Consulting Project Assignment Optimization Using Monte Carlo Simulation and Nonlinear Programming

The following hypothetical example combines Monte Carlo Risk Analysis and Nonlinear Programming to optimize the assignment of consultants to projects. This example extends and improves upon another example presented on our Nonlinear Programming page. If you are not familiar with that page, you may wish to go there and read the example before proceeding, because it provides a lot of background detail not presented here. You may also wish first to visit another of our pages that introduces Monte Carlo simulation and provides more background explantion on the technique.

Here is the statement of the original nonlinear programming problem:

Assignment of Consultants to Projects

Consulting Project	Consultants Assigned	Probability Parameter	Success Probability	Profit if Successful	Expected Profit
Merger	10	5.3	0.6536	$750,000.00	$490,196.08
Acquisition	10	3.7	0.7299	$650,000.00	$474,452.55
Turnaround	10	8.4	0.5435	$820,000.00	$445,652.17
Take Public	10	1.1	0.9009	$440,000.00	$396,396.40
Private Buyout	10	3.9	0.7194	$595,000.00	$428,057.55
Total Assigned	50			Total	$2,234,754.76
Total Available	50				

Briefly, the problem requires us to assign up to 50 available management consultants to a total of five recently sold projects. This is a nonlinear programming problem because different projects can benefit more than others from additional consultants above a minumum base of five consultants. The problem begins by assigning the same number of consultants (10) to each project. We then try to optimize the number assigned to each project.

Here is the result of the initial nonlinear programming optimization:

Assignment of Consultants to Projects

Consulting Project	Consultants Assigned	Probability Parameter	Success Probability	Profit if Successful	Expected Profit
Merger	12	5.3	0.6936	$750,000.00	$520,231.21
Acquisition	10	3.7	0.7299	$650,000.00	$474,452.55
Turnaround	14	8.4	0.6250	$820,000.00	$512,500.00
Take Public	5	1.1	0.8197	$440,000.00	$360,655.74
Private Buyout	9	3.9	0.6977	$595,000.00	$415,116.28
Total Assigned	50			Total	$2,282,955.79
Total Available	50				

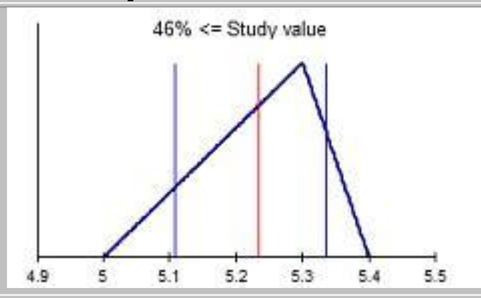
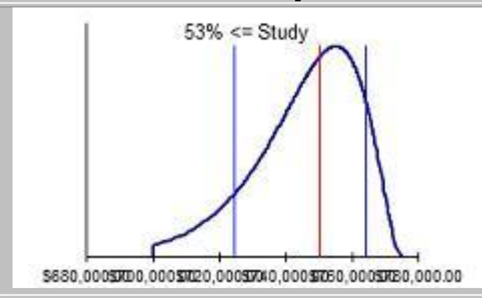
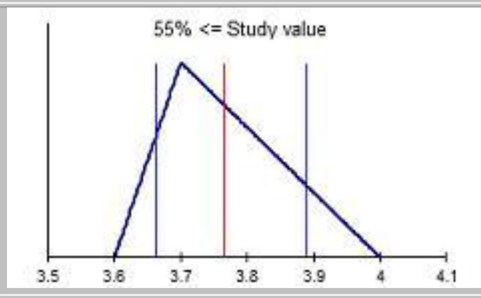
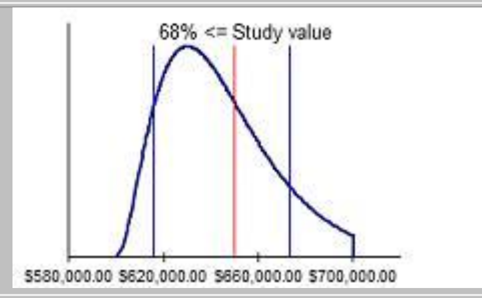
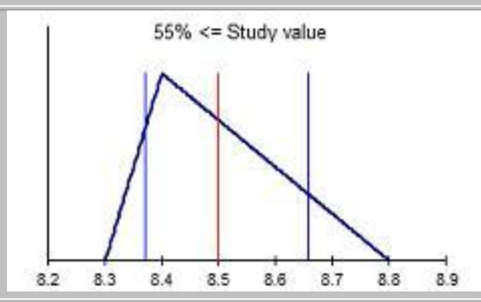
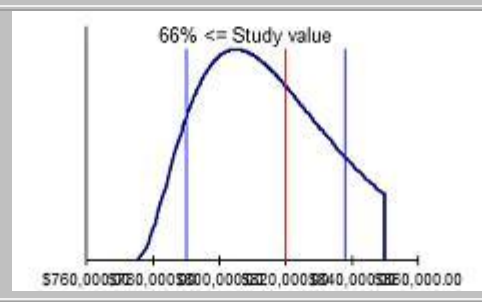
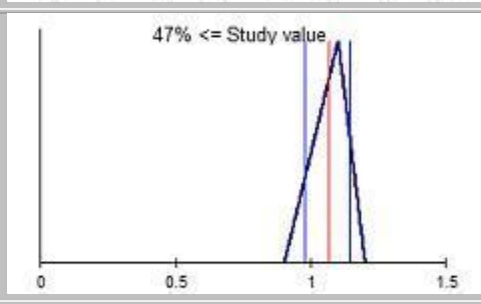
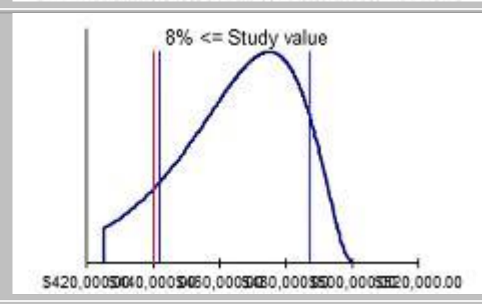
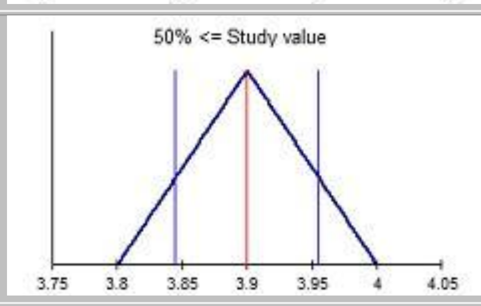
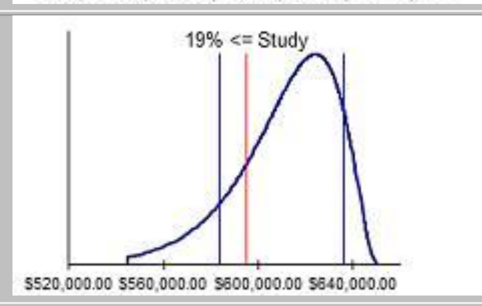
As the table above indicates, we have increased our estimated profit across all projects by nearly $50,000 by adjusting the number of consultants assigned to various projects.

But in reality there is some uncertainty behind the numbers in the table. For example, the "Probability Parameter" in the table is a nonlinear weighting factor that causes changes in the "Success Probability" as a function of changes in the number of consultants assigned to a project. But the "Probability Parameter" is not an exact number; it may vary slightly based on the nature of the project and the consultants assigned to the project, because the past experience that led to the calculation of the Probability Parameter is not identical to the current situation.

Similarly, the "Profit if Successful" number may vary somewhat due to specifics of a current project contract that may be different from previous project contracts on which the estimate is based. Just as we calculate the Success Probability by multiplying the number of consultants assigned to a project by the Probability Parameter, so do we also multiply the resulting Success Probability by the Profit if Successful estimate to arrive at the final "Expected Profit" number for each project.

So we will attempt to model these uncertainties using Monte Carlo simulation before rerunning our nonlinear programming model. We will first create random-variable probability distributions around the "Probability Parameter" and the "Profit if Successful" values in the table above. The shapes of these distributions will depend partly on our past experience with similar types of project, partly on our knowledge of the current client situation and the consulting agreement, and partly on intuition and common sense.

We will construct Triangular probability distributions around each of the five Probability Parameter values; right-skewed Gamma probability distributions around the "Profit if Successful" values for the Acquisition and Turnaround projects; and left-skewed Gamma probability distributions around the "Profit if Successful" values for the Merger, Private Buyout and Take Public projects:

Type of Project	Probability Parameter Distribution	Success Probability Distribution
Merger		
Acquisition		
Turnaround		
Taking Public		
Private Buyout		

[The shape and skew of each distribution is based partly on the tendency for the Taking Public and Private Buyout situations to be somewhat easier consulting engagements than an Acquisition or Turnaround. Also, the Merger situation typically involves working for the smaller of two companies involved in a deal; and traditionally, the stock price delta of the smaller company, on which part of the consulting fee is based, benefits more from a Merger than that of the larger company/acquirer, that typically sees their stock price fall.]

Here is the updated project assignment problem after performing the Monte Carlo risk analyses, that consisted of 2,000 independent simulation runs for each of the 10 cells in the previous table:

Assignment of Consultants to Projects

Consulting Project	Consultants Assigned	Probability Parameter	Success Probability	Profit if Successful	Expected Profit
Merger	10	5.233331911	0.656455204	$746,313.02	$489,921.06
Acquisition	10	3.766668089	0.726392177	$641,920.68	$466,286.16
Turnaround	10	8.5	0.540540541	$812,703.29	$439,299.08
Take Public	10	1.066666135	0.903614501	$466,159.09	$421,228.12
Private Buyout	10	3.9	0.71942446	$612,276.58	$440,486.75
Total Assigned	50			Total	$2,257,221.17
Total Available	50				

Notice the new "expected values" for the Probability Parameter and the Profit if Successful variables. As a result of the Monte Carlo simulation, the initial Total Expected Profit has increased from about $2,235,000 to about $2,257,000. Now we will rerun the nonlinear programming optimization routine on the modified input data:

Assignment of Consultants to Projects

Consulting Project	Consultants Assigned	Probability Parameter	Success Probability	Profit if Successful	Expected Profit
Merger	12	5.233331911	0.696325009	$746,313.02	$519,676.42
Acquisition	10	3.766668089	0.726392177	$641,920.68	$466,286.16
Turnaround	14	8.5	0.622222222	$812,703.29	$505,682.05
Take Public	5	1.066666135	0.824175896	$466,159.09	$384,197.09
Private Buyout	9	3.9	0.697674419	$612,276.58	$427,169.70
Total Assigned	50			Total	$2,303,011.42
Total Available	50				

The optimization solution assigns the consultants to various projects in exactly the same numbers as before, with the Turnaround project getting the most consultants (14) and the Taking Public project getting the fewest (five). So that hasn't changed as a result of the Monte Carlo risk simulation. But the Total Expected Profit is now about $2,303,000. This is an improvement of about $20,000 over the previous optimization result. Notice that the Expected Profit from the Merger project is about the same as before; the Expected Profit from the

Acquisition and Turnaround projects has declined somewhat; and the Expected Profit from the Take Public and Private Buyout projects has increased somewhat.

Conclusion

We have demonstrated the use of Monte Carlo risk simulation in combination with Nonlinear Programming to optimize consulting project assignments and maximize expected total profit. The Monte Carlo simulation has given us more precision in making our estimates, has helped us to manage risk, and has also resulted in an increase in total expected profit. By applying both of these techniques together, we have increased Total Estimated Profit from about $2,235,000 to about $2,303,000. So a few hours of analytic work has increased Total Estimated Profit by about $68,000.