Risk Analysis and Monte Carlo Simulation

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So you're new to the idea of risk analysis, and you've got a lot of questions. What is risk? What do we mean by a "model?" What exactly is Monte Carlo simulation? Is anyone in your industry using this technique? This article is a simple overview to help you to understand what risk analysis is and why Monte Carlo simulation has become an increasingly popular and necessary technique for business analysis and forecasting.

What is Risk?

Uncertainty about a situation can often indicate risk, which is the possibility of loss, damage, or any other undesirable event. Most people desire low risk, which would translate to a high probability of success, profit, or some form of gain.

For example, if sales for next month are above a certain amount (a desirable event), then orders will reduce the inventory, and there will be a delay in shipping orders (an undesirable event). If a shipping delay means losing orders, then that possibility presents a risk.

Thus, there are two points to keep in mind when analyzing risk:
> 1. Where is the risk?
> 2. How significant is the risk?

Almost any change, good or bad, poses some risk. Your own analysis will usually reveal numerous potential risk areas: overtime costs, inventory shortages, future sales, geological survey results, personnel fluctuations, unpredictable demand, changing labor costs, government approvals, potential mergers, pending legislation.

What is a model?

Once you have identified the risks, a model can help you to quantify them. Quantifying risk means putting a price on risk, to help you decide whether a risk is worth taking. For example, if there is a 25% chance of running over schedule, costing you a $100 out of your own pocket, that might be a risk you are willing to take. But if you have a 5% of running over schedule, knowing that there is a $10,000 penalty, you might be less willing to take that risk.

One very popular modeling tool is a spreadsheet such as Microsoft's Excel. If you only use spreadsheets to hold data--sales data, inventory data, account data, etc., then you don't have a model. Even if you have formulas that total or subtotal the data, you might not have a model.

A model is a spreadsheet that has taken the leap from being a data organizer to an analysis tool. A model represents a process with combinations of data, formulas, and functions. As you add cells that help you better understand and analyze your data, your data spreadsheet becomes a spreadsheet model.

SPREADSHEET RISK ANALYSIS

Identifying risks in your spreadsheet

So now you realize that you either have a model or need to create one. You might notice that your model has some values in it that you are unsure of. Perhaps you don't have the actual data yet (this month's sales figures) or the value varies unpredictably (individual item cost).

For each component, or variable, of the model (e.g., costs, rates, demands), you can ask yourself, "How sure am I of this value? Will it vary? Is this a best estimate or a known fact?" Since you constructed the model, you will probably be quick to identify which variables are uncertain. This

lack of knowledge about particular values, or the knowledge that some values may always vary, helps you to identify your risks.

The traditional modeling landscape
Traditionally, spreadsheet analysis tried to capture this uncertainty in one of three ways: Point estimates, Range estimates, and What-if scenarios.

Point estimates are when you use what you think are the most likely values (technically referred to as the mode) for the uncertain variables. These estimates are the easiest, but can return very misleading results. For example, try crossing a river with an average depth of three feet. Or, if it takes you an average of 25 minutes to get to the airport, leave 25 minutes before your flight takes off. You will miss your plane 50% of the time.

Range estimates typically calculate three scenarios: the best case, the worst case, and the most likely case. These types of estimates can show you the range of outcomes, but not the probability of any of these outcomes.

What-if scenarios are usually based on the range estimates and calculate as many scenarios as you can think of. What is the worst case? What if sales are best case but expenses are the worst case? What if sales are average, but expenses are the best case? What if sales are average, expenses are average, but sales for the next month are flat? As you can see, this form of analysis is extremely time consuming, and results in lots of data, but still doesn't give you the probability of achieving different outcomes.

The problem with spreadsheets
A good spreadsheet model can be helpful in identifying your risks since cells with formulas and cell references identify causal relationships among variables. One of the drawbacks of conventional spreadsheets, however, is that you can only enter one value in a cell at a time. A spreadsheet will not allow you to enter a range of values or multiple values for a cell. Therefore, to perform range or what-if estimates, your only alternatives are to manually play with the model or create multiple versions of the model.

What you are looking for then is a better way of representing the range of uncertain values, your obvious risks, and a quicker method of generating multiple model outcomes that you can analyze. This is where Monte Carlo simulation comes in handy.

WHAT IS MONTE CARLO SIMULATION?

What do we mean by "simulation?"
When we use the word simulation, we refer to any analytical method meant to imitate a real-life system, especially when other analyses are too mathematically complex or too difficult to reproduce. Monte Carlo simulation is a form of simulation that randomly generates values for uncertain variables over and over to simulate a model.

Without the aid of simulation, a spreadsheet model will only reveal a single outcome, generally the most likely or average scenario. Spreadsheet risk analysis uses both a model and simulation to automatically analyze the effect of varying inputs on outputs of the modeled system. Because spreadsheets themselves cannot run simulations, you will need a spreadsheet add-in to provide this functionality. One available simulation add-in for Excel is Crystal Ball 2000, which will be used in this example.

How did Monte Carlo simulation get its name?
Monte Carlo simulation was named for Monte Carlo, Monaco, where the primary attractions are casinos containing games of chance. Games of chance such as roulette wheels, dice, and slot machines, exhibit random behavior.

The random behavior in games of chance is similar to how Monte Carlo simulation selects variable values at random to simulate a model. When you roll a die, you know that a 1, 2, 3, 4, 5, or 6 will come up, but you don't know which for any particular roll. It's the same with the variables that have a known range of values but an uncertain value for any particular time or event (e.g. interest rates, staffing needs, stock prices, inventory, phone calls per minute).

Modifying the uncertain variables in your spreadsheet?

For each uncertain variable, Crystal Ball lets you define the possible values with a probability distribution. A distribution is an equation that describes shape and range that represent the natural uncertainty around the input value. The type of distribution you select is based on the conditions surrounding that variable. Distribution types include:

For example, in the dice example above, you are equally likely to roll a 1, 2, 3, 4, 5, or 6, so you would select a uniform distribution, which is an equation that states that each outcome is equally likely. Products like Crystal Ball 2000 can automatically create distributions for you so that you do not need to know the formal equation.

What happens during a simulation?

When you run a simulation, the software repeatedly samples values from the distributions and thus calculates multiple scenarios. During a single simulation, or trial, Crystal Ball randomly selects a value from each of the distributions and enters it into the proper spreadsheet cell. Excel then recalculates the spreadsheet, which displays a new scenario. Depending upon the complexity of your model, a program like Crystal Ball can run hundreds or even thousands of trails in minutes.

Analyzing Simulation Results

For every model, you have a set of important outputs, such as totals, net profits, or gross expenses, which you want to analyze. Crystal Ball lets you define those cells as forecasts, and the program saves the simulated values of each forecast cell for later analysis. For example, if you simulate a model for 1000 trials, and you have Net Profit selected as a forecast, you will have 1000 Net Profits to analyze at the end of the simulation.

During the simulation, you can watch a histogram of the results develop for each forecast. While the simulation runs, you can see how the forecasts stabilize toward a smooth frequency distribution. After hundreds or thousands of trials, you can view the statistics of the results (such as the mean forecast value) and the certainty of any outcome.
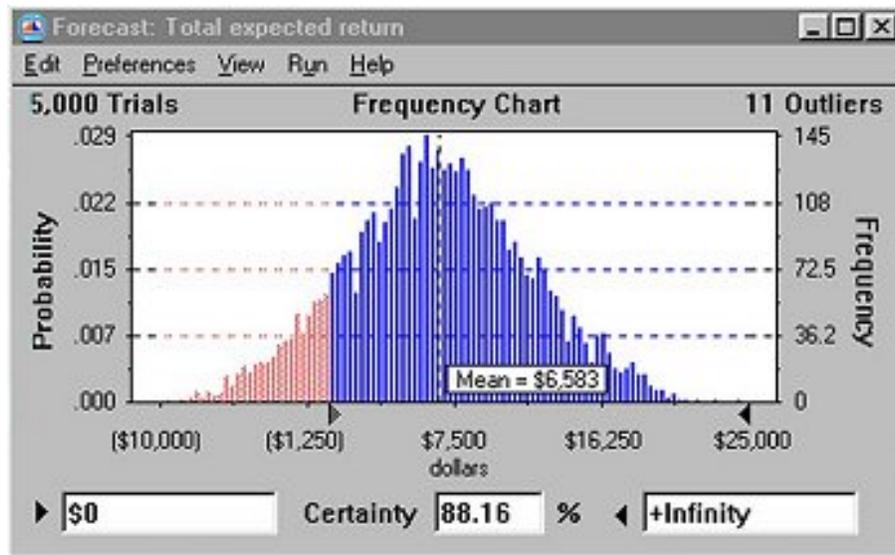
Certainty is the percent chance that a particular forecast value would fall within a specified range. The example above is a forecast for Total expected return. You can find the certainty of breaking even (results better than $0) by entering the $0 amount as the lower limit. Of the 5000 trials that were run, 4408 (or 88.16%) of those had a positive total expected return, so your certainty of breaking even is 88.16%.

The Benefits of Monte Carlo Simulation

As you can see from the above example, simulation can result in a far more rigorous analysis in far less time. Not only does simulation allow you to determine the certainty of a specific outcome, it can help you to understand the range of possible outcomes. After analyzing your results, you can begin to challenge and refine your basic model assumptions, resulting in more accurate risk forecasts. Simply put, with a richer understanding of your inherent risks, you have a higher probability of achieving success.

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