Using Monte Carlo Simulations in Multi-Attribute Decision Analysis

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Overview

- Background
- Three challenges of using “static” multi-attribute models
- Using Monte Carlo simulations
  - Case Study: Building a project portfolio for a pharma Technical Services Organization
- Conclusions

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Background

- Case study based on an actual decision support application but names and data have been changed
- All charts and data generated using Optsee® (see www.DecisionManagement.com for more information)
- For in-depth discussion of some of the mathematics of this approach, see “Simulation Techniques for the Sensitivity Analysis of Multi-criteria Decision Models,” Butler, J.C., J. Jia and J.S. Dyer, European Journal of Operational Research, Vol. 103, No. 3, Dec. 16, 1997, pp. 531-545 (Google it)

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Background: Monte Carlo Simulation Methodology

- Named after Monte Carlo, Monaco; a city that is famous for its casinos and games of chance
- Games of chance exhibit random behavior; e.g. a shuffled deck of 52 cards
- Monte Carlo simulations involve creating multiple random outcomes, usually based on probability distributions, and then statistically analyzing the results
- Widely used for predictive financial modeling

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Challenge 1: Attribute Weighting vs. Ranking

- Hard to select and/or agree upon attribute weights
- Easier to select and/or agree upon attribute ranking

Rank	Attribute Name	Best Outcome	Worst Outcome	Weight
1	Reward ($mm)	100	30	1800
2	Cost ($mm)	5	50	1300
3	Prob. of Market Success (%)	90	40	1000
4	Prob. of Technical Success (%)	90	10	850
5	Time to Market (Weeks)	20	520	800
6	Comp. Strength (1 is Strongest)	1	5	600
7	Tech. Maturity (5=Most Mature)	5	1	500

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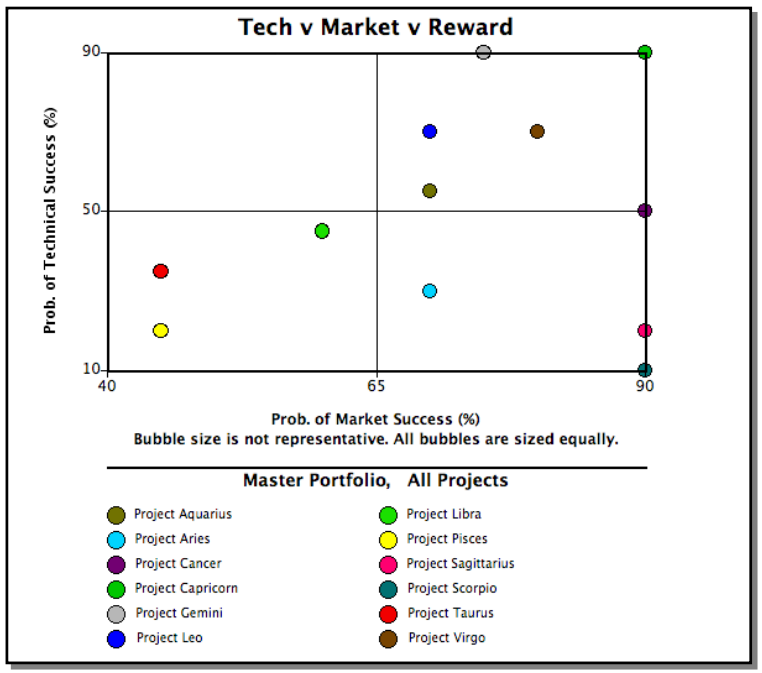
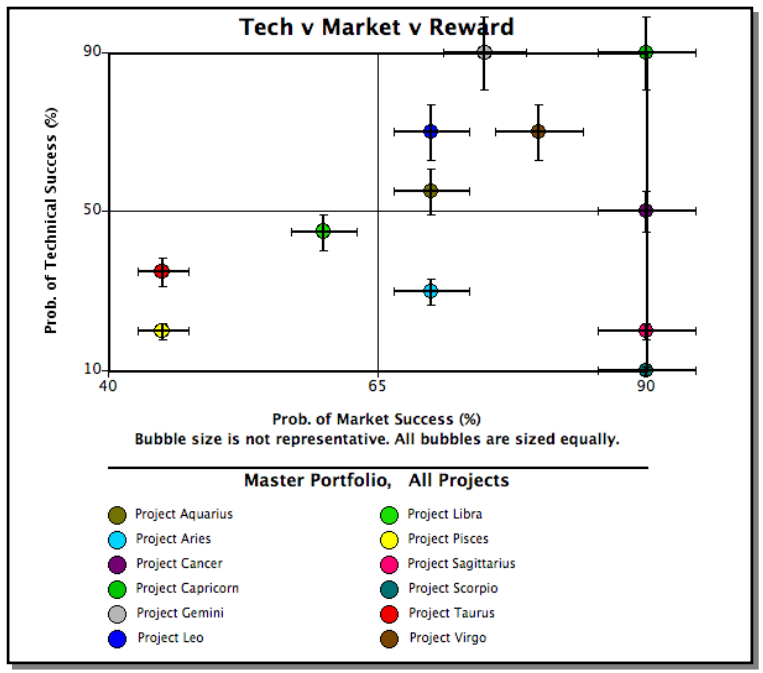
Challenge 2: Single Data Point Analysis

- Single data points often do not reflect business reality
- Decision makers like to integrate uncertainty into their decision analyses

Single Data Points



Data With Uncertainty



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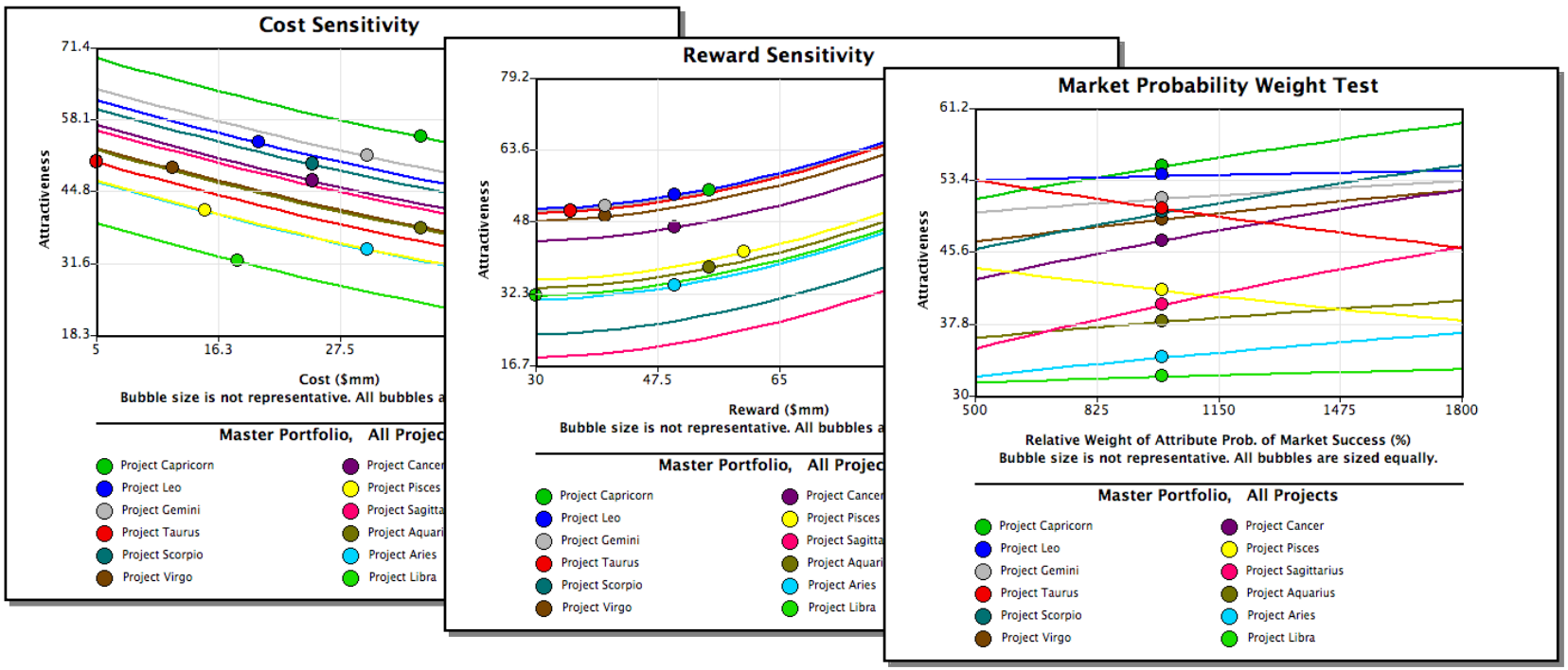
Challenge 3: Sensitivity Testing

- Tests just one criteria at a time
- Tedious, often confusing, leads to “chart burn-out”



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Solution: Monte Carlo Simulations

- Test your portfolios in thousands of different decision models using 3 basic simulation types:
  - **Rank-Order Variable Decision Models:** Attribute weights are randomly varied but the attribute rank order is held constant
  - **Variable Scenarios**: Attribute weights are held constant, but choice values are varied within the defined uncertainty ranges
  - **Combined:** Both attribute weights and choice values are varied simultaneously
- Results reported as clearly ranked alternatives in statistical reports and charts
- Does not require tedious sensitivity analysis and multiple bubble charts are optional
- Scales well for prioritizing and optimizing large portfolios

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Case Study: Pharma Tech Services Description

- Budget over $10 million (outside costs)
- Responsible for dozens of products in two plants (national and international)
- Multiple contract manufacturers (raw materials and finished product)
- Current “portfolio” is more than 60 projects (not including “fire fights”)
- “Portfolio management” is ad hoc
- Projects come from departments with often-conflicting priorities e.g. Compliance, Marketing, R&D, Manufacturing
- No prior experience with decision support tools or techniques

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Case Study: Goals

Overall Goals: Develop a Project Prioritization Process that:

- Organizes and quantifies project priorities using internal and external inputs
- Provides a meaningful and understandable project portfolio ranking to business partners
- Manages the process efficiently on an on-going basis.

Initial Goal: Demonstrate a methodology that satisfactorily models the decision makers' intuitive project prioritization

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Case Study: The Decision Model

Note that “Best Outcome” here is indicative of most impact on business not necessarily most desirable (such as “Loss of Sales)

“Rank” is dependent on “Weight”

Decision Model Name: All Technical Services Projects					
Rank	**Attribute Name**	**Best Outcome**	**Worst Outcome**	**Utility Curve**	**Weight**
1	Compliance Risk (10 is highest)	10	0	50/50	5000
2	Loss of Sales ($mm)	1000	0	40/60	4500
3	Supply Risk (10 is highest)	10	0	38/62	4250
4	Cost ($m)	10	1000	50/50	3900
5	Urgency (5 is most urgent)	5	1	30/70	3500
6	Prob. of Success (10 is highest)	10	0	50/50	3000
7	Resources (Person/Years)	0.1	10	50/50	2000
8	Time to Complete (Months)	1	24	50/50	1500

Indicates shape of Utility Curve

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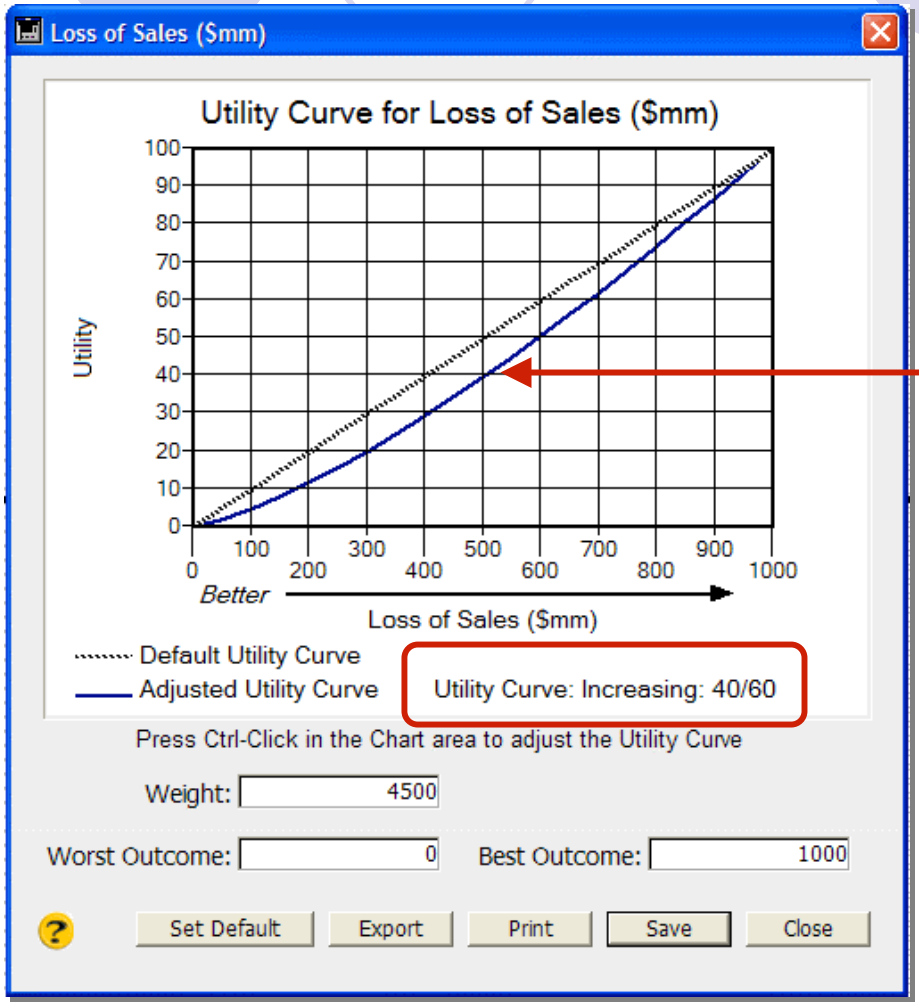
Case Study: The Utility Curves



This curve has been adjusted to reflect an increasing preference for higher loss-of-sales projects relative to the neutral (straight) line. Thus, 60% of utility value is realized above $500mm

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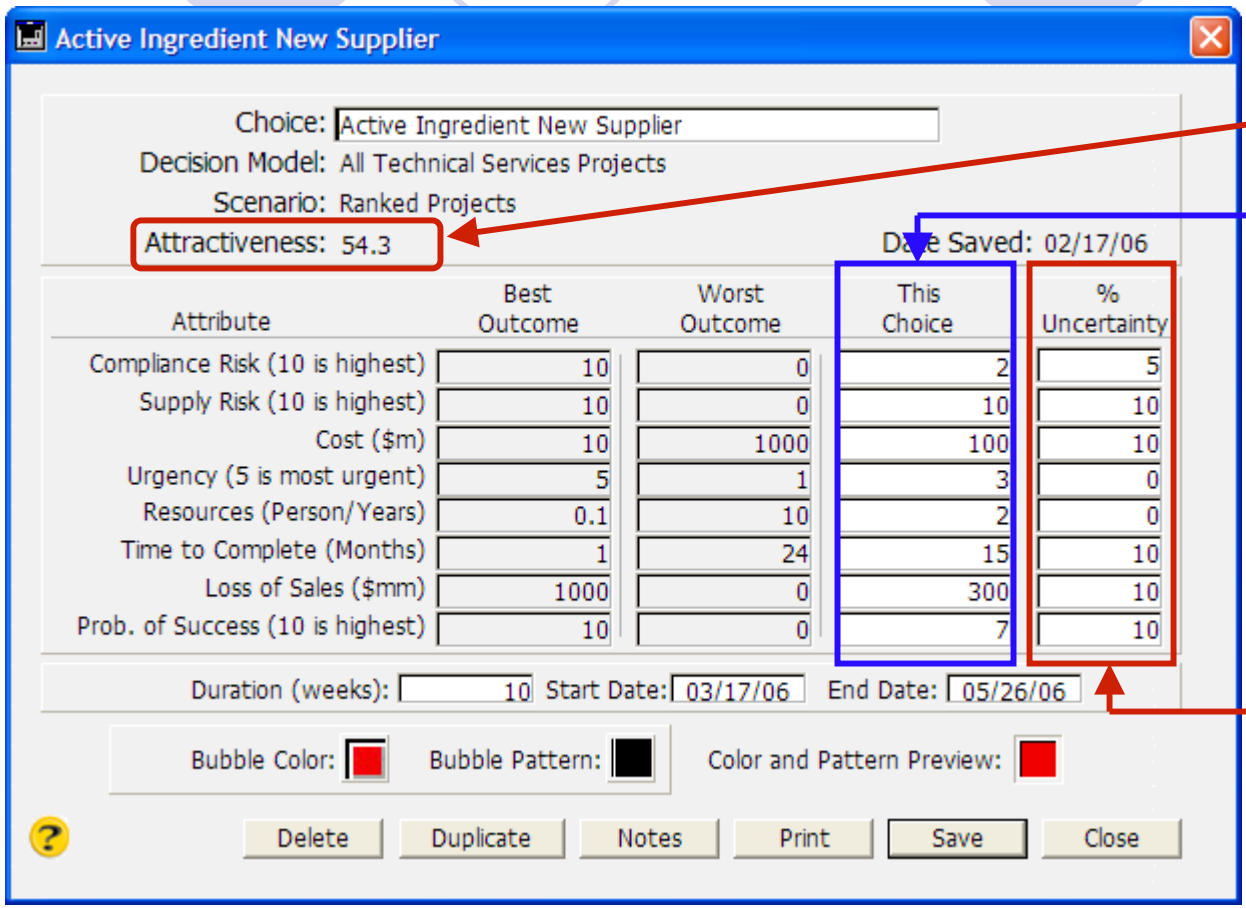
Case Study: Entering Choice Uncertainties



Overall Attractiveness

Actual Choice Values

+/- Percent Uncertainty

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Case Study: The Scenario

Individual attractiveness values

Decision Model Name: All Technical Services Projects										
Scenario Name: Ranked Projects										
Rank	Choice Name	Overall Attract.	Compliance Risk (10 is highest)	Supply Risk (10 is highest)	Cost ($m)	Urgency (5 is most urgent)	Resources (Person/Years)	Time to Complete (Months)	Loss of Sales ($mm)	Prob. of Success (10 is highest)
1	Tablet Stability Investigation	69.8	9.5	8	100	4	1	6	60	9
2	Improve Equipment Flexibility	64.8	7	7	75	5	0.5	2	80	4
3	Batch Failure Investigation	63.5	9	7	90	4	1	9	100	6
4	Review/Revise Labeling Docs	55.7	6	5	200	4	0.5	6	40	8
5	Active Ingredient New Supplier	54.3	2	10	100	3	2	15	300	7
6	Qualification of New Equipment	51.8	0	10	20	3	0.5	12	50	8
7	Documentation System (Approval)	50.8	4	0	10	4	0.25	3	0	9
8	New Tablet Reformulation	39.6	2	3	100	2.5	1	12	10	8
9	Print Logo Changes 10 Products	35.8	0	0	50	1	0.25	6	0	10
10	Batch Processing 2 Products	32.2	1	0	30	1	0.5	6	0	5
	Number of Choices: 10	518.3	40.5	50	775	31.5	7.5	77	640	74

Overall attractiveness of the portfolio
(useful for optimizing against constraints)

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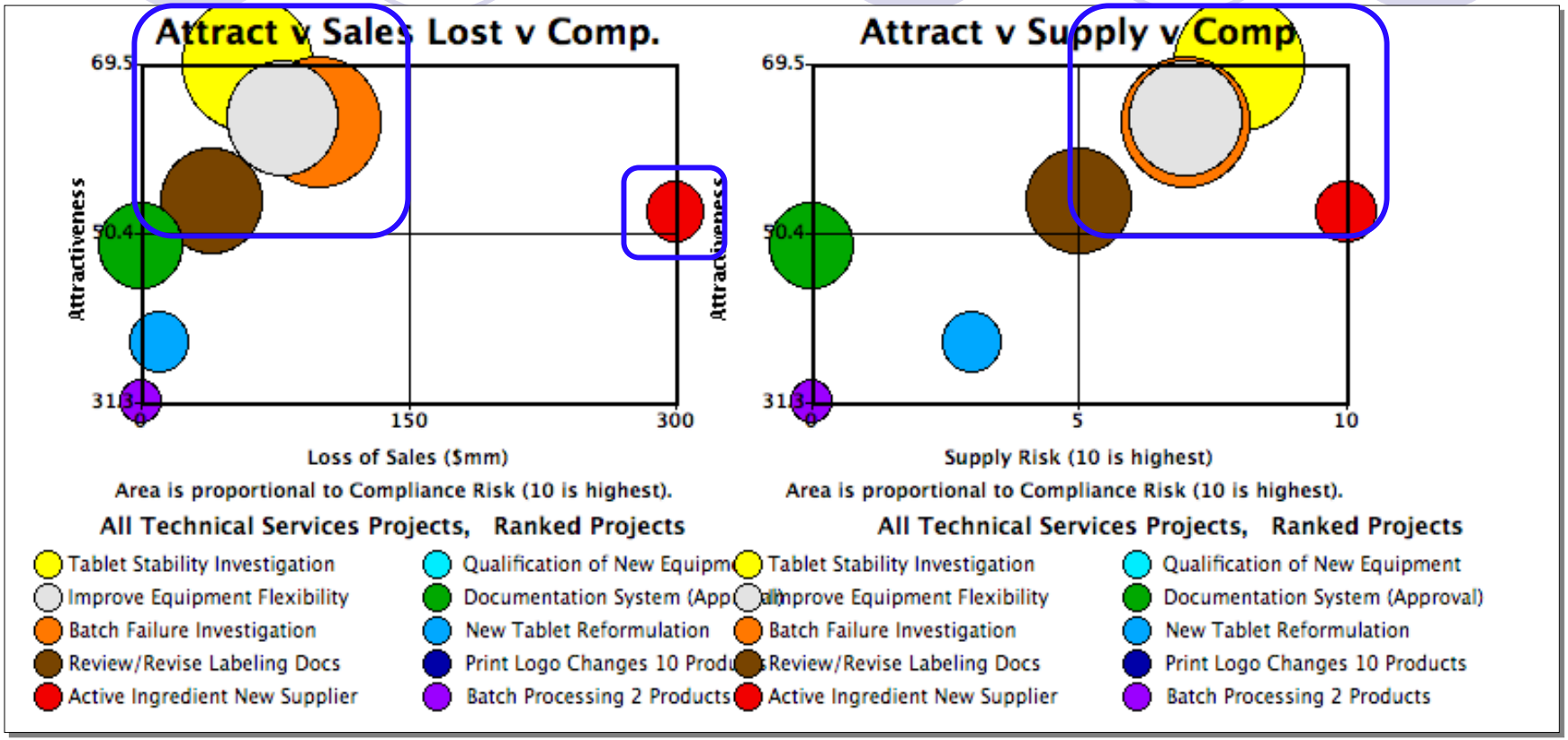
Case Study: Static Model



This model ranked the projects similarly to how the decision makers would have ranked them.

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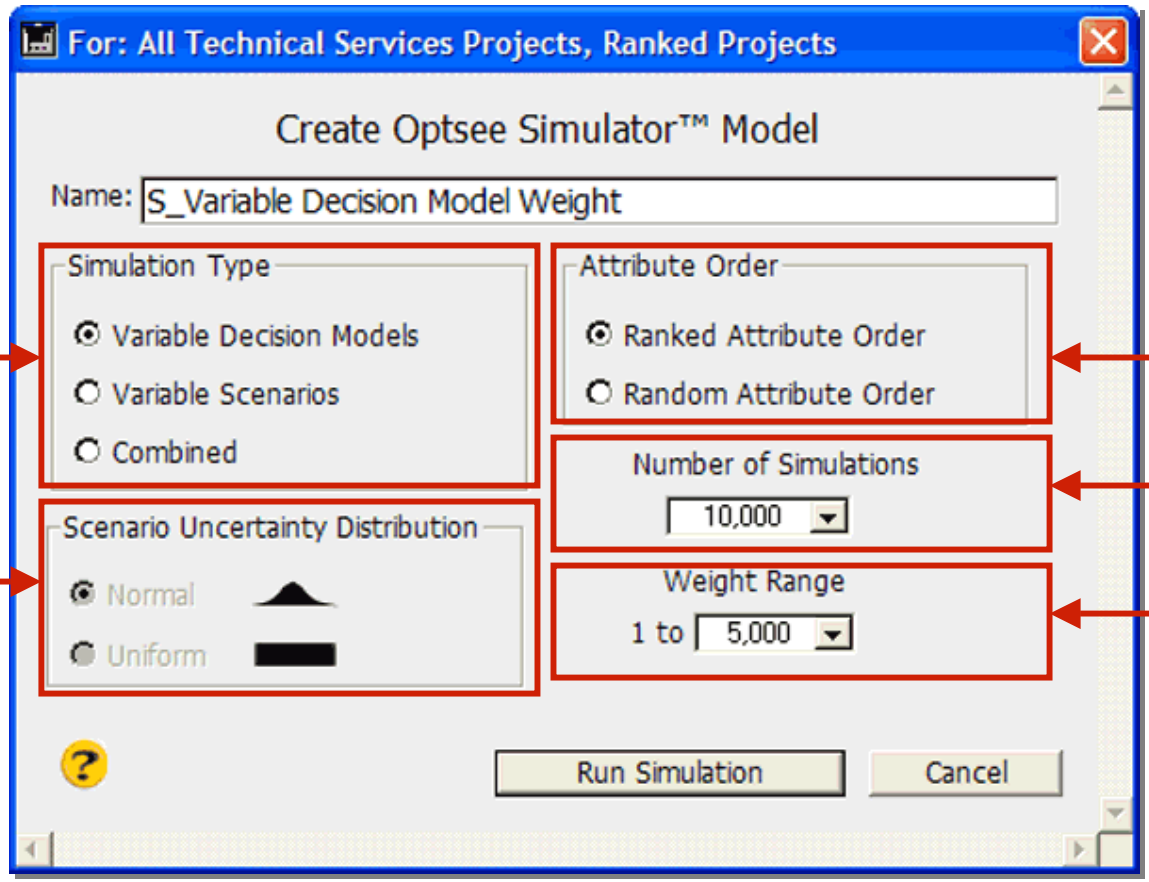
Case Study: Setting-Up A Monte Carlo Simulation



Simulation type

Normal or uniform scenario uncertainty distribution

Fixed or random attribute weight order ("Ranked" maintains the parent decision model order)

Number of tests, up to 100,000

Maximum (highest) attribute weight

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Case Study: Variable Model Weights Results

Average Rank and Standard Deviation

Optsee Simulator[a] Summary Statistics

Simulation Model: S_Variable Decision Model Weight
Number of Simulations: 10,000
Scenario: Ranked Projects
Maximum Weight: 5,000
Simulation Type: Decision Models, Ranked

Rank	Choice Name	Average Rank	Standard Dev. Rank	Highest Rank	Lowest Rank	Cumulative %	Average Attract.	Standard Dev. Attract.
1	Tablet Stability Investigation	1	0	1	1	100	67.8	4.26
2	Batch Failure Investigation	2.04	0.184	2	3	94.4	62.9	3.98
3	Improve Equipment Flexibility	2.96	0.184	2	3	84.6	58.8	3.86
4	Review/Revise Labeling Docs	4.32	0.476	4	6	70.3	48.8	3.8
5	Active Ingredient New Supplier	4.77	0.588	4	6	65.5	45.8	5.13
6	Documentation System (Approval)	6.33	0.626	5	7	49.1	39	5.11
7	Qualification of New Equipment	6.64	0.604	5	9	45.9	37.2	7.5
8	New Tablet Reformulation	7.94	0.236	7	8	32.2	29.2	4.38
9	Batch Processing 2 Products	9.32	0.469	8	10	17.7	21.4	4.46
10	Print Logo Changes 10 Products	9.68	0.467	9	10	13.9	20.5	6.02

Attractiveness values are used in a new scenario

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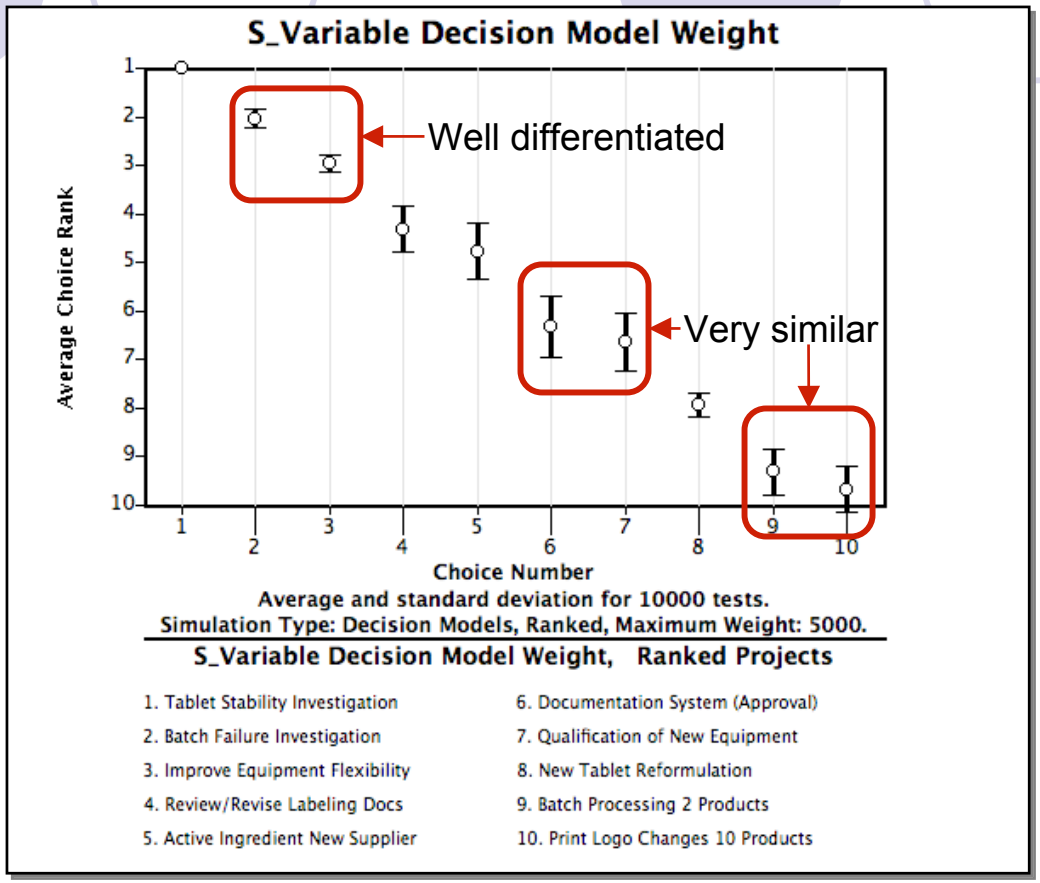
Case Study: Variable Weights Results, 10,000 Tests



This chart displays the average ranking and standard deviation of each project. Six of ten projects switched rankings relative to the “static” model.

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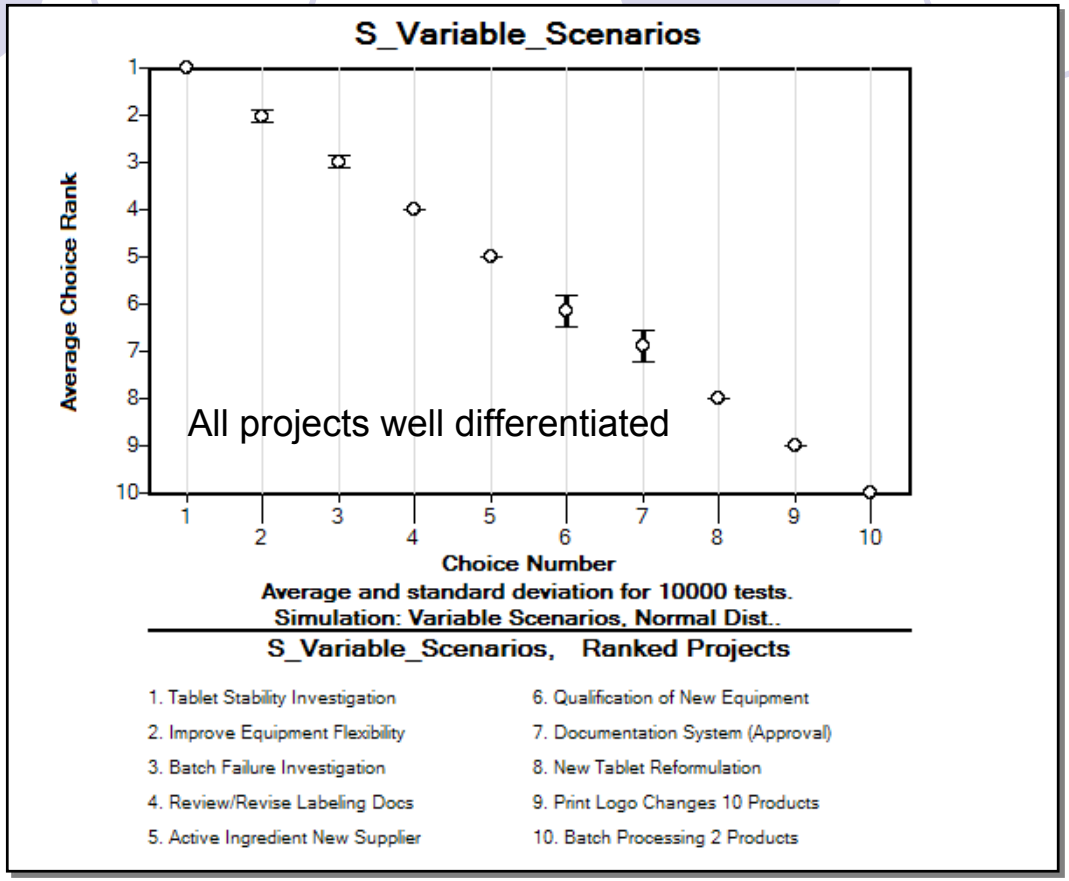
Case Study: Variable Scenarios Results, 10,000 Tests



Project rank order was the same as in the static model - but the standard deviations were very low. Thus, testing a normal distribution over the uncertainty ranges did not impact the project rankings.

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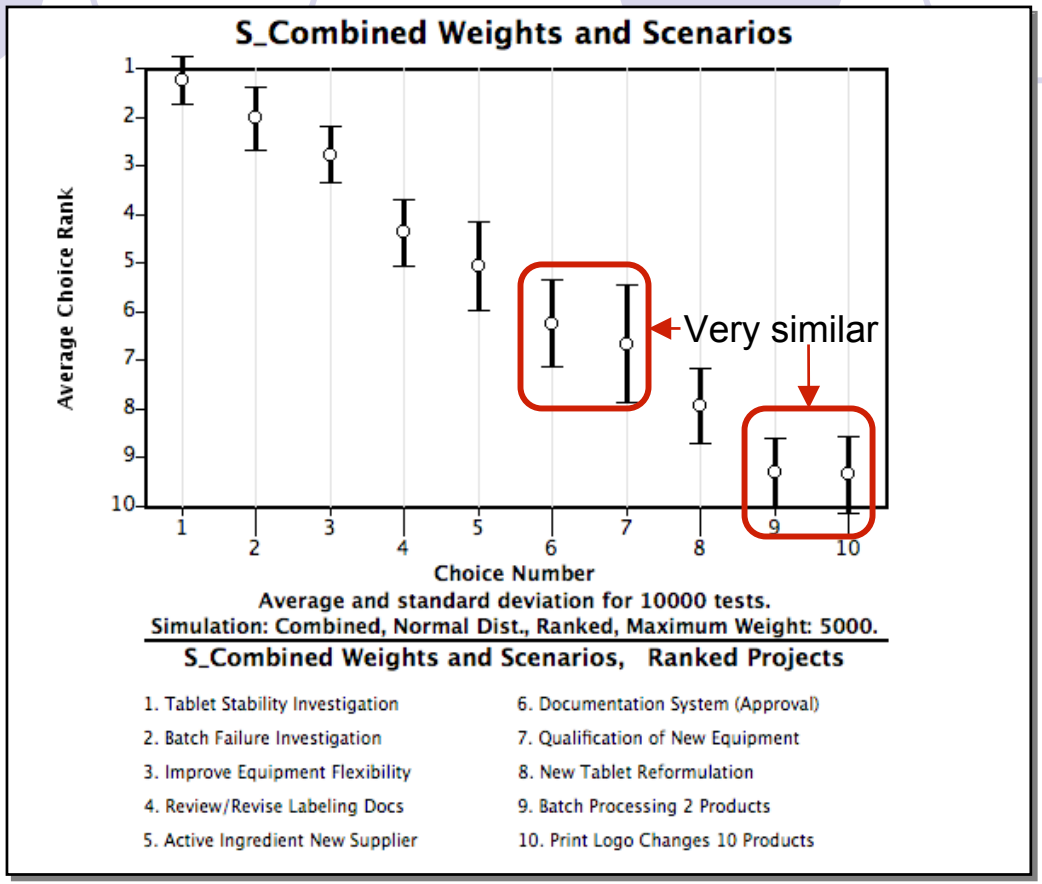
Case Study: Combined Results, 10,000 Tests



Note the larger standard deviations but rank order was the same as the variable weights simulation

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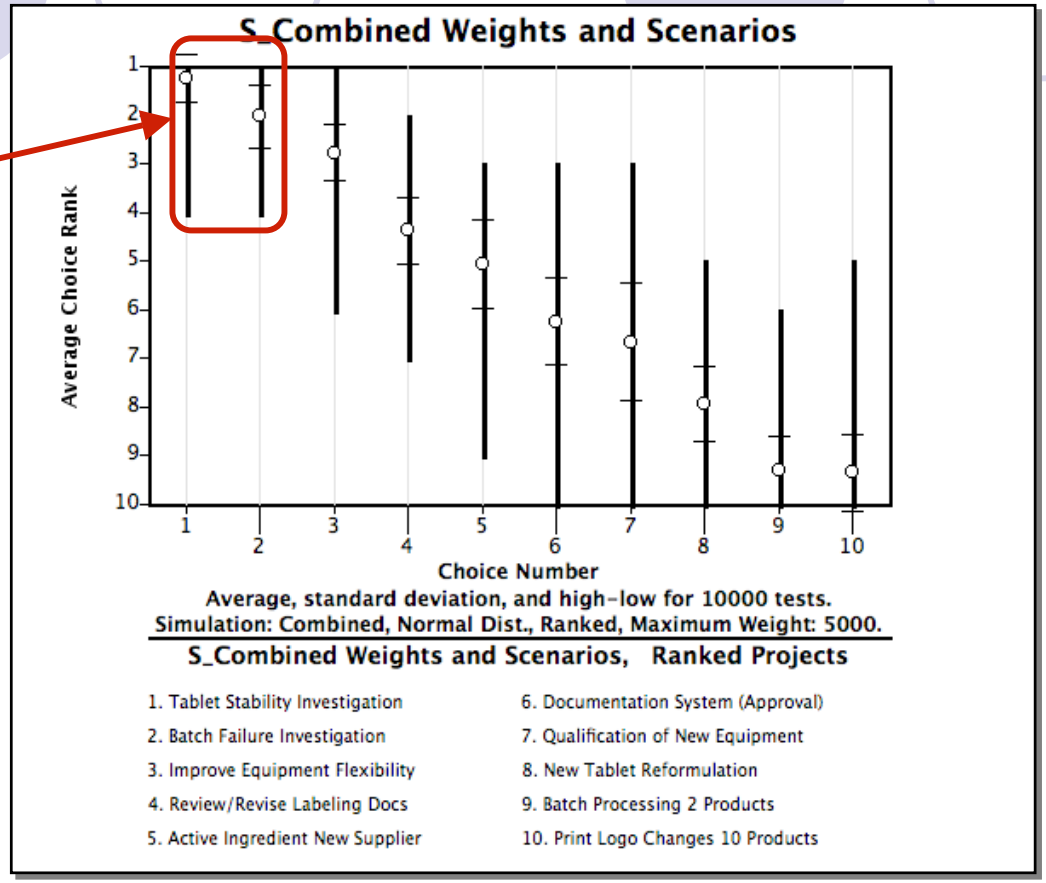
Case Study: Combined Results, 10,000 Tests

Same high and low



High and low are another indication of relative strength, but they can be misleading, so we need to look at cumulative percent rankings.

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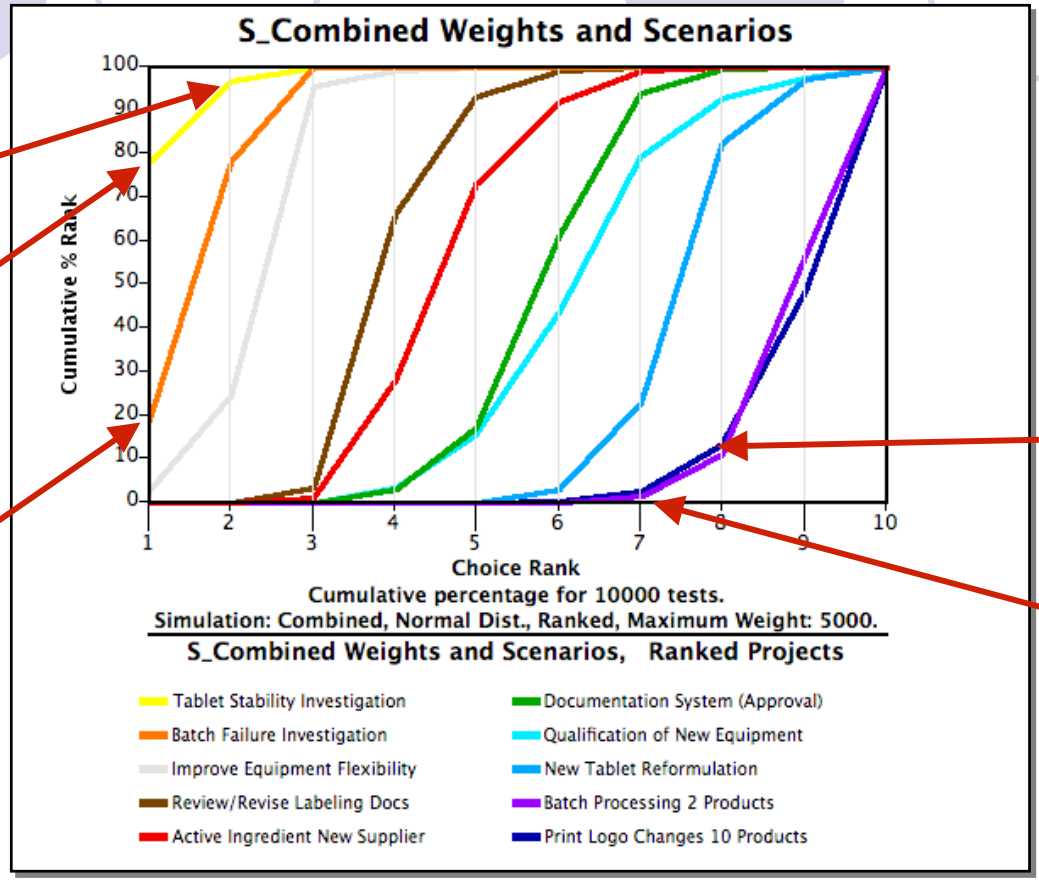
Case Study: Cumulative Percentage Line Chart



Ranked #2 or higher
In ~96% of models

Ranked #1 in
~77% of models

Ranked #1 in
~20% of models

Ranked #8 or higher
In ~12% of models

Ranked #7 or higher
In ~3% of models

This chart provides another indicator of relative project strength by showing the cumulative percentage a project was ranked at a given rank. For example, “Tablet Stability Investigation” was ranked #1 or #2 in ~96% of the 10,000 tests, indicative of a very strong project. The last two projects are essentially identical in attractiveness.

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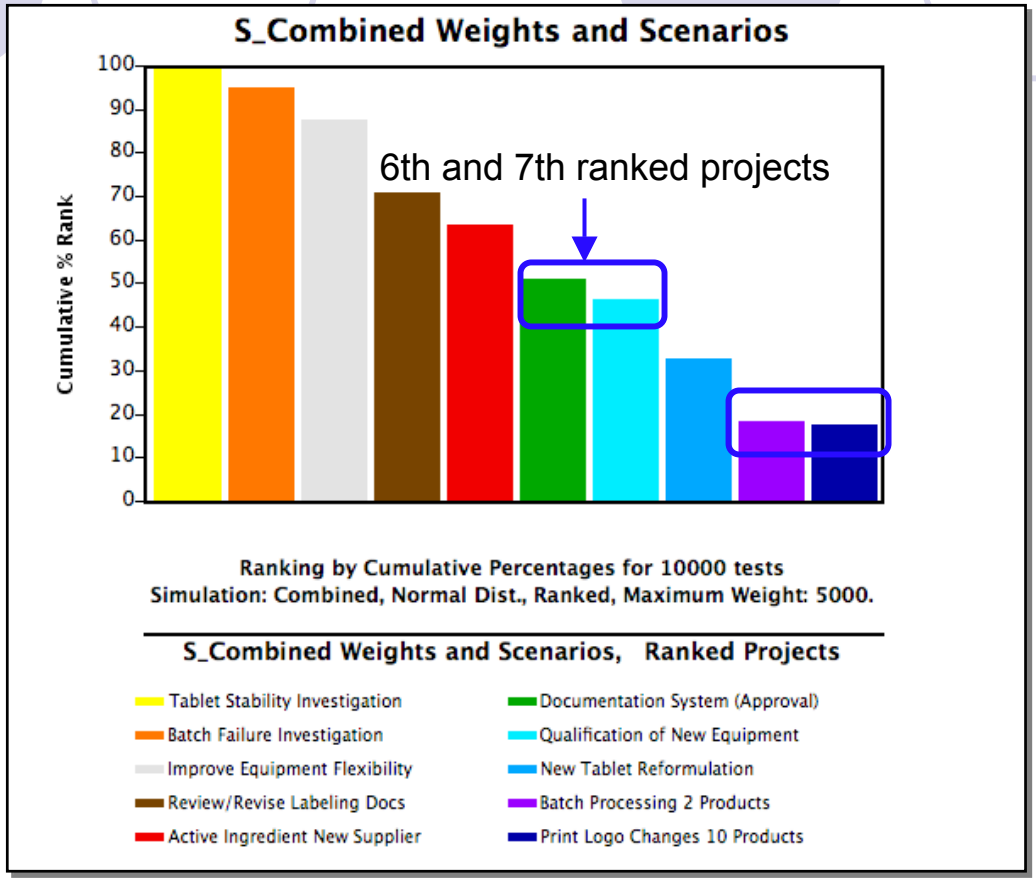
Case Study: Cumulative Percentage Bar Chart



This chart displays the normalized areas under the curves from the cumulative percentage line chart (previous slide). Note that the 6th and 7th ranked projects are much more differentiated than the last two projects

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Case Study: Summary Comparison Table

Choice Name	Static Decision Model Ranking	Variable Decision Models Ranking	Variable Choice Uncertainty Ranking	Combined Decision Models and Uncertainty Ranking
Tablet Stability Investigation	1	1	1	1
Improve Equipment Flexibility	2	3	2	3
Batch Failure Investigation	3	2	3	2
Review/Revise Labeling Docs	4	4	4	4
Active Ingredient New Supplier	5	5	5	5
Qualification of New Equipment	6	7	6	7
Documentation System (Approval)	7	6	7	6
New Tablet Reformulation	8	8	8	8
Print Logo Changes 10 Products	9	10	9	10
Batch Processing 2 Products	10	9	10	9

The decision makers were very satisfied with the results from the combined Monte Carlo decision model, and felt that it would scale well for prioritizing and optimizing the larger 60+ project analysis.

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Case Study: Conclusion

- Both simulation and static models gave satisfactory results
- The decision makers were most comfortable with the combined simulation analysis and results - “easy to test” and “reflects how we would rank them”
- The simulation models were more reflective of their real-life business decision-making
- Provided confidence that the simulation modeling would scale well for optimizing the larger (60+ project) portfolio

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