

New Horizons in Predictive Modeling and Risk Analysis:

*How the Monte Carlo Method is Turning the Ordinary
Spreadsheet into a Powerful Decision-Making Tool*

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ABSTRACT

Risk analysis aims to quantify life's fundamental uncertainty. It also speaks to our tireless drive to understand the principles underlying that uncertainty. Across business, science, engineering—and life itself—we are always seeking more control and less risk in our decision-making, and so we constantly innovate and improve on risk-analysis methods. As a result, we now have ingenious tools to help us analyze, forecast, and manipulate risk and, ideally, turn it to our advantage.

Recent dramatic gains in computer performance have revolutionized risk analysis, giving desktop-based software the ability to perform predictive modeling feats once reserved for supercomputers. This leap forward in sophisticated risk and simulation analysis, using familiar spreadsheet software, has transformed decision-making at all levels of the enterprise. Today's spreadsheet modelers now have robust tools at their command to guide a decision-maker smoothly and confidently through the densest thicket of options.

Real-time simulation and risk-analysis intelligence work in diverse environments, delivering the ability to communicate models and their conclusions enterprise-wide at the click of a mouse. Such tools have not replaced intuition and experience in decision-making, but rather marry these intangibles with mathematical modeling to yield a deeply insightful spectrum of potential outcomes and choices. Simulation analysis has always been critical to accurate, informed corporate decision-making; only now it has become not only mathematically sophisticated, but simple to obtain and employ and easily affordable.

Willingness to take risks is integral to competitiveness, profitability and even survival in today's dynamic, unrelenting business environment. This white paper explores the latest capabilities and applications that enable predictive modeling, as well as the role of innovative software tools in supporting informed, reliable and productive business decisions.

PREDICTIVE MODELING: MOVING BEYOND THE SPREADSHEET TO IMPROVE RISK ANALYSIS AND DECISION-MAKING

Whether addressing strategic plans across a decade or making monthly departmental hiring decisions, the advantages of predictive modeling hold true across nearly every industry—aerospace, financial services, manufacturing, oil and gas, pharmaceutical, utilities, and more. Any industry that relies on performance management and business intelligence improves its decision-making process by using predictive modeling, with its quick, verifiable results and unlimited breadth of scenarios.

Now, the merging of risk analysis software with the spreadsheet interface opens a new horizon of functionality in analyzing potential outcomes. The spreadsheet is an ideal vehicle for predictive modeling, forecasting, simulation and optimization, thanks to its convenience, familiarity and ease-of-use. As such, it offers the potential to empower all manner of professionals in applying sophisticated modeling techniques to their respective challenges. Now they can visualize a broad range of nuanced results to guide them in choosing the best course of action, or to respond to a trend or challenge with a higher chance of successful outcome.

Risk analysis and predictive modeling are far superior to conventional “min/max” estimates when it comes to defining an accurate and pertinent range of possible outcomes. And automating this process surpasses multiple manual “what if” type forecasts to deliver deep insight into factors driving variation and uncertainty. Predictive modeling reduces the time required to produce useful forecasts and knowledgeable decisions about where to focus resources. Perhaps most importantly, modeling is completely objective, relying on the verifiability and disinterestedness of the computer to support decision-makers in evaluating the risks and benefits of respective courses of action.

The following steps might comprise a workable sequence in developing a computerized risk-evaluation strategy:

1. Identifying risk exposures
2. Measuring these exposures
3. Building a risk model
4. Defining risk-taking and risk retention activities
5. Aggregation
6. Effectiveness testing
7. Ongoing risk-monitoring, management, and control

The Monte Carlo Method: Driving Success in Predictive Modeling

The Monte Carlo method of predictive modeling originated in the work of S. Ulam and Nicholas Metropolis, who derived their initial theory by observing games of chance—roulette wheels, dice, slot machines and so forth—in the glittering casinos

of Monte Carlo, Monaco. The Monte Carlo method models the role of chance in the data generation process, using random numbers and probability to solve problems. People create an artificial model of a real-life system and then simulate, or run, any number of potential scenarios to enable study and deeper understanding. The Monte Carlo method can simulate dauntingly complex phenomena such as global weather patterns and atmospheric radiation—just as it can evaluate the wisdom of buying versus leasing a car or other common financial decisions.

Monte Carlo simulation enables direct observation of the choices, patterns, and potential outcomes that inform lower-risk courses of action. The process helps us understand the properties of statistics computed from sample data, even as it tests and proves various “recipes” under differing circumstances. Change the parameters—and you literally create a different world. In the past, only the highest-performance computers had the power to carry out such volume calculations. Today, people can see instant results on the desktop, adding unprecedented insight and accuracy to decision-making.

The Monte Carlo Method in Action: Handling Life’s Uncertainties

When users employ the Excel spreadsheet in its customary way to inform response variables, this process is *deterministic*. In other words, it yields the same results, no matter how many times figures are re-calculated.

Alternatively, the Monte Carlo method of simulation *iteratively* or repetitively evaluates a model, using sets of defined random numbers as inputs. If a model is complex, nonlinear, or involves more than a few uncertainties, a Monte Carlo simulation can handle thousands of scenarios with subtle shades of variation. This *stochastic*, or probabilistic, analysis more truly reflects our complex world and generates a more accurate view of the truth.

Because the Monte Carlo method enables analysis of lifelike uncertainty, it is a far superior way to express how random variation, lack of knowledge, or outright error can affect the performance or reliability of a system, or the wisdom of a decision. In Monte Carlo simulation, inputs can be randomly generated from probability distributions to simulate samples from an actual population. Inputs that most closely map to known data or that represent the most accurate knowledge available are far more likely to yield useful results.

Applications for Risk Analysis Span Nearly Every Major Corporate Function, Including:

- **Corporate budgeting and planning analysis**
- **Budgetary cost projections**
- **Cost estimate projections**
- **Financial forecasting and cost analysis**
- **Project and business sensitivity analysis**
- **Risk analysis for strategic decisions**
- **Stock performance projections**

Applying the Monte Carlo Method to the Real World

Predictive models can forecast a variety of events; for example, future share prices, credit defaults, insurance claims, customer product-ordering preferences, and so on. For the insurance industry, for example, the Monte Carlo method enables development of models that calculate the probability of claims resulting from annual policy applications. For credit companies, the Monte Carlo method dynamically shapes decision-making about the wisdom of each lending decision and likelihood of default, based on data collected from past customer loans and factoring in the demographics and unique financial information of each new borrower.

For marketing purposes, the Monte Carlo method helps companies develop programs targeted toward ideal customers, based on records of past customer behavior and any other factors the marketers may wish to add into the mix. They can also predict potential customer churn on the basis of past customer information and help marketers design retention programs to pre-empt or repair such damage.

Key Factors in Performing Successful Predictive Modeling

One factor crucial to predictive analysis is the availability of useful data. Such data can be extracted from historical information, assembled by sampling survey statistics, or in various other ways. With usable, quality data to fill the predictive application domains, users can develop accurate models quite easily. Some industries generate data that is ideal for predictive analytics—insurance, credit finance, and direct marketing, to name a few.

Sometimes however, the historical data needed to define a distribution or to forecast a data series such as software sales may be incomplete for many reasons. Under these circumstances, a powerful advantage in Monte Carlo simulation is that even when data is partial, missing, or estimated, one may still create distributions to represent the uncertainty or variability around the model input. With some conventional wisdom or defined rough limits from a subject matter expert, a user can still describe the ranges and likelihood of unknown factors in the model and derive useful results.

Another—sometimes critical—factor in carrying out successful predictive modeling is the intuition or insight driven by experience; in other words, the human factor. The same logic that says you cannot learn to drive a car without at some point actually sitting in the car and turning it on also applies to predictive modeling as well. Processes are performed by software tools that can learn patterns from data, but they cannot yet apply patterns with human insight and intelligence.

Senior executives are hired to make major decisions in the face of uncertainty, and taking responsibility for outcomes is integral to the job. Supportive techniques and tools to help executives calculate outcomes of various scenarios have existed for years, and the Monte Carlo method is one of the most sophisticated and accurate of these. Ironically, however, senior executives are notorious for not availing

themselves of sophisticated technology tools. Often they simply do not understand how to use them; perhaps the software is perceived as too “mathematical” or complex for non-statisticians. They may feel that applications are “cold” and cannot reflect the gut reaction that so many executives pride themselves on and trust.

Such negative attitudes can result in needless waste and difficulty, such as unwise investments made or smart ones overlooked. Persisting in failed strategies or stubbornly relying on suboptimal information can result in headline-making negative results. For example, based on his considerable experience and understanding of the entertainment industry, Hollywood super-executive Lew Wasserman turned down the opportunity to produce the *Star Wars* series when it was initially offered to him by George Lucas. One must wonder what business decision Wasserman would have made had he had the advantage of predictive modeling software to inform his decision and been flexible enough to use it.

Closer to our time, highly respected firm Bessemer Venture Partners lists on its own [site](#), fifty opportunities “to completely screw up” by passing on such startups as Apple Computer, FedEx, eBay and Google. “Our reasons for passing on these investments varied. In some cases, we were making a conscious act of generosity to another, younger venture firm, down on their luck, who we felt could really use a billion dollars in gains. In other cases, our partners had already run out of spaces on the year's Schedule D and feared that another entry would require them to attach a separate sheet.”

For these sorts of reasons, it is crucial that managers be educated about the advantages of predictive modeling software and be open minded about the true risks and limitations of relying on intuition alone. Thanks to its familiarity, ease of use, and pervasiveness, Excel is an ideal means for allaying and reducing executive resistance to automated or mathematical risk analysis. Executive resistance needn't play out amid costly error when such intelligent tools as the Monte Carlo method are available to support informed, intelligent decision-making. The simple Excel spreadsheet can help to bring about new levels of accuracy and positive outcomes that benefit global enterprises and the economies of whole regions.

Risk and Uncertainty in the Business Model

Uncertainty itself contains volumes of relevant information to those capable of mining and using it. Ignoring the workings of uncertainty can raise risks and expose an organization to failure, but using the right tool set; absorbing and then employing the knowledge it delivers can help assure a successful outcome. To perform successful risk analysis, uncertainty must be quantified and expressed accurately, whether the challenge is creating a business case, determining pricing, calculating VaR or NPV, estimating future costs, forecasting demand, or assessing the financial risks in new ventures and proposals. With uncertainty factored in, one is in a much stronger position to make the best decisions.

Components of risk analysis include sensitivity analysis, correlation, historical data fitting and optimization. **Sensitivity analysis** helps to clarify the most relevant

input variables. **Correlation** allows linking of uncertain inputs and accounting for their positive or negative dependencies. **Historical data fitting** compares that data to the distribution algorithms and calculates the best possible fit and parameters. **Optimization** accommodates risk and uncertainty but still allows for choosing optimal settings, such as staffing levels, investment amounts, and product prices.

Using the Spreadsheet to Perform Sophisticated Simulation

The ability to use a spreadsheet for performing advanced analysis would greatly help a company to create accurate cost and financial predictions and make intelligent decisions. An Excel-based tool that can perform Monte Carlo simulation, optimization, and forecasting would be ideal. But since Excel does not have the capability to run and analyze stochastic simulations, it takes another dimension of functionality, provided by a program such as Oracle's Crystal Ball (formerly Decisioneering, Inc.), to make Excel truly relevant to the chaotic, uncertain world. Since 1986, this company has been providing decision analysis software and solutions that empower individuals and organizations to make accurate decisions.

A Crystal-Ball enhanced Excel spreadsheet enables users to replace min/max estimates with a more relevant range of all possible outcomes; reduce the time required to produce estimates; eliminate multiple manual "what if?" estimates; mitigate cost and schedule risks; gain immediate insight to the driving inputs and output variations; make knowledgeable decisions on where to focus resources; and provide decision-makers with the confidence to take risks based on insight, experience—and mathematical probabilities.

Enhancing the Capability and Accuracy of Excel in Representing the Real World

Crystal Ball profoundly enhances the range and capabilities of Excel by replacing static single values with dynamic probability distributions and random model simulation.

Monte Carlo simulation has proven itself to be an extremely reliable method when fed random numbers—mathematically selected values—that conform to a probability distribution. The result is a major leap beyond basic Excel into a dynamic spreadsheet with quantifiable outcomes, deep insights, and immense potential advantages—such as the ability to calculate a ten-percent probability of staying under budget or to predict with ninety-percent certainty that a reservoir contains 100 million barrels of oil.

The seemingly random behavior that characterizes games of chance resembles the way Monte Carlo simulation selects variable values at random to simulate a model. Each time a die is rolled, for example, any number can come up, but nobody knows which number for any particular roll. So variables with a known range of values that are uncertain for any specific time or event—such as stock prices or phone calls per minute—can create multiple scenarios, which can be analyzed to inform a

spreadsheet model. Correctly applied, Monte Carlo simulation delivers unrivaled insight that deterministic models cannot approach.

How it Works: Integration of Computing and Spreadsheets to Calculate and Communicate the Certainty of Any Outcome

Crystal Ball is an example of an easy-to-use add-in, which is designed to help all levels of Excel users perform simulation, modeling, optimization, and forecasting to predict and reduce the effects of variation. Users are able to easily define probability distributions on uncertain model variables, and to generate random values from within the defined probability ranges. They can then create and analyze thousands of potential scenarios and quantify the level of risk for each and every one of them. Crystal Ball can be applied to existing or new spreadsheet models, and the enhancements provided by this tool do not alter the formulae or functions of the original spreadsheet.

In Crystal Ball, probability distributions are referred to as “assumptions” and are the basic inputs used to define the uncertainty in any model variable. The best way to identify which variables to convert from single values to probability distributions is to decide which variables are known and which are “soft” and uncertain.

With Crystal Ball, a user first creates a valid, verifiable deterministic model that represents the most likely scenario. Input might consist of budget figures, discounted cash flows, supply chain forecasts, product demand, project cost estimates and so forth. In gathering data for a model, a user adds assumptions and forecasts according to the most desirable risk analysis forecast. Using such techniques as cell referencing as a best practice offer a simulation model the greatest transparency and ease of management.

Crystal Ball then fits continuous distributions to available data and defines correlation coefficients between related pairs of assumptions. With assumptions defined based on a user’s own knowledge and intuition, the more one knows about a variable, the more accurate the distribution becomes.

During a simulation, Crystal Ball runs as many trials requested and saves forecast values for later analysis. As the simulation begins and the forecast (or frequency) chart builds, users can see the spreadsheet values change with the insertion of randomly generated values (from the probability distributions) into the assumption cells. Decision-makers can now evaluate courses of action instantly based on their individual levels of risk-tolerance and potential outcomes. Rather than communicating one value for the result, the program allows results to be expressed in fine-grained ranges. Decision-makers can then judge whether a current process is acceptable vis a vis risk tolerance—or perhaps reduce variability in some process steps to meet more stringent risk requirements. By changing the variation in the assumption and running the simulation again, forecast results change. Changing the parameters of the dominant step(s) may improve the certainty of achieving a performance target to 90% or better.

CUSTOMER STUDY: DEVELOPING A RISK-MANAGEMENT PROCESS

Huybert Groenendaal, PhD, MBA, MSc, is a partner at Vose Consulting, a company that conducts risk analysis for clients using the Monte Carlo method and, frequently, Oracle Crystal Ball. Dr. Groenendaal described the experience of a company that Vose has worked with for at least two years that has evolved “from being very skeptical initially to fully embracing the Monte Carlo approach.” This S&P 500 company, whose line of business is oil and gas, instituted and now maintains a comprehensive risk management department as a result of its experience with the Monte Carlo process.

The client company constructs very large, high-value, high-investment pipelines spanning hundreds of miles across complex geographies. Naturally, such a company would want to know all it can about risk and the multitudes of factors affecting the financial success and timeliness of construction. The company’s own customers are heavily invested in the process and in finishing it within budget and time frame, i.e. before winter starts.

“Initially, this company had no experience with the Monte Carlo process,” says Dr. Groenendaal. “They proposed a ‘risk-free’ experiment to evaluate our offering.” The company was in the process of completing a large pipeline project. They wished to see, in retrospect, how a Monte Carlo method analysis, using Oracle Crystal Ball software, would have functioned for the project post facto. Providing the Vose team no information as to the actual (confidential) final figures or outcome of the project, the company challenged Vose to “predict” the potential of this project to successfully meet its budget. The information given to Vose was that which was available to the oil and gas company before it started the project.

“We sat down with their engineers, cost estimators, financial analysts, and so forth,” says Dr. Groenendaal, “and spent a few days discussing the risks of the project, reviewing the data, and evaluating the best estimates that the oil and gas company had used in projecting the budget. Using Crystal Ball, we conducted the Monte Carlo risk analysis and predicted that there was about a one percent probability that the project would come in on budget!”

In fact, the Crystal Ball evaluation was spot-on. The project had indeed run over budget—and of course accurate figures would have been invaluable to the oil and gas company in preventing overruns, delays, and the potential for ongoing losses and other revenue and profit-draining issues. The success and profitability of the entire project had relied on an optimistic evaluation, unsupported by the laws of probability. What could have worked to the oil and gas company’s advantage, namely knowledge of the true risks and their impact, had remained a mystery.

“What really struck them was that our tool predicted what they had actually seen to be true,” says Dr. Groenendaal. “We ourselves knew nothing about the results, and when we came out with our pessimistic prediction, we had to trust our own risk analysis skill and software. For example, in building a pipeline, weather is a critical and often unpredictable factor. A wet summer slows down construction, while

hurricane frequency, location, and probability add yet more complexity. In addition, the pipeline length was hundreds of miles. Unexpected environmental issues had to be factored in, such as endangered species residing along its course, with their potential to add length and cost in skirting their habitat. Regulatory issues such as time required to obtain permits, which can vary from county to county, might also pose huge delays. Paying crews to sit idle for long periods of time awaiting permits, weather, and other issues to resolve is a huge risk—as is the potential for escalation of capital expenditures such as fuel.

“It was obvious that all their best experience and professional analysis had fallen short, because it lacked the resources and insight of Monte Carlo analysis to inform their estimates. With so many unknowns, they had no way of understanding what they were really facing until mathematics and probability were applied.

“At that point,” says Dr. Groenendaal, “the client realized the value of the Monte Carlo method. We have now been involved with them for the past two years, helping them set up a dedicated department that evaluates key risk factors for projects—a very cost-effective investment for a company whose undertakings range into multiple millions of dollars. The company has gone from skepticism to advocacy.

“Today, the oil and gas company uses the Monte Carlo method at a number of levels. The project manager employs it as a tool to generate a more realistic budget and assess time-allocation and risk priorities. From a more senior perspective, a CFO or even CEO would wish to know how much investment is needed across a slate of major projects; to be able to provide accurate figures to Wall Street analysts about the company’s debt obligations and estimated revenue. So Crystal Ball has the ability to support a company from project manager through senior executive management.

“What Monte Carlo really delivers is the ability to evaluate not just one scenario, but nearly every potential future scenario; to simulate the story of a project reflecting anything that can potentially affect it—what can really hurt you—as well as issues that may have you worried but are not really of concern. Because we have a deep understanding of the Monte Carlo method, we could perform calculations for the oil and gas company that yielded accurate results very quickly. We have been able to train them now in the methodologies involved, so that they could incorporate them into their own organization. The Monte Carlo method is so cost-effective that the oil and gas company could actually build a whole department dedicated to risk analysis with the certainty that the investment would be more than justified on the balance sheet in terms of productivity, cost-control and profit.”

Predictive Modeling and Risk Analysis in EPM—A New Frontier?

Enterprise Performance Management (EPM) comprises all methodologies, systems, metrics, and structures that support the management process. It offers relevant, actionable knowledge and insight as well as drives realization of the goals of an organization’s stakeholders, leading to sustained competitive viability and growth.

With the rising sophistication of computers, companies have implemented transaction systems—enterprise resource planning (ERP), customer relationship management (CRM), human capital management (HCM), and supply chain management (SCM)—to run various parts of the business.

These systems generate and capture a huge volumes of high-value data, creating the potential for phenomenally improved insight into business performance—but also creating a potential for fragmentation and lack of visibility. The purpose of analytical software is to provide a single view of performance across functions. And business intelligence (BI) tools, along with performance management applications are resources for keeping businesses integrated and transparent.

EPM can contribute the data needed for predictive modeling and fuel this process across departments, helping executives or managers to add intelligence to their roles and drive decisions back into the operational systems. Crystal Ball enables companies to use existing EPM data to manage uncertainty and create relevant, informed business forecasts. The more seamless the link between EPM and predictive modeling, the more agile the organization and the better its ability to respond authoritatively and effectively to market and organizational change.

An EPM system integrates management processes under a single umbrella and gives managers greater confidence in the numbers and better ability to calculate financial results, and evaluate the success of their decisions. To these purposes, and with better integrated information than ever before, predictive analysis is a resource whose time has come.

SUMMARY

The power of today's spreadsheet-based risk analysis illuminates a thousand—or ten thousand—possible outcomes in terms of probability. Most importantly, it reveals the best courses of action and points the way toward implementing them. Such agility and intelligence provide huge advantages in successful decision-making to companies with the foresight to apply them.

For many executives, a perception of risk analysis applications as too complicated hampers acceptance of these resources. However, as managers who are more familiar with the software come on board and rise in the ranks, the ability to model the future and offer defined outcome probabilities will become more common and in fact essential to role of leader in a company. Relatively simple and inexpensive value-adds such as Crystal Ball can revolutionize a company's ability to evaluate risk accurately and can significantly improve their business horizons.

In addition to driving creative and strategic thought leadership across industries and enterprises, predictive modeling results in better business practices from the ground up in every department where uncertainty affects decision-making. The benefits of better business practices, improved resource allocation, cost-savings, competitiveness, compliance and growth are brought within reach by innovative, smart software that delivers exceptional value for a relatively small investment.



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Oracle Corporation
World Headquarters
500 Oracle Parkway
Redwood Shores, CA 94065
U.S.A.

Worldwide Inquiries:
Phone: +1.650.506.7000
Fax: +1.650.506.7200
oracle.com

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