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# Using Monte Carlo Simulation for a Capital Budgeting Project

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**Although many types of analyses are useful in determining the scope and possible success of a project, Monte Carlo simulation actually helps managers understand and visualize risk and uncertainty by mapping all possible outcomes of a project.**

Monte Carlo simulation is a powerful spreadsheet-based tool that allows managers to better understand and visualize risk and uncertainty in discounted cash flow (DCF) analysis. The primary output, a histogram of net present values (NPV), maps the entire distribution of possible outcomes as a bell-shaped curve and therefore estimates the probability of success for the project (e.g., NPV > zero). Although we use fictional names, we illustrate a real capital budgeting problem using Monte Carlo simulation to demonstrate how employing this tool can result in more-informed decision making.

Finance theory states that expected (mean) cash flows should be discounted at the opportunity cost of capital using a decision rule to accept or reject all positive or negative NPV projects. A central issue for managers, however, is how to deal with uncertainty—i.e., the fact that expected cash flows are only a point estimate of a large number of possible realizations. Traditional finance textbooks suggest two tools for this—sensitivity analysis and scenario analysis. Sensitivity analysis tweaks one variable at a time and evaluates the effect on the project's net present value, and scenario analysis examines a limited number of combinations of variables: worst-case (WC), most-likely-case (MLC), and best-case (BC) estimates of financial variables that determine future cash flows (e.g., sales, costs, growth rates, investment in working capital, etc.). The output is three project NPVs where all variables simultaneously take on one of the three hypothetical realizations. Neither tool produces probabilities of success or failure for the project.

Monte Carlo simulation, however, overcomes the limitations of sensitivity and scenario analyses by examining the effects of all possible combinations of variables and their realizations. Although the inputs are no different from scenario analysis, Monte Carlo simulation treats the estimates as a triangular distribution with the probability of WC and BC realizations being close to zero and increasing linearly up to the MLC. The simulation package then draws randomly from this distribution (100,000 times in our examples) for all variables that are specified in the DCF model and calculates an NPV for each draw. The result is a bell-shaped distribution function of NPVs (i.e., the area under the curve is equal to one) that provides estimates of the probability of success and failure. Sensitivity analysis applied to the Monte Carlo results allows us to address issues such as:

1. Which variables are the most important—i.e., have a large impact on the NPV calculation and/or have a high level of uncertainty? This helps focus management attention on relevant issues and actions that might reduce uncertainty.
2. Suppose the project-evaluation team sees that there is an optimistic bias in the forecast of unit sales. It is a simple matter to change the WC and/or the BC estimate and determine the resulting decrease in the probability of a successful project.
3. Suppose management believes that prices and volume are negatively correlated—i.e., on average, higher prices result in lower sales volume. Alternatively, many costs move up or down together, implying a positive correlation. Simulation software permits the financial modeler to specify such correlations and quantify their effects on the probability of success or failure.

An interesting byproduct of simulation is that it can clearly highlight implausible assumptions. Consider a project submitted to the capital expenditure committee with a 99% probability of success and an internal rate of return (IRR) greater than the cost of capital. On the surface, it appears to be the perfect project—high returns with little chance of failure. Projects with high returns, however, by definition must be risky projects because, as we know, there is no free lunch. Therefore, the probability of a positive NPV project cannot be close to 100%—even projects that earn their cost of capital are risky. Monte Carlo simulation can be a useful tool for detecting the inherent optimistic bias of project originators.

The two main commercial simulation software packages are Crystal Ball and @Risk. We will use Crystal Ball to analyze a capital expenditure project involving the purchase, installation, and commercial use of an MRI scanner a group of physicians affiliated with a large state university purchased. One of us has used Crystal Ball in MBA classroom and executive education programs, so we know it has sufficient uncertainty about future outcomes of volume, product mix, prices, and costs to provide sophisticated users of financial information with a rich forum for discussion and analysis.

## The MRI Scanner Project

CRSA, a physicians group affiliated with a university medical center, is considering the purchase of a new state-of-the-art MRI scanner. Dr. Margaret Reed, CEO of CRSA, believes a market for this service exists (more than 2,500 scans per year at a separate location) and that the group can make a significant amount of money on the investment, which would provide much-needed funding to meet the group's research and teaching missions.

General Electric Medical Systems offers the first Open Bore MRI scanner with a total imaging matrix, 16 channels, twin-speed, dual-gradient, and high-definition format. The base cost is $1.4 million, but the customer must also purchase a number of accessories, such as injectors, workstation, and computers.

The clinical operations of CRSA departments (cardiology, neurology, orthopedics, etc.) are distinct legal and economic entities with some centralized management functions (legal, accounting, planning, etc.). Instead of mandating the project, Dr. Reed has decided to finance the venture by selling shares of stock to individual departments. In this new era for the group, CRSA analyzes capital investment projects using DCF techniques with uncertainty explicitly incorporated into the analysis. All department chairs have completed executive education programs in business and are sophisticated users of financial information. Therefore, investors will expect a fully integrated set of pro forma financial statements (balance sheet, income statement, and cash flow statement) that calculate free cash flows to investors. Of particular importance to Dr. Reed is the transparency of the assumptions about the future and resulting NPV/IRR.

### Vocabulary

Readers will need to understand two terms from the healthcare industry.

**CPT® Codes:** A registered trademark of the American Medical Association, CPT stands for current procedural terminology. The codes provide a comprehensive description of medical, surgical, and diagnostic services and are designed to communicate uniform information about medical procedures among physicians, coders, patients, accreditation organizations, and payers for administrative, financial, and analytical purposes (adapted from Wikipedia).

**RVU:** RVU (relative value unit) represents the level of effort, expertise, and resources required for medical procedures. Medicare and HMO reimbursement rates are often a constant dollar amount times the RVU for a procedure, so higher numbers represent more-difficult and, therefore, expensive procedures.

### Forecasting Assumptions

Any capital expenditure project requires forecasts of key financial and operating variables that determine cash flows in order to perform an NPV analysis. In this analysis, the key variables are product mix, reimbursement rates, volume (number of scans), collection period, and operating costs (see Table 1).

**(1) Product Mix:** The actual MRI scanner project used historical data from another installation on the type of scan (CPT code), its RVU, and the number of scans to predict the weighted average (WA) RVU of 19.13 per scan (see Table 2). Our examination of the data showed a logical grouping to summarize product mix into low RVU (48% of total) and high RVU (52% of total) scans. Therefore, the key product-mix variable that must be predicted is the fraction of low RVU scans (the fraction of high RVU scans will be its complement).

**(2) Reimbursement:** An analysis of recent reimbursement rates per RVU revealed an average of $34.50 across different providers. Multiplied by the WA RVU, this figure is the expected reimbursement per scan for year one. The key variable is whether the change in reimbursement rate will go up or down in the future, and this will determine the projected revenue per scan over the five-year life of the project.

**(3) Volume:** The average cycle time for an MRI scan is about one hour, so, based on a 12-hour day, the maximum capacity of the facility is about 12 scans per day. The key variables we need to predict are the number of scans in the first year and the subsequent increase. These estimates, in combination with the number of facility days per year (five days per week times 48 weeks per year), is the basis for predicting the annual number of scans.

**(4) Capital Expenditures:** Base cost for the GE Medical Systems scanner is $1.4 million, but that figure does not include a number of accessories, such as injectors, workstation, and computers, so the total investment is $1.468 million. These numbers are known with certainty because of the GE bid on the proposal. The estimated residual value is $0.2 million.

**Working Capital:** Working capital requirements in our model include accounts receivable, supplies inventory, and minimum operating cash balance. WC, MLC, and BC estimates are required for the simulation.

**(5) Financing:** Total capitalization for the project was conservatively estimated at $2.2 million. The cost of equity capital (COEC) for the departments is 11%, and the income tax rate is 40%. We calculate NPV and IRR for an all-equity-financed project and avoid weighted average cost of capital (WACC) and capital structure issues.

**(6) Operating Costs:** These include direct supplies (primarily film), personnel, and other operating costs. In each case we assume that estimates for the first year are fairly accurate, but the annual increase in costs is the variable to forecast.

**Variable Costs:** Film for the scanner is estimated to be $65 per scan. The first-year cost is known with considerable accuracy, but we must also forecast increases for the simulation.

**Personnel Costs:** Two MRI technicians need to be on duty at all times. Running 1.5 shifts per day (12 hours) requires three FTEs. In addition, one registration clerk needs to be on duty, requiring 1.5 FTEs. Estimates for year one are based on current salary levels for MRI

## Table 1: Forecasting Assumptions

| NPV = | $87,134 | | IRR = | 12.5% |
|---|---|---|---|---|

(1) Product Mix

| | # CPT Codes | Volume: # Scans | Volume: Percent | Average RVU | WA RVU |
|---|---|---|---|---|---|
| CPT Codes: Group 1 | 19 | 285 | 48.0% | 11.98 | 19.13 |
| CPT Codes: Group 2 | 11 | 309 | 52.0% | 25.73 | |

WA = weighted average

(2) Reimbursement per RVU $34.50

| Year | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| WA reimbursement per scan | $659.99 | $646.79 | $633.85 | $621.17 | $608.75 |

(3) Volume

| Year | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| # Facility days per year | 240 | 240 | 240 | 240 | 240 |
| # Scans per day | 4.3 | 5.2 | 6.2 | 7.4 | 8.9 |
| # Scans per year | 1,032 | 1,238 | 1,486 | 1,783 | 2,140 |

(4) Capital Expenditures

| | |
|---|---|
| MRI Scanner | $1,400,000 |
| Injector | $35,000 |
| Workstation | $17,000 |
| Computers | $6,000 |
| Furniture & Fixtures | $10,000 |
| Total | $1,468,000 |
| Estimated residual value | $200,000 |
| Depreciation expense | $253,600 |

Working Capital

| | |
|---|---|
| # Days' receivables | 75 |
| Supplies inventory (# days) | 15 |
| Min cash: sales | 15.0% |

(5) Financing

| | |
|---|---|
| Equity | $2,200,000 |
| Cost of equity capital | 11.0% |
| Income tax rate | 40.0% |

(6) Operating Costs

Direct supplies (variable with # scans) $65.00

Personnel Costs

| | Annual Cost | Annual Salary | # FTEs |
|---|---|---|---|
| MRI technician | $90,000 | $30,000 | 3.0 |
| Registration clerks | $37,500 | $25,000 | 1.5 |
| Total | $127,500 | | |

Other Operating Costs (all fixed)

| | |
|---|---|
| Rent | $44,000 |
| Office supplies | $3,900 |
| Telephone | $1,400 |
| Utilities | $1,000 |
| Maintenance | $43,000 |
| Other | $11,000 |
| Physicist service contract | $2,800 |
| Licensure of equipment | $2,500 |
| Insurance | $19,000 |
| Total Other Operating Costs | $128,600 |

(7) Summary

| Year | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Revenues | $681,105 | $800,720 | $941,900 | $1,107,551 | $1,302,723 |
| Variable costs | $67,080 | $84,494 | $101,420 | $121,690 | $146,055 |
| Personnel costs | $127,500 | $133,875 | $140,569 | $147,597 | $154,977 |
| Other operating costs | $128,600 | $135,030 | $141,782 | $148,871 | $156,314 |

**Table 2: CPT Codes Product Mix**

**Low RVU Group**

| CPT CODE | Volume | Technical RVU | | RVU x Vol. |
|---|---|---|---|---|
| 73218 | 3 | 11 | .49 | 34.47 |
| 73221 | 28 | 11.49 | | 321.72 |
| 73718 | 7 | 11 | .49 | 80.43 |
| 73721 | 56 | 11.49 | | 643.44 |
| 71550 | 1 | 11 | .55 | 11.55 |
| 72195 | 5 | 11 | .55 | 57.75 |
| 74181 | 3 | 11.55 | | 34.65 |
| 70544 | 33 | 11.70 | | 386.10 |
| 70547 | 3 | 11 | .70 | 35.10 |
| 70548 | 1 | 11 | .70 | 11.70 |
| 70551 | 39 | 11.70 | | 456.30 |
| 72141 | 23 | 11.70 | | 269.10 |
| 73725 | 1 | 11 | .70 | 11.70 |
| 74185 | 18 | 11.70 | | 210.60 |
| 72146 | 4 | 12.97 | | 51.88 |
| 72148 | 42 | 12.97 | | 544.74 |
| 74182 | 1 | 13.85 | | 13.85 |
| 70552 | 16 | 14.03 | | 224.48 |
| 72149 | 1 | 14.03 | | 14.03 |
| Sum | 285 | | | 3,413.59 |

**High RVU Group**

| CPT CODE | Volume | Technical RVU | RVU x Vol. |
|---|---|---|---|
| 70546 | 4 | 22.81 | 91.24 |
| 70549 | 16 | 22.81 | 364.96 |
| 70543 | 8 | 25.52 | 204.16 |
| 73720 | 1 | 25.52 | 25.52 |
| 73723 | 1 | 25.52 | 25.52 |
| 72197 | 8 | 25.59 | 204.72 |
| 74183 | 23 | 25.59 | 588.57 |
| 70553 | 192 | 25.99 | 4,990.08 |
| 72156 | 21 | 25.99 | 545.79 |
| 72157 | 12 | 25.99 | 311.88 |
| 72158 | 23 | 25.99 | 597.77 |
| Sum | 309 | | 7,950.21 |

| Group | Product Mix | WA RVU |
|---|---|---|
| Low RVU | 48% | 11.98 |
| High RVU | 52% | 25.73 |
| All | 100% | 19.13 |

technicians and clerks. Increases in personnel costs are subject to uncertainty.

**Other Operating Costs:** Table 1 shows estimates for year one that GE Medical Systems provided; increases are subject to uncertainty.

**(7)** This table summarizes income statement items through the operating expenses.

## NPV Analysis

Table 3 presents the pro forma income statements, balance sheets, and cash flow statements. Income statement numbers are derived from the summary table in Table 1. We determined all numbers on the balance sheet (except retained earnings) by formula through the forecasting assumptions. Therefore, the plug number to complete the balance sheet is ending retained earnings each year. With this number, implied dividends are computed from the clean surplus relation:

$$\text{Ret Earn}_0 + \text{NI}_1 - \text{DIV}_1 = \text{Ret Earn}_1$$

The dividends represent free cash flow (FCF) to investors, who, in this case, are CRSA departments that decided to purchase shares in the MRI scanner project. We use FCF to investors to determine the project's NPV and IRR. Note that the cash flow statement articulates with the balance sheet; i.e., net cash flow each period is equal to successive changes in cash balances. It is also interesting to note that cumulative cash flows do not turn positive until the project's fifth year.

The project NPV equals $87,134, and the IRR equals 12.5%. MLC estimates of all forecasted variables gave us these point estimates. One would conclude that the investors should accept the project because it has a positive NPV and an

**Table 3:** NPV Analysis

| **Income Statement** | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Revenue | | $681,105 | $800,720 | $941,900 | $1,107,551 | $1,302,723 |
| Operating Expenses | | | | | | |
| Supplies | | $67,080 | $84,494 | $101,420 | $121,690 | $146,055 |
| Personnel | | $127,500 | $133,875 | $140,569 | $147,597 | $154,977 |
| Operating | | $128,600 | $135,030 | $141,782 | $148,871 | $156,314 |
| Depreciation | | $253,600 | $253,600 | $253,600 | $253,600 | $253,600 |
| Pretax Income | | $104,325 | $193,722 | $304,531 | $435,793 | $591,777 |
| Income Taxes | | $41,730 | $77,489 | $121,812 | $174,317 | $236,711 |
| Net Income | | $62,595 | 6,233 | $182,718 | $261,476 | $355,066 |

| **Balance Sheet** | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Assets | | | | | | |
| Cash | $589,290 | $102,166 | $120,108 | $141,285 | $166,133 | $0 |
| Accounts Receivable | $139,953 | $139,953 | $164,532 | $193,541 | $227,579 | $0 |
| Inventories | $2,757 | $2,757 | $3,307 | $3,969 | $4,763 | $0 |
| Equipment (net) | $1,468,000 | $1,214,400 | $960,800 | $707,200 | $453,600 | $0 |
| Total Assets | $2,200,000 | $1,459,275 | $1,248,747 | $1,045,996 | $852,074 | $0 |
| | | | | | | |
| Contributed Capital | $2,200,000 | $2,200,000 | $2,200,000 | $2,200,000 | $2,200,000 | $2,200,000 |
| Retained Earnings | $0 | 40,725) | ($951,253) | ($1,157,004) | ($1,347,926) | ($2,200,000) |
| Total Stockholders' Equity | $2,200,000 | $1,459,275 | $1,248,747 | $1,045,996 | $852,074 | $0 |

| **Cash Flow Statement** | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| CF from Operating Activities | | | | | | |
| Net Income | | $62,595 | 6,233 | $182,718 | $261,476 | $355,066 |
| Depreciation | | $253,600 | $253,600 | $253,600 | $253,600 | $253,600 |
| Δ Accounts Receivable | | $0 | ($24,579) | ($29,010) | ($34,038) | $227,579 |
| Δ Inventories | | $0 | ($550) | ($662) | ($793) | $4,763 |
| CF from Operating Activities | | $316,195 | $344,704 | $406,646 | $480,245 | $841,008 |
| | | | | | | |
| CF from Investing Activities | | $0 | $0 | $0 | $0 | ,0$20 |
| | | | | | | |
| CF from Financing Activities | | | | | | |
| Dividends | | ($803,319) | ($326,762) | ($385,469) | ($455,397) | ($1,207,141) |
| | | | | | | |
| Net Cash Flow | | ($487,125) | $17,942 | $21,177 | $24,848 | ($166,133) |

| Year | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Cash Flows to Investors | ($2,200,000) | $803,319 | $326,762 | $385,469 | $455,397 | $1,207,141 |
| Cumulative Cash Flows to Investors | ($2,200,000) | ($1,396,681) | ($1,069,919) | ($684,450) | ($229,052) | $978,088 |

NPV = $87,134

IRR = 12.5%

**Table 4: WC, MLC, and BC Assumptions**

| | WC | MLC | BC |
|---|---|---|---|
| Product Mix (Group 1 %) | 51.0% | 48.0% | 45.0% |
| Growth in Reimbursement | -4.0% | -2.0% | 0.0% |
| # Scans per Day, Year 1 | 3.6 | 4.3 | 5.0 |
| Growth in # Scans per Day | 15.0% | 20.0% | 25.0% |
| Estimated Residual Value | $150,000 | $200,000 | $250,000 |
| # Days' Receivables | 80 | 75 | 70 |
| Increase in Costs of Direct Supplies | 7.0% | 5.0% | 3.0% |
| Increase in Personnel Costs | 7.0% | 5.0% | 3.0% |
| Increase in Other Operating Costs | 7.0% | 5.0% | 3.0% |

IRR greater than the cost of equity capital (11.0%), but the picture changes dramatically when we introduce uncertainty.

### Uncertainty and Risk

Monte Carlo simulation requires the user to estimate a probability distribution to reflect the uncertainty for each random variable. A common technique in financial forecasting assumes a triangular distribution using the WC, MLC, and BC estimates. The triangular distribution assigns a near-zero probability to the WC and BC outcomes and the highest probability to the MLC outcome.

Table 4 shows the assumptions for WC, MLC, and BC realizations of all random variables. Figure 1 illustrates the probability distribution for the number of scans in year one. The shape of the distribution for other random variables is similar; i.e., for now, the distributions are symmetric for the MLC scenario, which means that the MLC and expected value for each assumption are the same.

Crystal Ball draws 100,000 random samples for each

**Figure 1: Probablity Distribution of Scans per Day in Year 1**

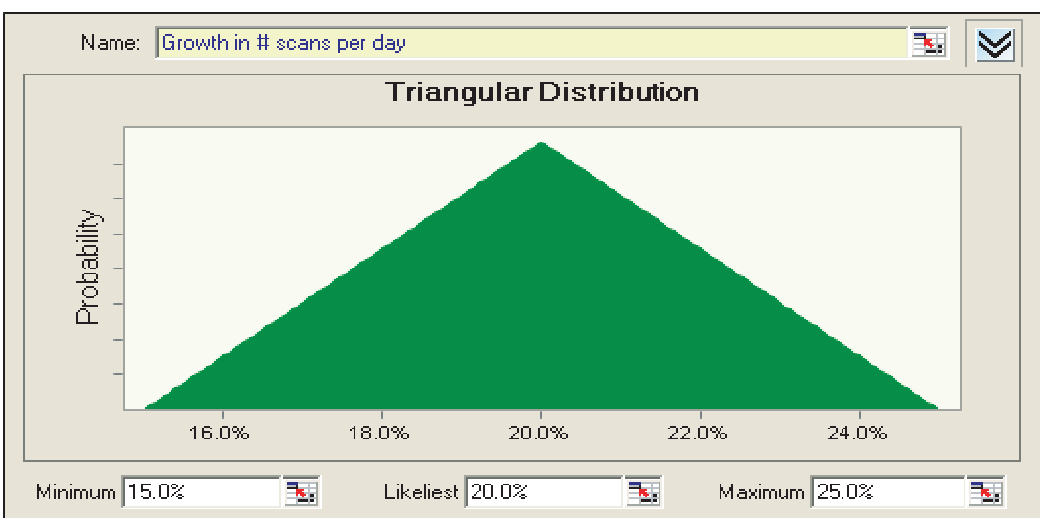
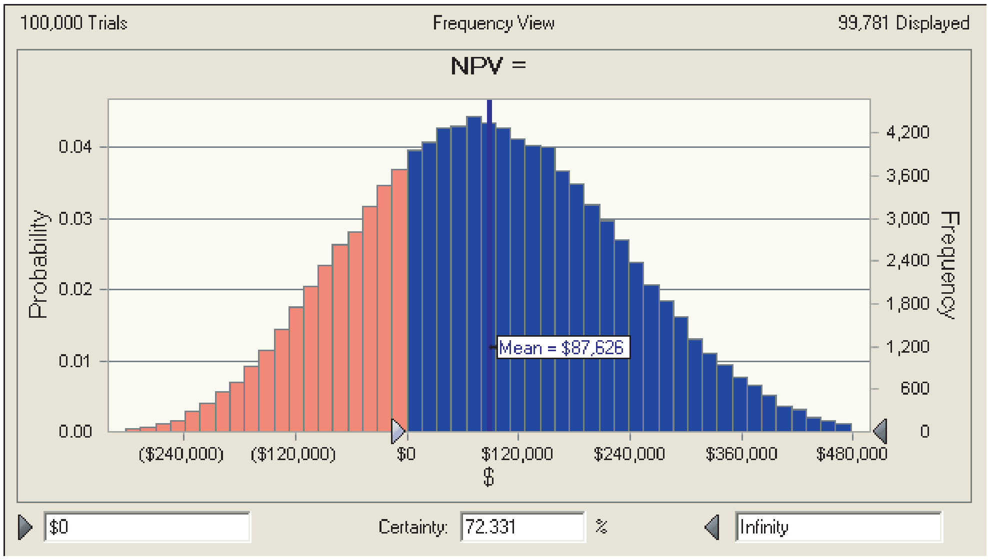


**Figure 2:** **Distribution Function of NPVs with Probability of Positive NPV Highlighted in Blue**




variable and uses the pro forma financial statements in Table 3 to calculate the project's NPV for each draw. The primary output of Crystal Ball is the distribution function of NPVs with the probability of a positive NPV project at 72.3%, which is highlighted in blue in Figure 2 (see the "certainty" box at the bottom of the figure). Note that the probability of success is not 100%—it is, after all, a risky project. Because the MLC and expected value are the same for each assumption, it is also true that the mean of the NPV distribution ($87,626) will be very close to the NPV calculated earlier using all of the MLC values (see Table 1). The difference is because of the randomness of simulation technology.

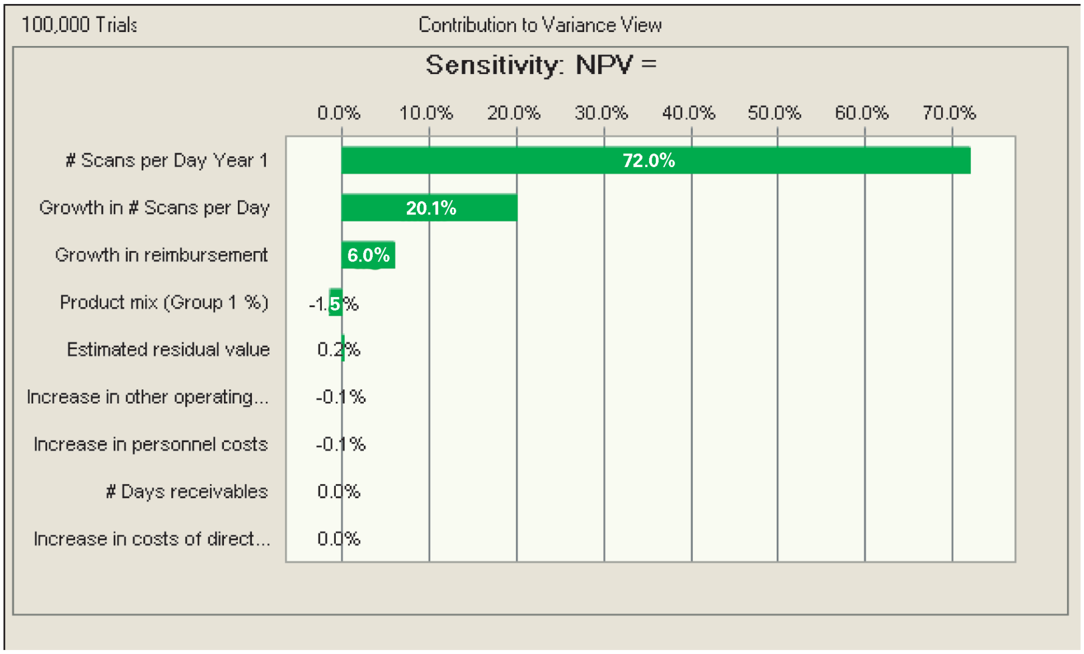
Crystal Ball also produces a contribution-to-variance chart as shown in Figure 3. This chart quantifies how much each assumption affects the project NPV. For example, the number of scans in year one is the primary driver of the project NPV, accounting for 72% of its variation. The growth in the number of scans (20.1%), the growth in reimbursement rates (6%), and the product mix (1.5%) also contribute visibly to the variation in the project NPV. In contrast, residual value, increases in costs, and the collection period have a negligible effect on NPV. In the following analyses, therefore, we will drop these assumptions from the simulation and use the MLC as a point estimate for each one.

### Optimistic Assumptions

It is generally acknowledged that the originators or champions of projects may be optimistically biased in their assumptions about the financial and operational variables affecting cash flows, and this can have a significant effect on the estimated probability of the project's success. To demonstrate the effect of this bias, we will assume that only the increase in scans (the second-most-important assumption, accounting for 20% of the variation in NPV) is subject to this distortion and that the WC estimate should really be 5% per year instead of 15% per year (see Table 4). The new probability distribution for growth in scans appears in Figure 4 and helps us visualize uncertainty. Note that the expected value (mean) is now 16.7%, whereas the MLC remains at 20% per year. We would expect this to also shift the mean NPV downward, but we do not know by how much. Here Monte Carlo simulation again provides a probability distribution that helps us visualize risk.

Figure 5 shows the distribution function of NPVs. The only change from the previous example is the different assumption about the WC realization of growth

Figure 3: **Contribution to Variance of Project NPV**




in scans. Note that the mean NPV is now negative (-$8,097) and that the probability of a positive NPV project has dropped from 72.3% to 47.8%. Decision makers can now visualize the effect of optimistic bias.

We now examine the relative importance of each assumption about NPV with a revised contribution-to-variance chart, as Figure 6 shows. The number of first-year scans is now less important to the project NPV, although it still accounts for 42% of the variation in NPV, and the growth in scans is now the most important assumption, contributing 53.9% to the variability of the project NPV.

Figure 4: **Revised Probability Distribution of Growth in Number of Scans per Day**

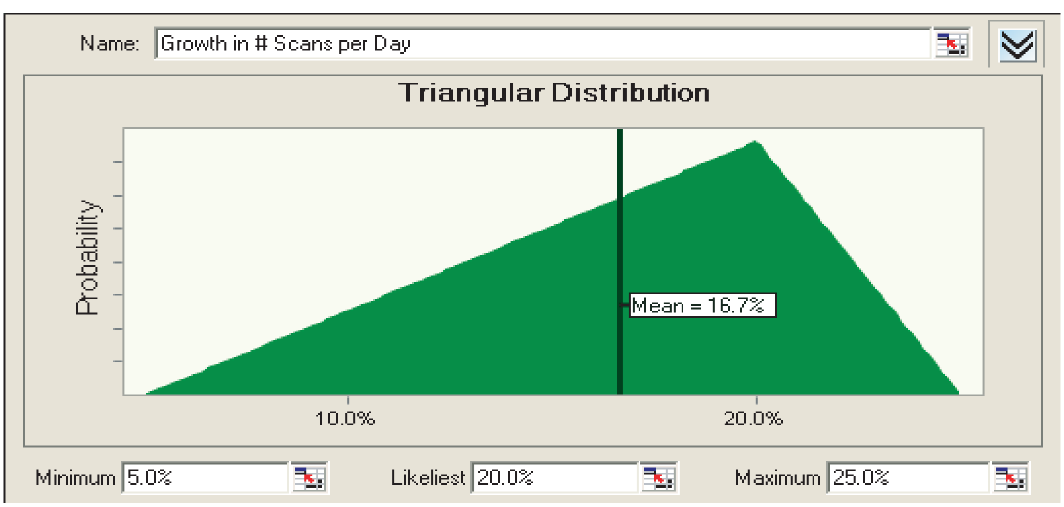
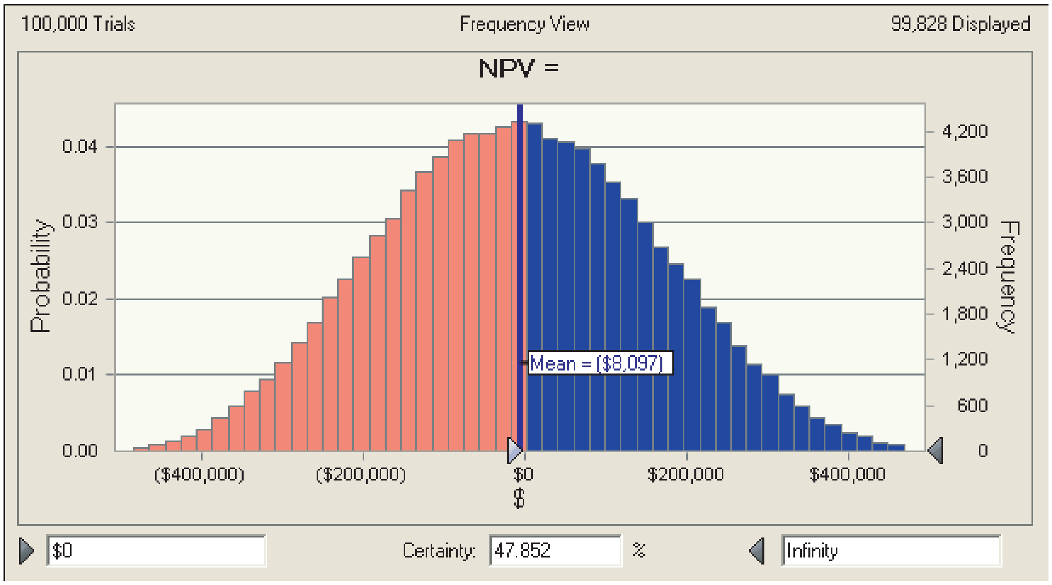


**Figure 5: Distribution Function of NPVs with Probability of Positive NPV Highlighted in Blue**




Management now has the information to perhaps make some adjustments to the project's design and implementation. For example, the number of scans in year one is still very important to the project's success. Does that justify a significant pre-opening marketing campaign? The growth in scans is even more important. Does that suggest additional marketing expenditures during the life of the project? NPV analysis and Monte Carlo simulation can answer these questions.

**Figure 6: Revised Contribution to Variance of Project NPV**

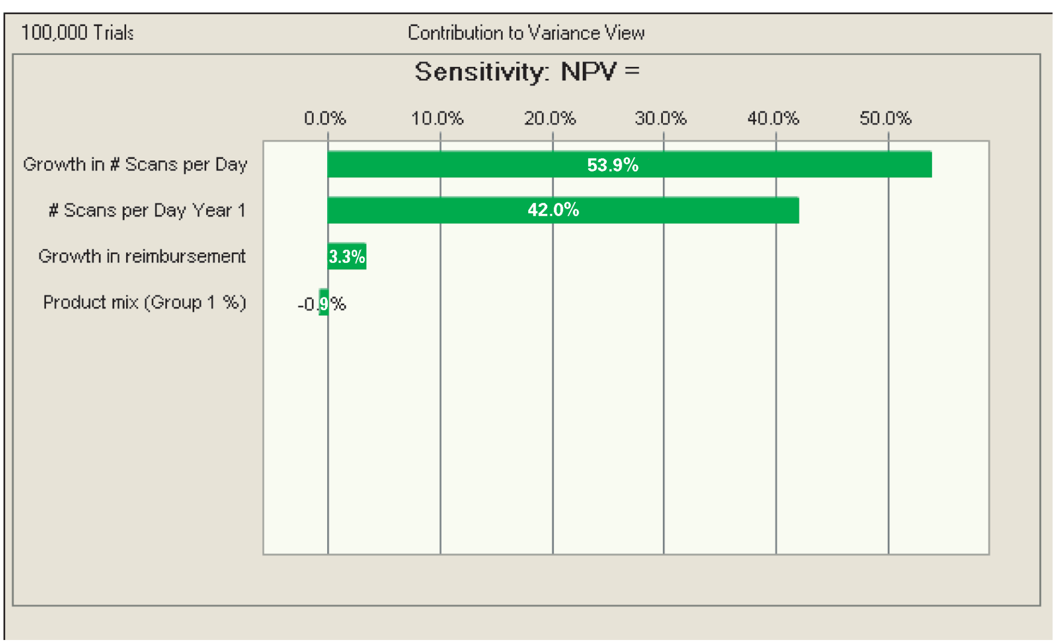
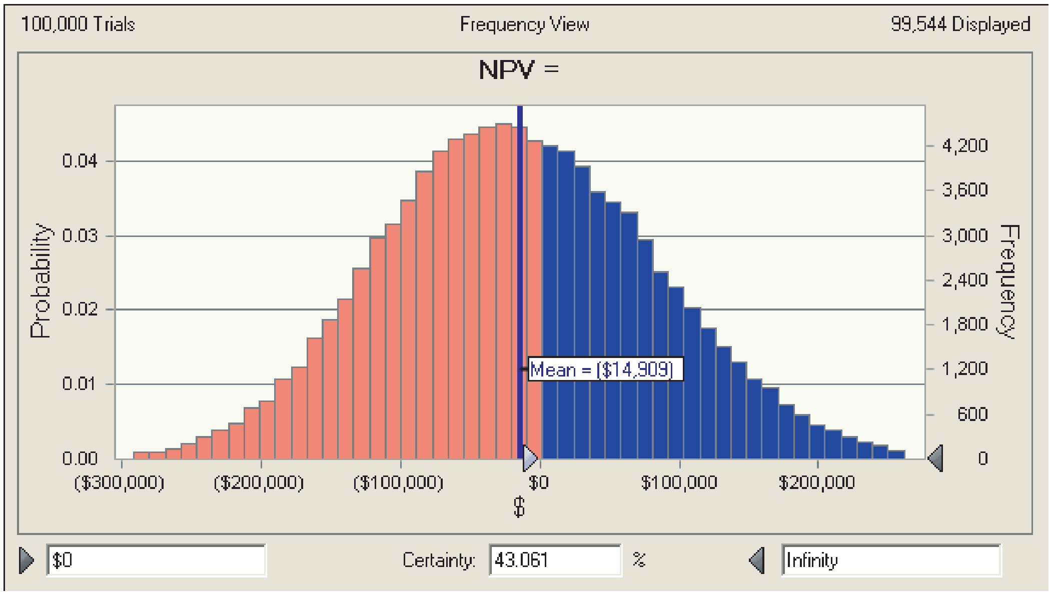


**Figure 7:** **Distribution Function of NPVs with Probability of Positive NPV Highlighted in Blue with Correlated Variables**




### Correlated Variables

Now we examine the effects of correlated variables on our MRI scanner project. Suppose the number of scans in year one is near the high end of the range. Could that encourage the entry of a competitor? Would it suggest that subsequent growth in the number of scans is low? On the other hand, if the first-year scans are low and competitor entry is thus discouraged, then subsequent growth might be high. In such a scenario, the number of scans in year one and the subsequent growth in scans would be negatively correlated.

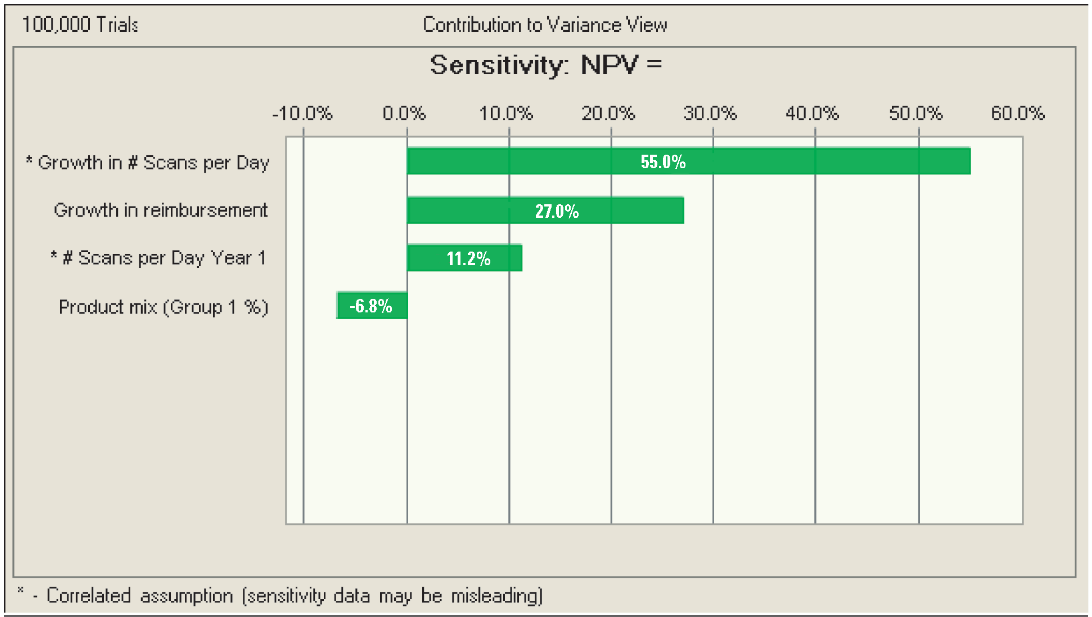
Alternatively, assume that the market is such that another MRI scanner is highly unlikely to be installed in the next five years. If the number of first-year scans is high, that might indicate robust demand for scans, so subsequent growth would also be high and vice versa. In this case, the first-year scans and subsequent growth would be positively correlated.

Figure 7 presents the distribution of NPVs for the case in which first-year scans and subsequent growth have a correlation coefficient of -0.70. The probability of success is slightly lower now (43% versus 47.8%), which suggests that negatively correlated variables do not change the project characteristics dramatically. A closer examination, however, reveals that the probability of extreme outcomes—a huge success (e.g., NPV > +$300,000) or a catastrophic failure (e.g., NPV < -$300,000)—has been reduced significantly compared to the distribution of NPVs in Figure 5 without correlated variables; i.e., the tails of the distribution are thinner.

The new contribution-to-variance chart is even more interesting (see Figure 8). It demonstrates that, with negatively correlated variables, the growth in reimbursement rates has become a much more important assumption, now accounting for 27% of the project NPV variance, compared to 3.3% in Figure 6. This suggests that management may want to scrutinize the assumptions about reimbursement rates more closely than was previously warranted.

The opposite happens if first-year scans and growth in scans are positively correlated. The probability of a positive NPV project increases slightly to 49.7% (figure not shown), but the importance of reimbursement rates becomes almost negligible. Understanding and including correlations among financial and operational variables is, therefore, an important part of capital budgeting analysis.

**Figure 8: New Contribution to Variance of Project NPV**




### Some Implications

We can draw the following implications from our analysis:

- Financial modeling using Excel and Crystal Ball is a useful tool for visualizing and quantifying the effects of uncertainty and risk on capital budgeting decisions.
- A triangular distribution for cash flow relevant variables dovetails nicely with the way managers typically view uncertainty—i.e., estimates of WC, MLC, and BC outcomes for financial and operating variables.
- The contribution-to-variance charts embedded in Crystal Ball help focus management's attention on the variables that are important to the decision, including actions to mitigate the effects of particular uncertainties (e.g., evaluating the desirability of marketing campaigns in our example).
- Monte Carlo simulation allows decision makers to quantify and visualize the effects of optimistic bias quickly and effectively. The same is true for correlated financial and operational variables.

Again, Monte Carlo simulation helps management accountants make better decisions because it examines the effects of all possible combinations of variables and lets managers better understand and visualize risk and uncertainty. Then they can estimate the probability of a project's success. ■

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