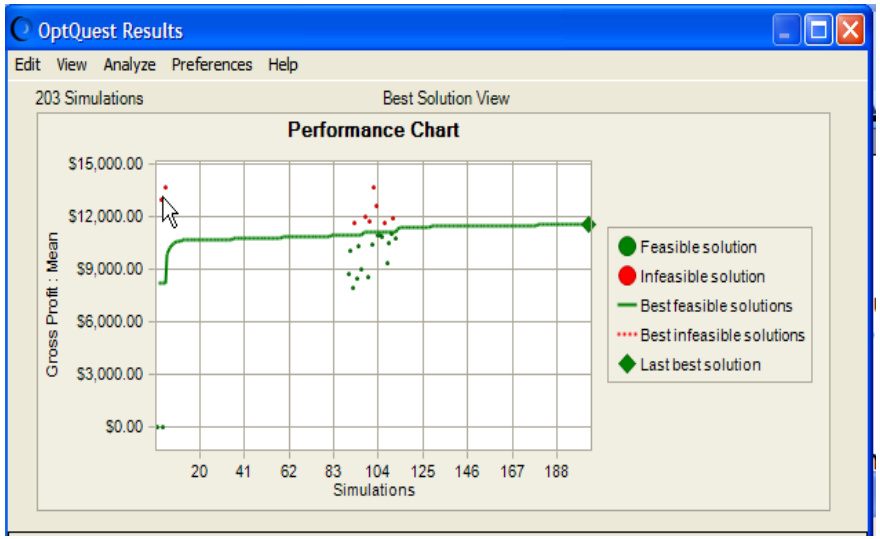
Stochastic Optimization

- Simulation is great, but can we do better?
- Introduction to optimization
  - Applications
  - Crystal Ball decision variables
  - Deterministic vs. Stochastic
- Using OptQuest
  - How it works
  - OptQuest menus, toolbars, and basic terminology

Stochastic Optimization

- Simulation models by themselves can only give you a range of possible outcomes for any situation. They don't tell you how to control the situation to achieve the best outcome.
- Stochastic Optimization is a combination of simulation and optimization, which lets you make the best (optimal) decisions while accounting for the variability or uncertainty inherent within a process.
- OptQuest enhances Crystal Ball by automatically searching for and finding optimal solutions to simulation models.



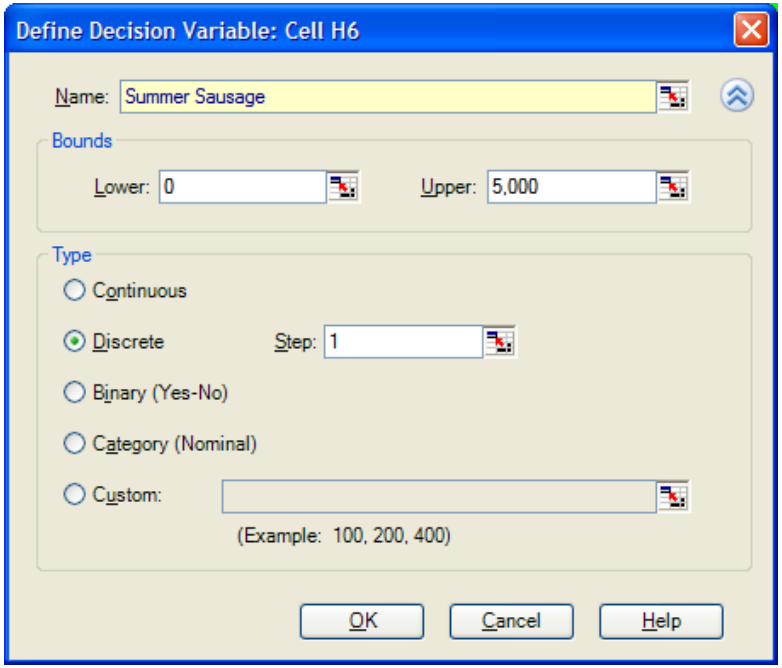


Optimization Applications

Business Question	Optimization's Answer
What level of demand are likely for next month?	Find the order points that maximize revenue.
What will production rates be for a new oilfield under consideration?	Determine number of wells to drill to maximize net present value.
Which stock portfolio should I pick?	Choose investments that have the highest return for given risk levels.
How should we manage our distribution operations?	Determine set of locations that minimize costs while meeting service requirements.

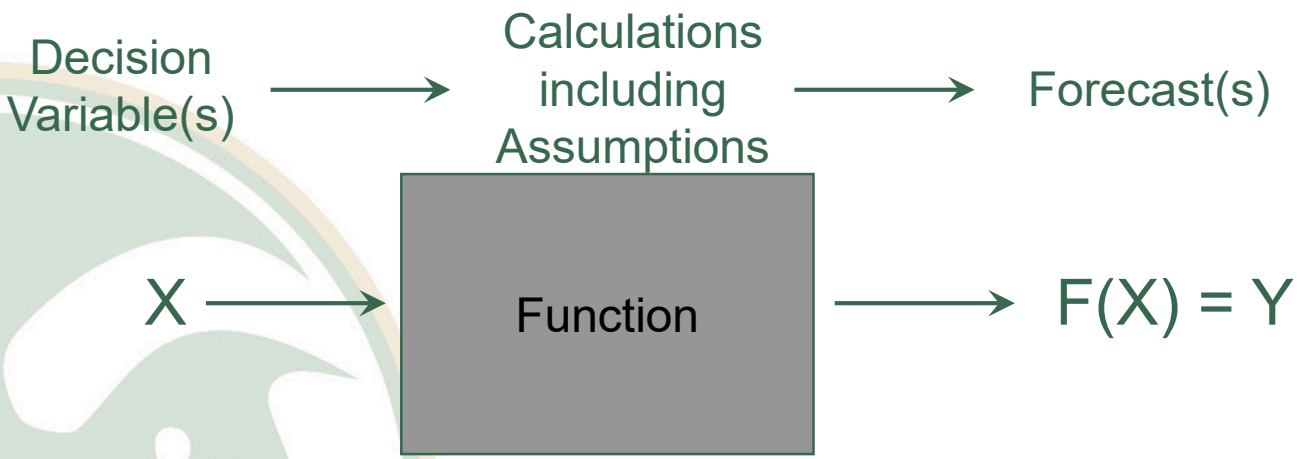
Crystal Ball Decision Variables

- We previously used Crystal Ball Assumptions and Forecasts in the our models
- With optimization, we also use Crystal Ball Decision variables
  - These are controllable inputs (X's)
  - Values that are not certain, but are within your control
- Examples: Amount of product to produce, amount of money to invest in each asset class



What is Optimization?

– Find the input values (Decision Variables) that make the output (Forecast Statistic) as large or as small as possible.



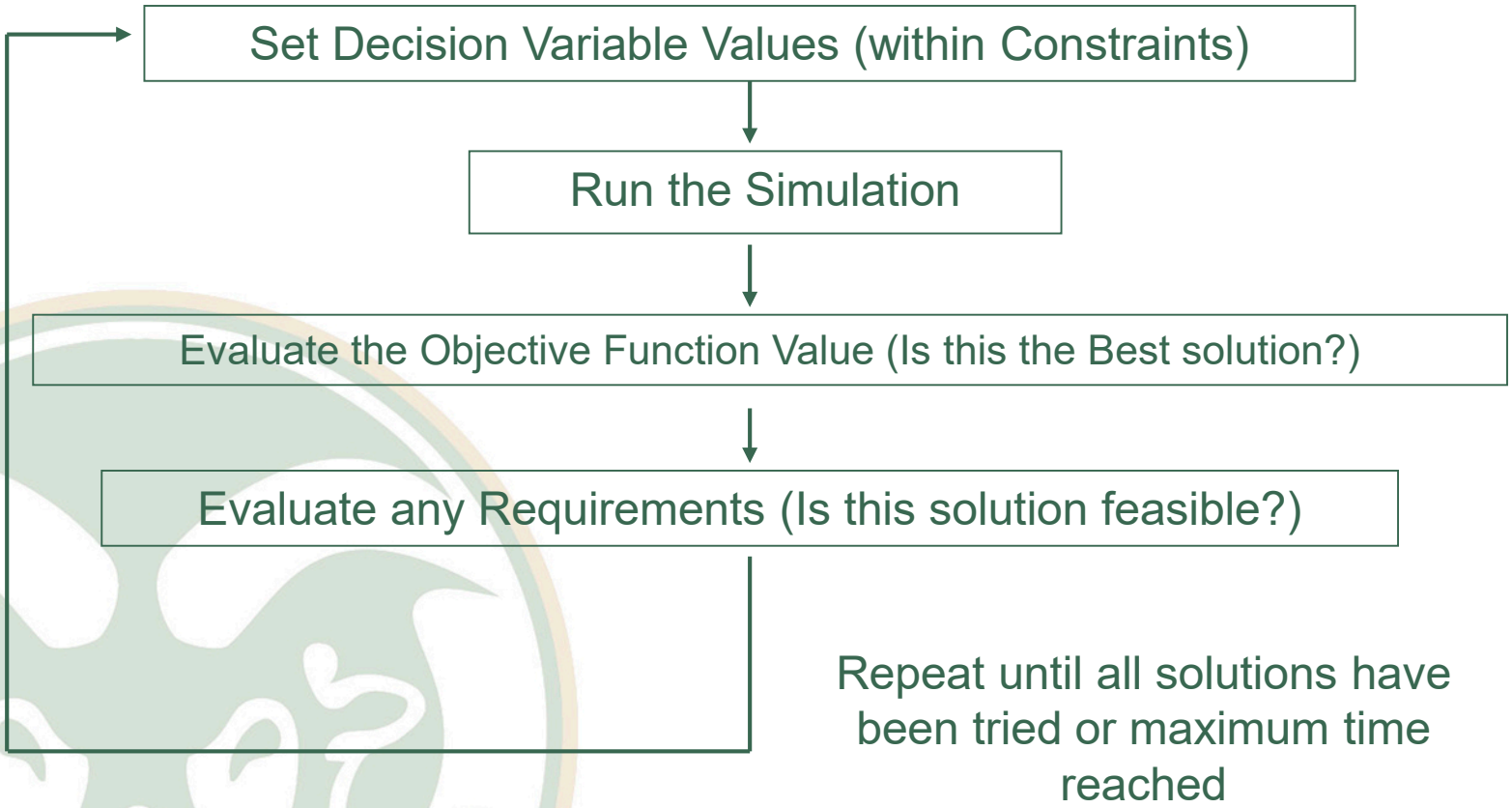
An optimization model answers the question "<u>What's best</u>?" rather than "What happened?" (statistics), "What if?" (simulation) or "What will happen?" (forecasting).

Deterministic vs. Stochastic Optimization

- Deterministic (e.g. MS Excel Solver)
  - Determines input values that place the output at its optimum.
  - Does not account for uncertainty in inputs or the range of possible outcomes.
  - Results in optimal single-point estimate of the output.

- Stochastic
  - Option to add statistical requirements on outputs.
    - Example: Maximize mean of return on investment (output) with a requirement that the standard deviation is less than a certain value.
  - Allows for real-world variation to be accounted for while optimizing the design.
  - Results in optimal design where the output is within acceptable variation limits.

How OptQuest Works

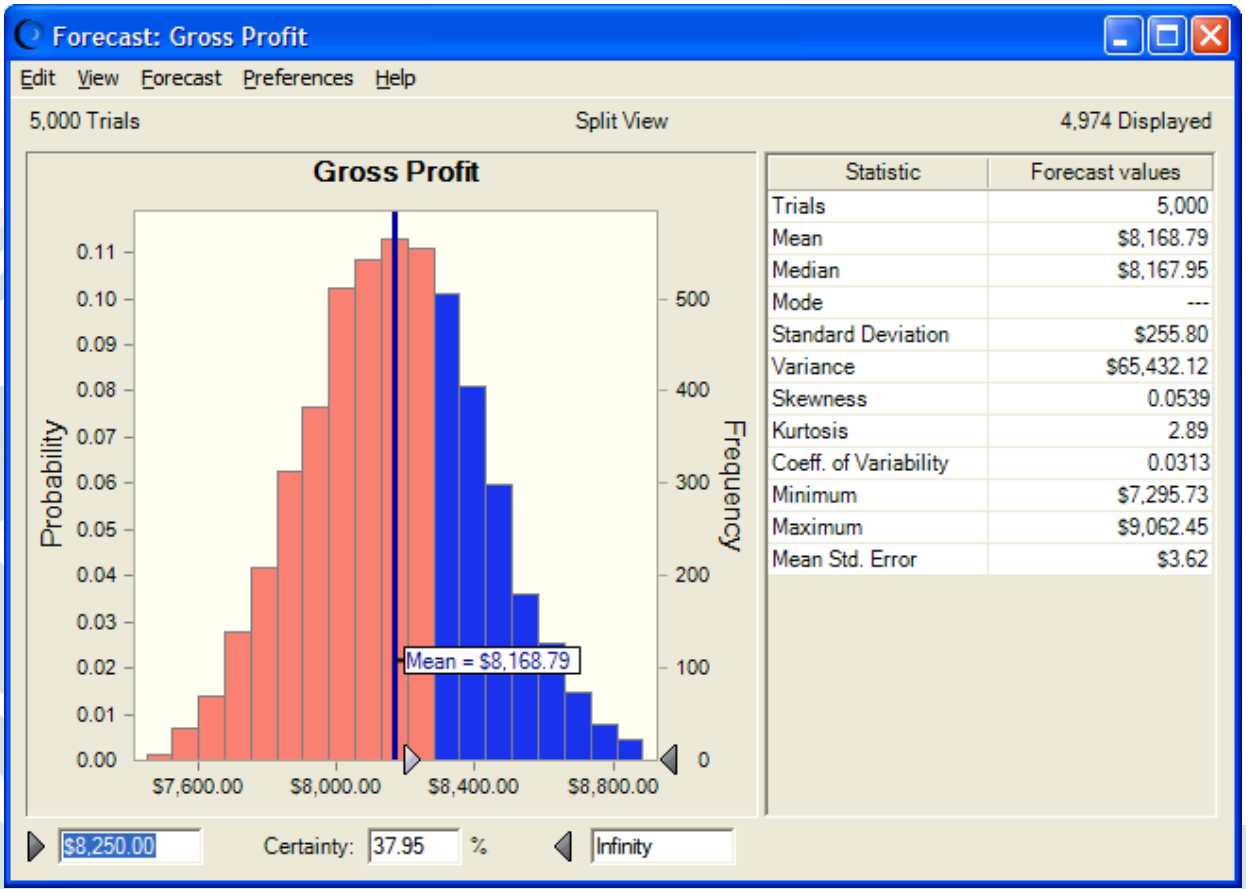


Example: Ray's Red Hots

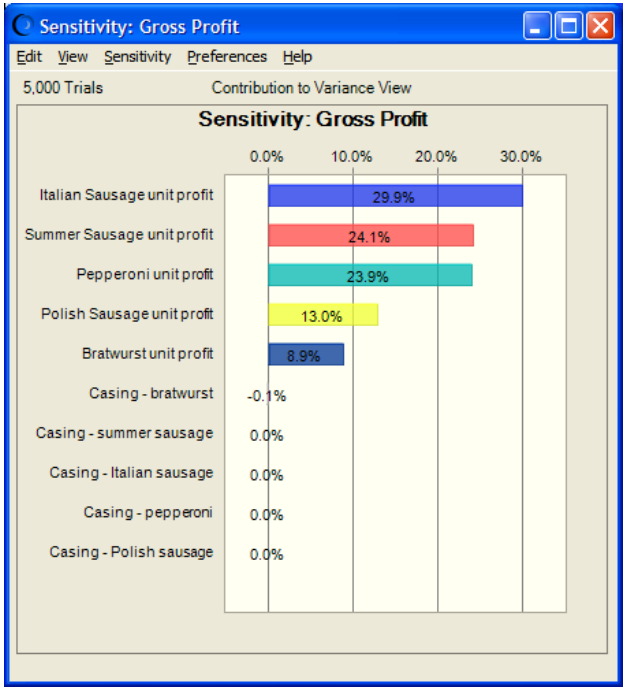
- Produce 5 types of sausage:
  - Summer sausage, Bratwurst, Italian Sausage, Pepperoni, Polish Sausage
- 4 ingredients:
  - Veal, Pork, Beef, Casing
- Must decide how much of each type of sausage to produce subject to ingredient constraints
- **Your goal: maximize profits while ensuring less than 5% chance of running out of casing.**

Example: Ray's Red Hots

- Run the simulation in Crystal Ball to understand the performance of the model without optimization.
- What are some key insights prior to performing optimization?



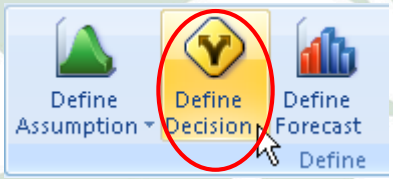
Statistic	Forecast values
Trials	5,000
Mean	$8,168.79
Median	$8,167.95
Mode	---
Standard Deviation	$255.80
Variance	$65,432.12
Skewness	0.0539
Kurtosis	2.89
Coeff. of Variability	0.0313
Minimum	$7,295.73
Maximum	$9,062.45
Mean Std. Error	$3.62



Example: Ray's Red Hots

- Add decision variables to the model for the quantity to produce for all 5 products
  - Use cell referencing for the name

1.



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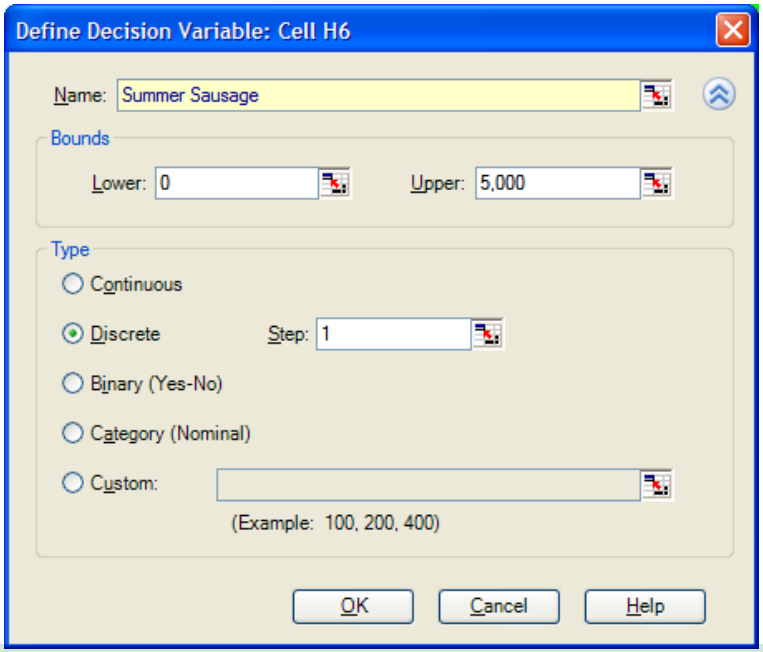
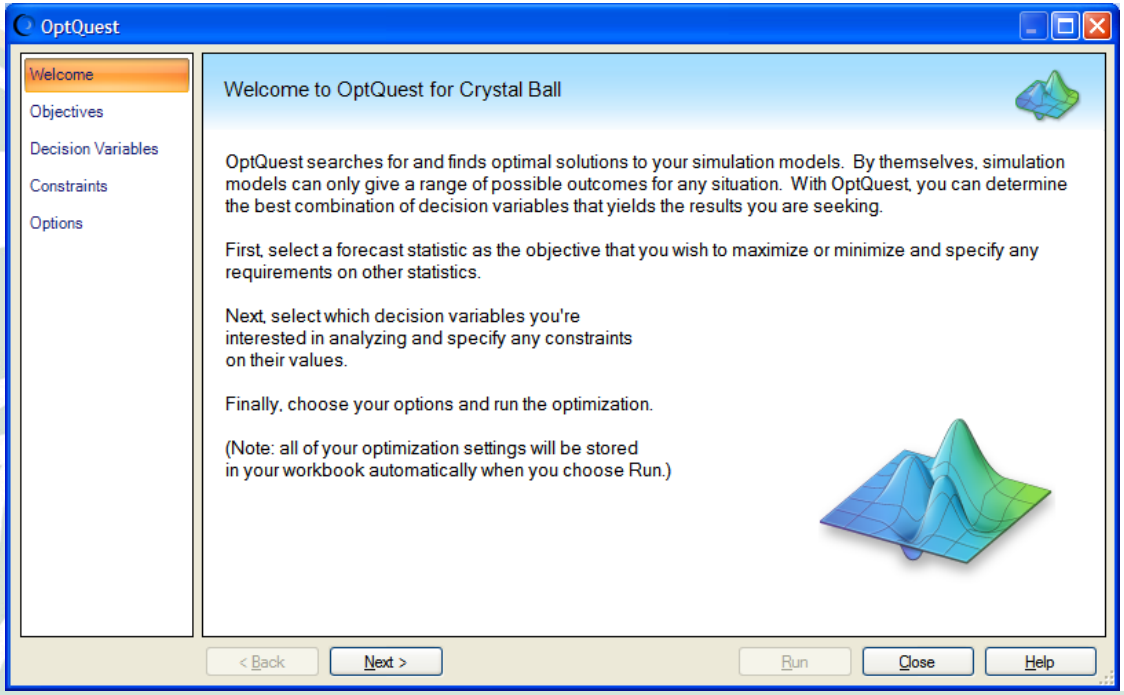


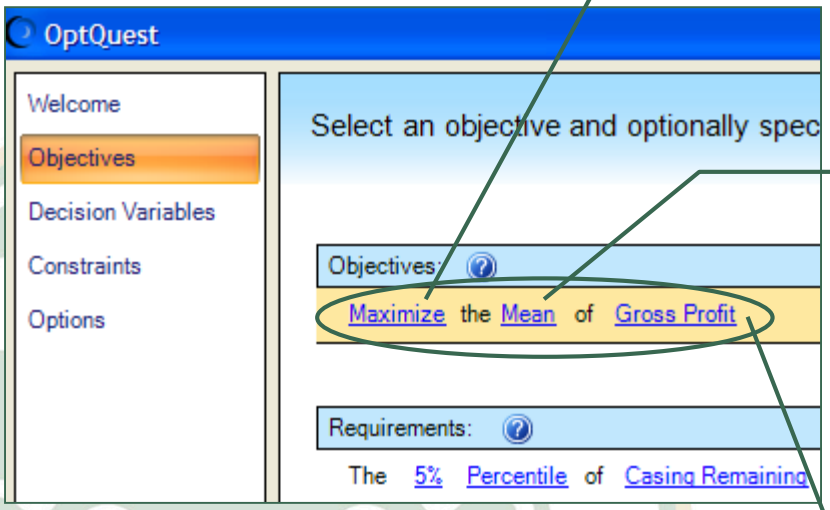
Launch OptQuest

- Select Run > OptQuest, or click on the OptQuest button on the ribbon.
- Review the Welcome screen, then click Next, or use the navigation panel to select Objectives

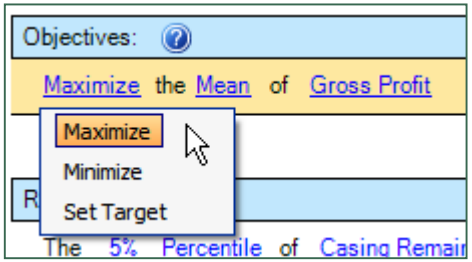
Navigation panel



Define Objective



1.



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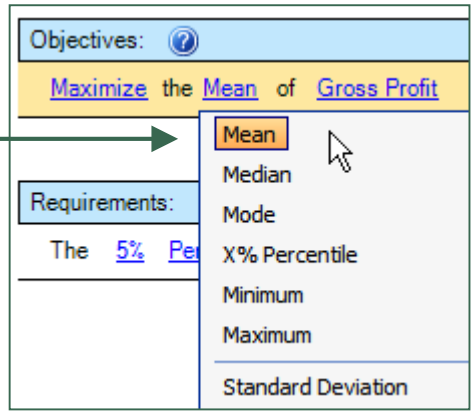
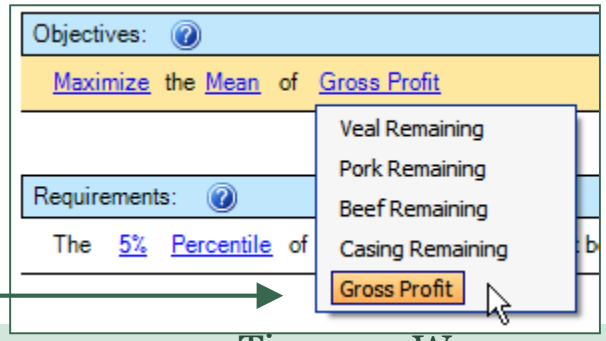


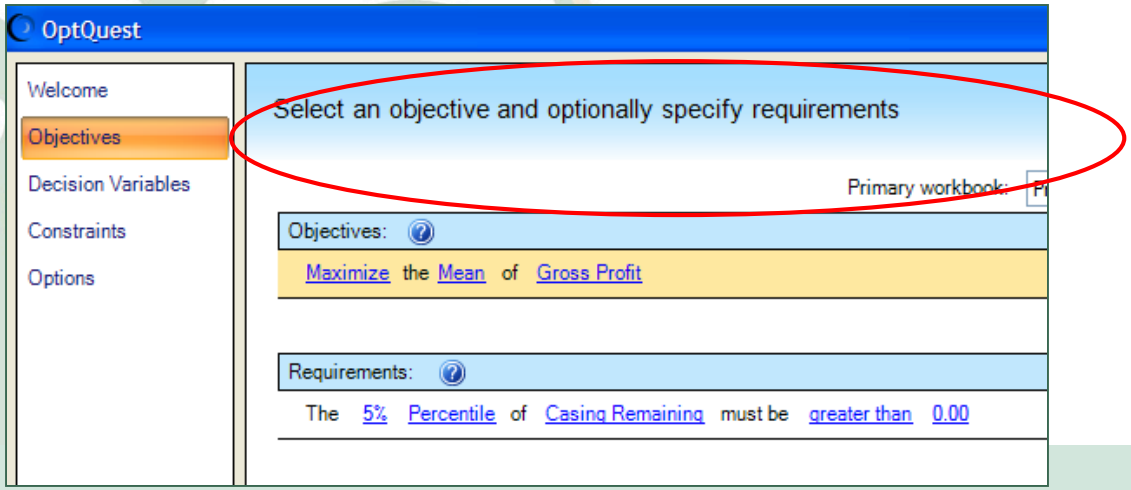
Because OptQuest performs stochastic optimization (i.e. running simulations) you can choose among many statistics to optimize.

3.



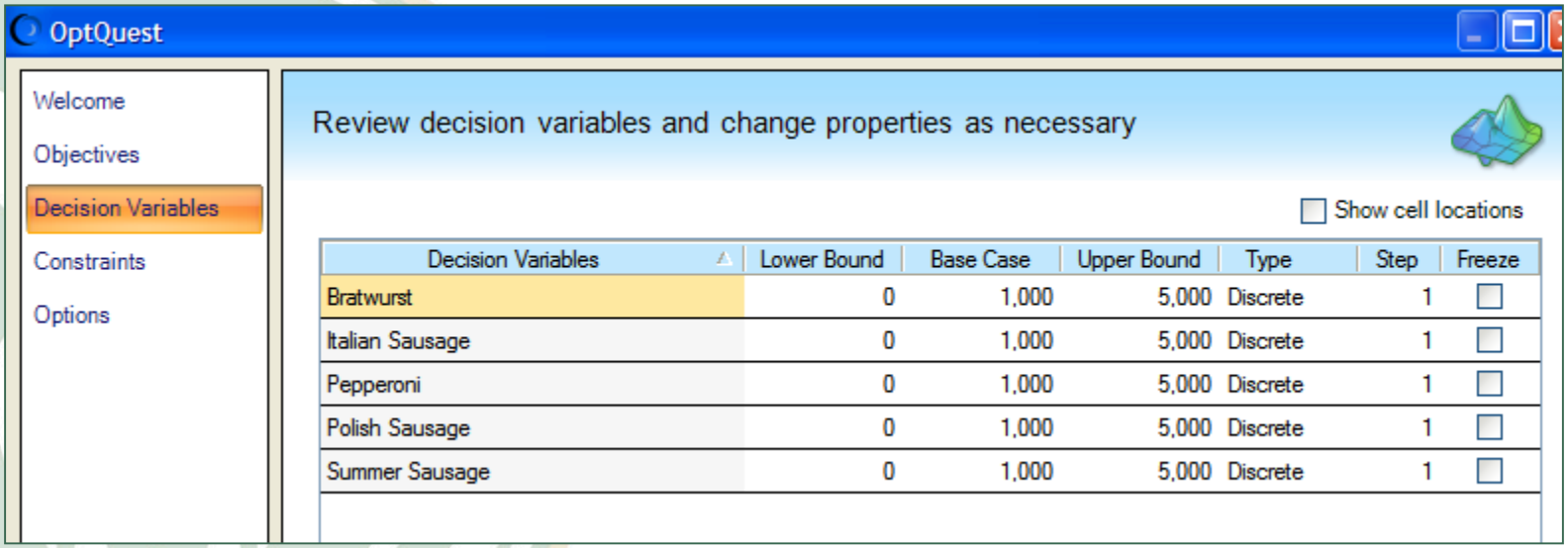
Define Requirements

- A model may or may not have requirements
- Requirements limit which solutions are acceptable, based on the simulation results
- Example: 95% certainty that Casing is available - expressed as 5th percentile of the forecast 'Casing Remaining' has lower bound 0.



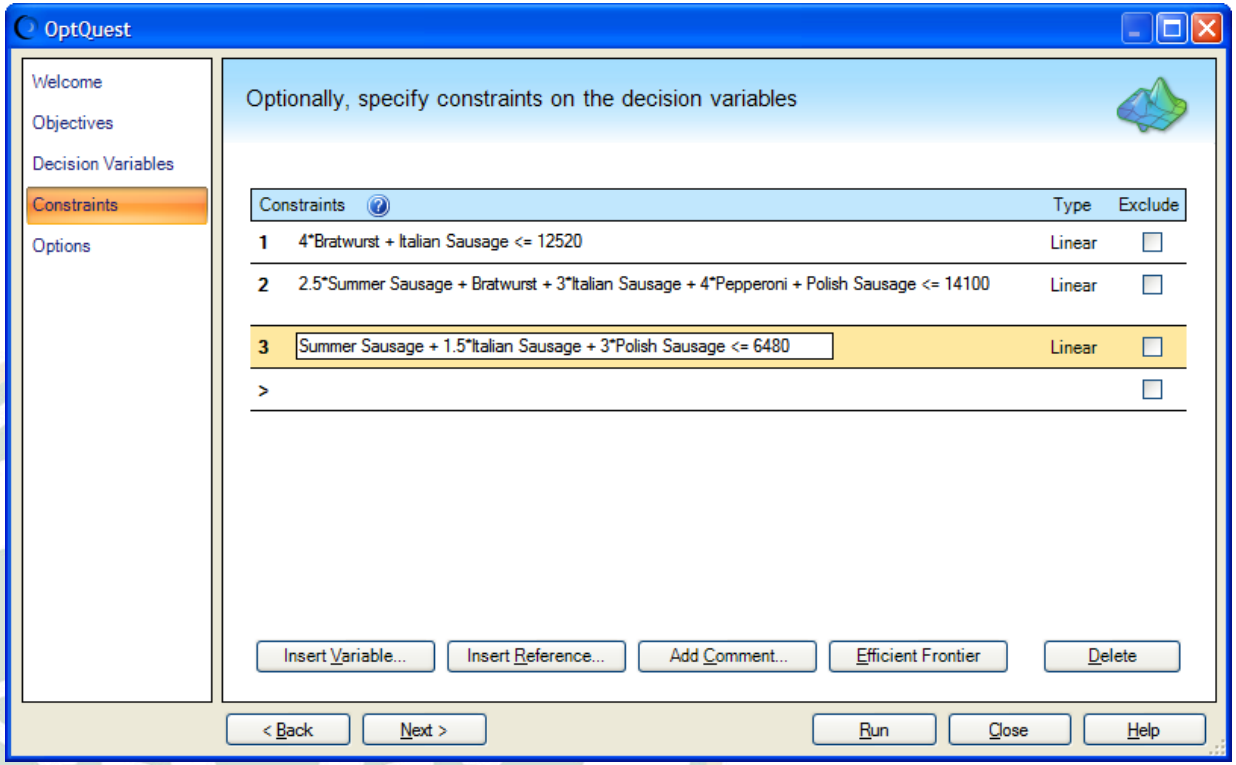
Select Decision Variables

- Review/Update Decision Variables imported from spreadsheet
- Freeze decision variables that should not be considered (optional)



Decision Variables	Lower Bound	Base Case	Upper Bound	Type	Step	Freeze
Bratwurst	0	1,000	5,000	Discrete	1	☐
Italian Sausage	0	1,000	5,000	Discrete	1	☐
Pepperoni	0	1,000	5,000	Discrete	1	☐
Polish Sausage	0	1,000	5,000	Discrete	1	☐
Summer Sausage	0	1,000	5,000	Discrete	1	☐

Define Constraints

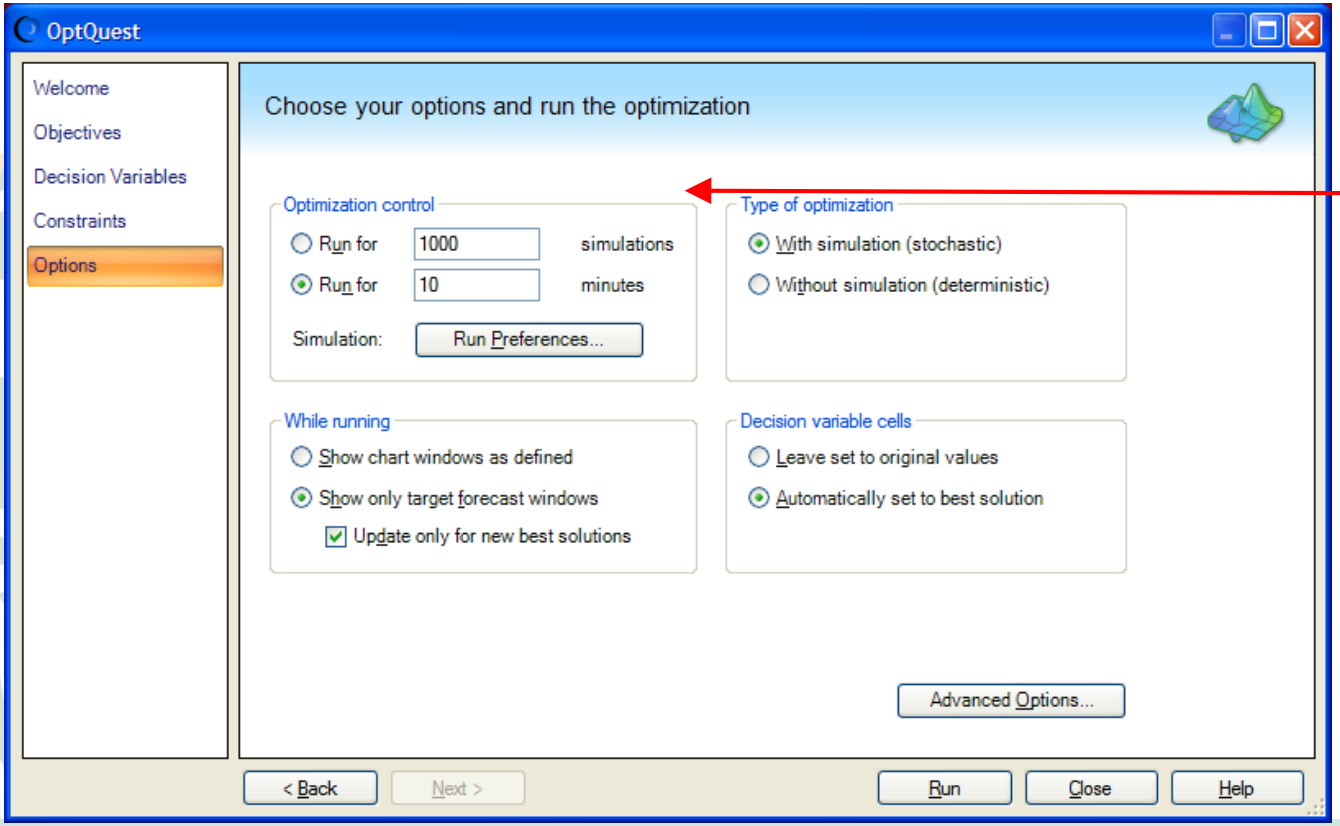


- A model may or may not have constraints
- Constraints restrict decision variable relationships
- Constraints may be linear or non-linear

Use these functions to help quickly build and document your constraint

Select Options

- Choose the number of simulations or time duration to run the optimization, then click



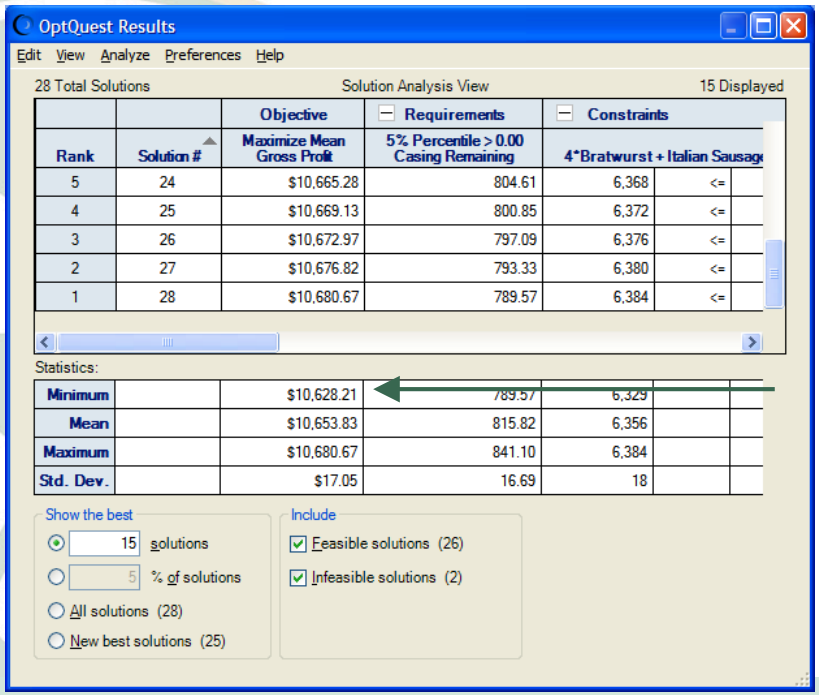
Crystal Ball run preferences (# of trials, run speed, etc), may be viewed and edited prior to beginning the optimization.

While the Optimization is Running

- Solution Analysis view (View > Solution Analysis)

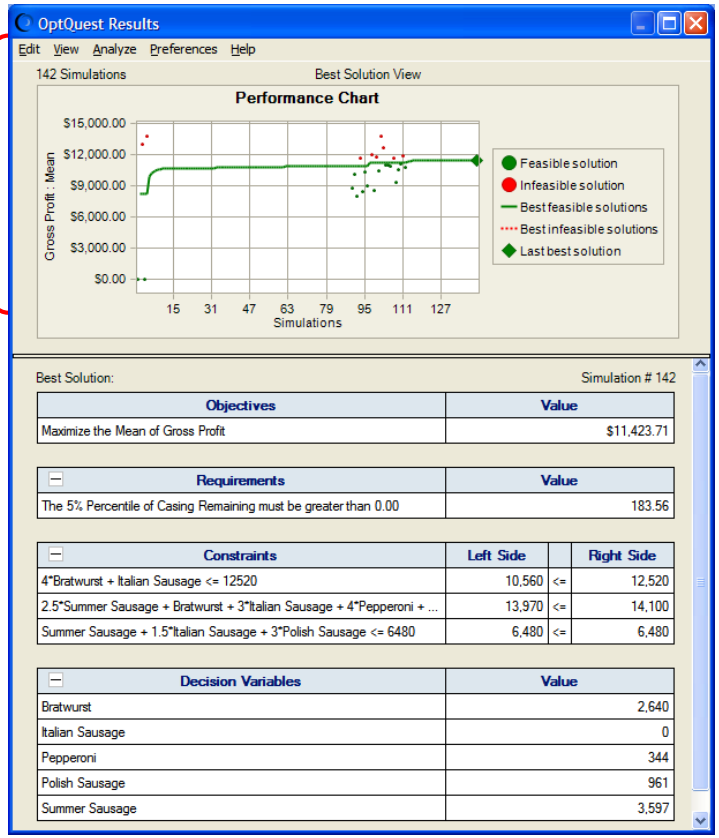
- View objective function, requirement, constraint, and decision variable information for solutions found during the optimization.

  Use filters to control which solutions are displayed



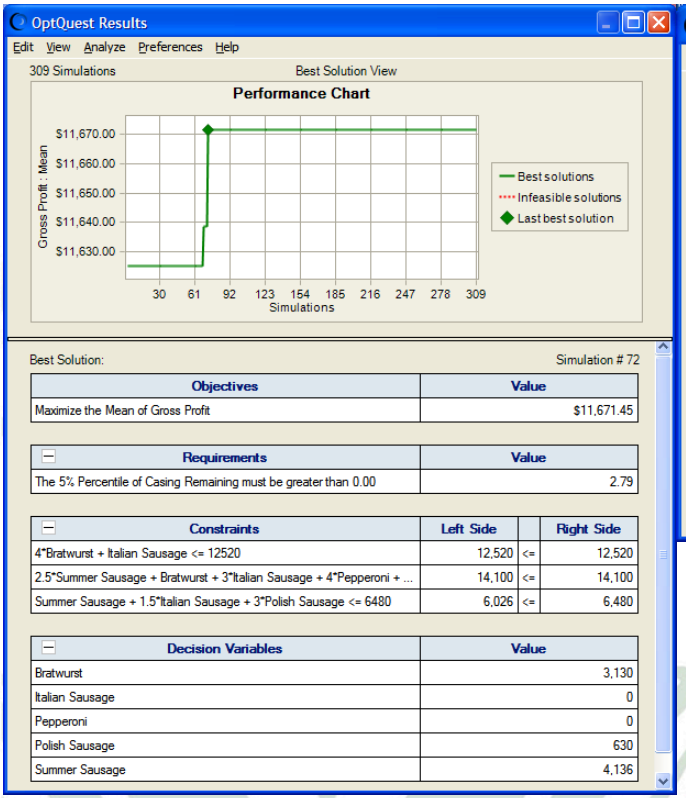
While the Optimization is Running

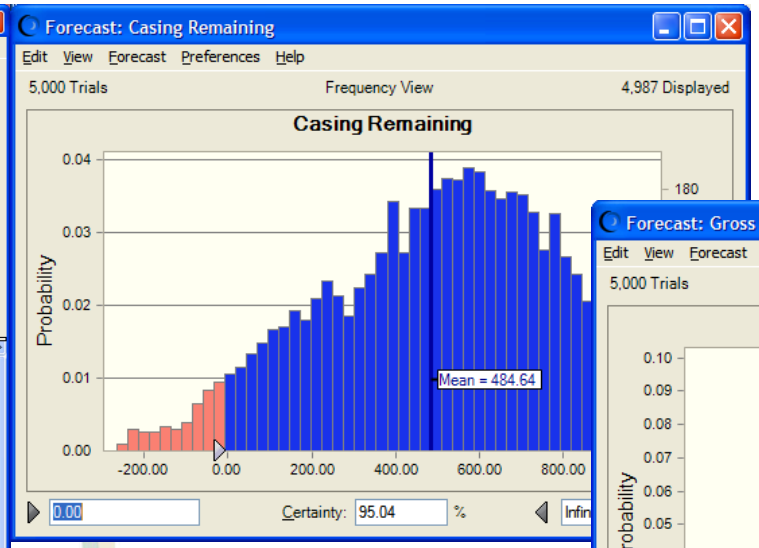
- Best Solution View (View > Best Solution)
- Performance chart plots the values of each simulation result (select Preferences > Show All Solutions to filter visible solutions)
- Information about the current best solution is displayed at the bottom

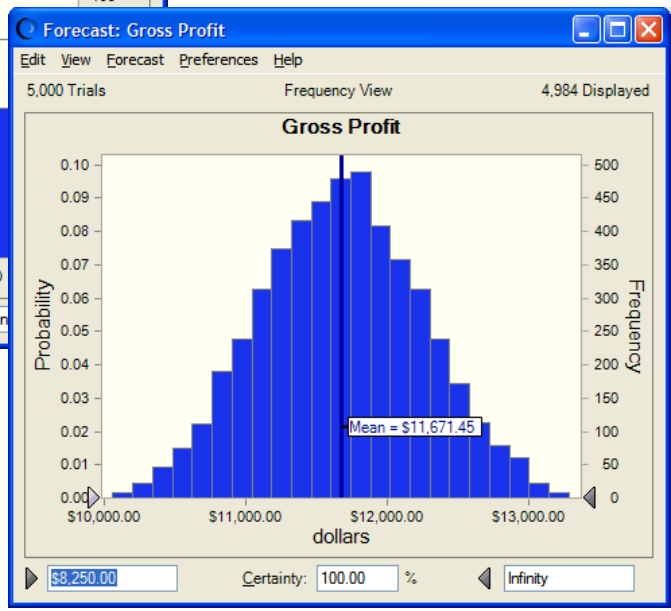


While the Optimization is Running

- Forecast charts of the current best solution may be viewed during and after the optimization run.

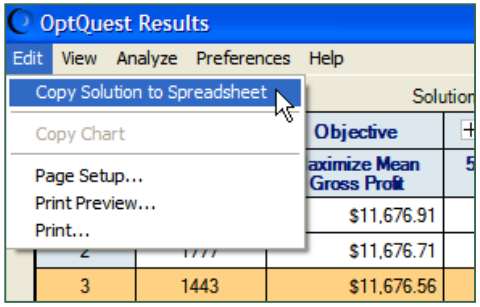




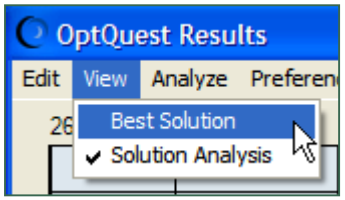


Optimization Results

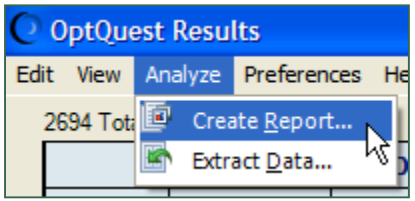
- Use the Edit menu to copy any solution's decision variable values to the spreadsheet



- Use the View menu to see the Best Solution or compare multiple solutions (Solution Analysis)



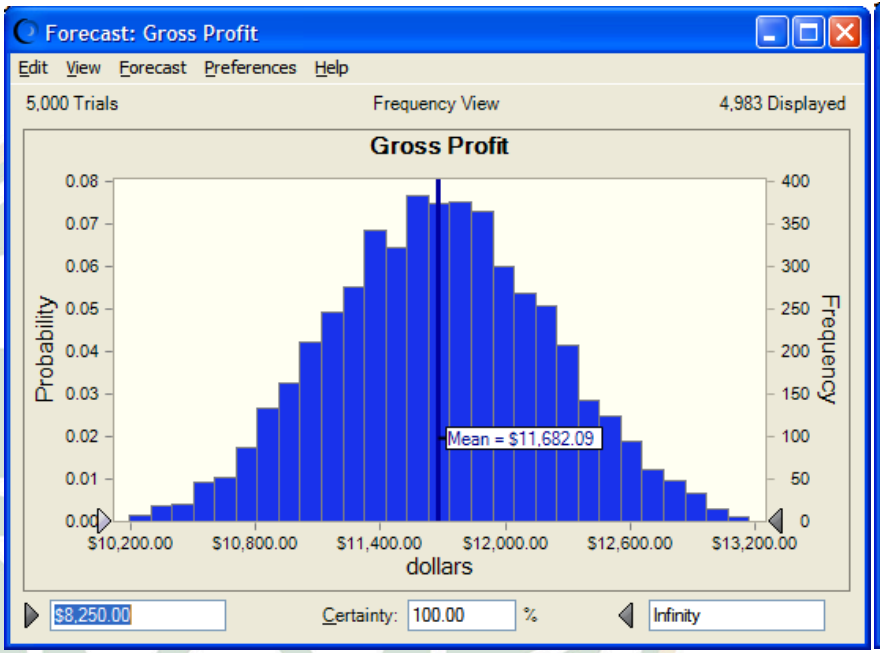
- Use the Analyze menu to create a report or extract your OptQuest results



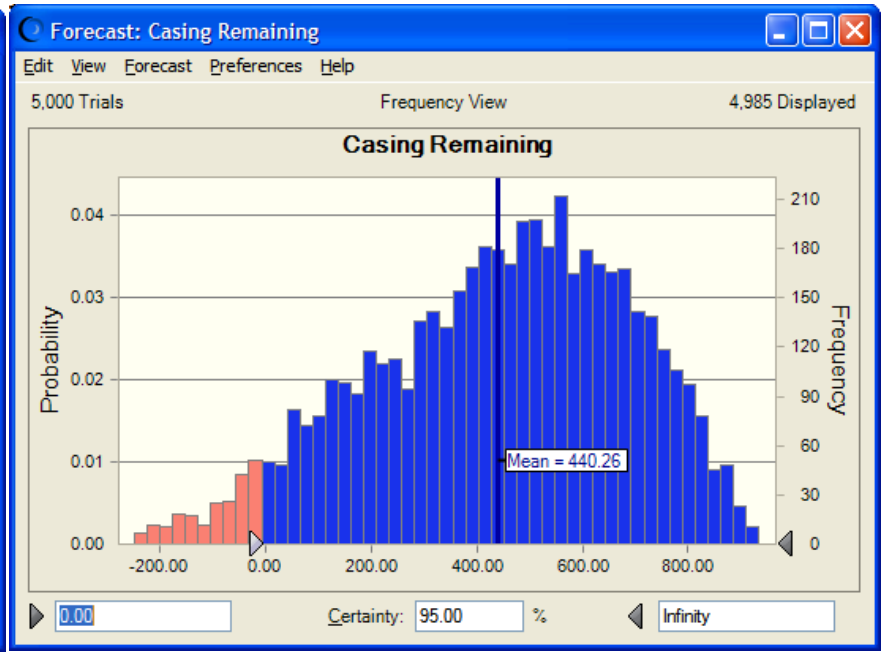
Optimization results

– Gross Profit improved from $8,169 to $11,682, while meeting the requirement for casing remaining.

Improved Gross Profit



Casing requirement satisfied



Compare results

	w/o Optimization	with Optimization
Mean Gross Profit	**$8,169**	**$11,682** ↑ 43%
% short casing	0%	~ 5%
Summer Sausage	1,000	3,714
Bratwurst	1,000	3,130
Italian Sausage	1,000	0
Pepperoni	1,000	23
Polish Sausage	1,000	922

Summary

- Simulation answers “What if?” while Optimization answers “What’s best?”
- Optimization is used across many industries, including management, manufacturing, finance, and engineering.
- Stochastic optimization offers more robust solutions compared to deterministic optimization.
- OptQuest is a powerful tool for stochastic optimization that works hand-in-hand with your Crystal Ball models.