assumptions that would render any single-point estimate of the project outcome nearly useless. The technique provides each member of multidisciplinary work teams a straightforward and effective framework for quantifying and accounting for each of the risk factors that will influence the outcome of his or her drilling project. In addition, Monte Carlo simulation provides management and team leadership something much more valuable than a single forecast of the project's NPV: It provides a probability distribution of the entire spectrum of project outcomes, allowing decision makers to explore any pertinent scenarios associated with the project value. These scenarios could include break-even probabilities as well as scenarios associated with extremely poor project results that could damage the project team's credibility and future access to capital, or outcomes that resulted in highly successful outcomes. Finally, Monte Carlo simulation of oil and gas prospects provides managers and team leaders critical information on which risk factors and assumptions are driving the projected probability of project outcomes, giving them the all-important feedback they need to focus their people and financial resources on addressing those risk assumptions that will have the greatest positive impact on their business, improving their efficiency and adding profits to their bottom line.

CASE STUDY: FINANCIAL PLANNING WITH SIMULATION

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Corporate America has increasingly altered the retirement landscape by shifting from defined benefit to defined contribution plans. As the baby boomers retire, they will have different financial planning needs than those of previous generations because they must manage their own retirement funds. A thoughtful financial planner has the ability to positively impact the lives of these retirees.

A Deterministic Plan

Today was the last day of work for Henry Tirement, and, until just now, he and his financial planner, Mr. Determinist, had never seriously discussed what to do with his 401k rollover. After a moment of fact gathering with Henry, Mr. D obtains the following information:

- Current assets are $1,000,000 in various mutual funds.
- Current age is 65.
- Desired retirement salary is $60,000 before-tax.
- Expected return on investments is 10 percent.
- Expected inflation is 3 percent.
- Life expectancy is age 95.
- No inheritance considerations.

With his financial calculator, Mr. D concludes that Henry can meet his retirement goals and, in fact, if he died at age 95, he'd have over $3.2 million in his portfolio. Mr. D knows that past performance does not guarantee future results, but past performance is all that we have to go by. With the stock market averaging over 10 percent for the past 75 years, Mr. D feels certain that this return is reasonable. As inflation has averaged 3 percent over the same time period, he feels that this assumption is also realistic. Mr. D delivers the good news to Henry and the plan is put into motion (Table 7.4).

Fast forward to 10 years later. Henry is not so thrilled anymore. He visits the office of Mr. D with his statements in hand and they sit down to discuss the portfolio performance. Writing down the return of each of the past 10 years, Mr. D calculates the average performance of Henry's portfolio (Table 7.5).

"You've averaged 10 percent per year!" Mr. D tells Henry. Befuddled, Henry scratches his head. He shows his last statement to Mr. D that shows a portfolio balance is $501,490.82.

Once again, Mr. D uses his spreadsheet program and obtains the results in Table 7.6.

Mr. D is not certain what has happened. Henry took out $60,000 at the beginning of each year and increased this amount by 3 percent annually. The portfolio return averaged 10 percent. Henry should have over $1.4 million by now.

Sequence of Returns Sitting in his office later that night, Mr. D thinks hard about what went wrong in the planning. He wonders what would have happened if the annual returns had occurred in reverse order (Table 7.7). The average return is still 10 percent and the withdrawal rate has not changed, but the portfolio ending balance is now $1.4 million. The only difference between the two situations is the sequence of returns. Enlightenment overcomes Mr. D, and he realizes that he has been employing a deterministic planning paradigm during a period of withdrawals.

TABLE 7.4 The Deterministic Plan

Year	Returns (%)	Beginning Balance ($)	Withdrawal ($)	Ending Balance ($)
1	10.00	1,000,000.00	60,000.00	1,034,000.00
2	10.00	1,034,000.00	61,800.00	1,069,420.00
3	10.00	1,069,420.00	63,654.00	1,106,342.60
4	10.00	1,106,342.60	65,563.62	1,144,856.88
5	10.00	1,144,856.88	67,530.53	1,185,058.98
6	10.00	1,185,058.98	69,556.44	1,227,052.79
7	10.00	1,227,052.79	71,643.14	1,270,950.62
8	10.00	1,270,950.62	73,792.43	1,316,874.01
9	10.00	1,316,874.01	76,006.20	1,364,954.58
10	10.00	1,364,954.58	78,286.39	1,415,335.01
11	10.00	1,415,335.01	80,634.98	1,468,170.03
12	10.00	1,468,170.03	83,054.03	1,523,627.60
13	10.00	1,523,627.60	85,545.65	1,581,890.14
14	10.00	1,581,890.14	88,112.02	1,643,155.93
15	10.00	1,643,155.93	90,755.38	1,707,640.60
16	10.00	1,707,640.60	93,478.04	1,775,578.81
17	10.00	1,775,578.81	96,282.39	1,847,226.07
18	10.00	1,847,226.07	99,170.86	1,922,860.73
19	10.00	1,922,860.73	102,145.98	2,002,786.22
20	10.00	2,002,786.22	105,210.36	2,087,333.45
21	10.00	2,087,333.45	108,366.67	2,176,863.45
22	10.00	2,176,863.45	111,617.67	2,271,770.35
23	10.00	2,271,770.35	114,966.20	2,372,484.56
24	10.00	2,372,484.56	118,415.19	2,479,476.31
25	10.00	2,479,476.31	121,967.65	2,593,259.53
26	10.00	2,593,259.53	125,626.68	2,714,396.14
27	10.00	2,714,396.14	129,395.48	2,843,500.73
28	10.00	2,843,500.73	133,277.34	2,981,245.73
29	10.00	2,981,245.73	137,275.66	3,128,367.08
30	10.00	3,128,367.08	141,393.93	3,285,670.46

Withdrawals Versus No Withdrawals Most financial planners understand the story of Henry. The important point of Henry's situation is that he took withdrawals from his portfolio during an unfortunate sequence of returns. During a period of regular withdrawals, it doesn't matter that his portfolio returns averaged 10 percent over the long run. It is the sequence of returns combined with regular withdrawals that was devastating to his portfolio. To

TABLE 7.5 The Actual Results

Year	Return %
1	–20.00
2	–10.00
3	9.00
4	8.00
5	12.00
6	–10.00
7	–2.00
8	25.00
9	27.00
10	61.00
Average Return	**10.00**

TABLE 7.6 Portfolio Balance Analysis

Year	Returns (%)	Withdrawal ($)	Ending Balance ($)
1	–20.00	60,000.00	752,000.00
2	–10.00	61,800.00	621,180.00
3	9.00	63,654.00	607,703.34
4	8.00	65,563.62	585,510.90
5	12.00	67,530.53	580,138.01
6	–10.00	69,556.44	459,523.41
7	–2.00	71,643.14	380,122.67
8	25.00	73,792.43	382,912.80
9	27.00	76,006.20	389,771.37
10	61.00	78,286.39	501,490.82

TABLE 7.7 Reversed Returns

Year	Return (%)	Withdrawal ($)	Ending Balance ($)
1	61.00	60,000.00	1,513,400.00
2	27.00	61,800.00	1,843,532.00
3	25.00	63,654.00	2,224,847.50
4	–2.00	65,563.62	2,116,098.20
5	–10.00	67,530.53	1,843,710.91
6	12.00	69,556.44	1,987,053.00
7	8.00	71,643.14	2,068,642.65
8	9.00	73,792.43	2,174,386.74
9	–10.00	76,006.20	1,888,542.48
10	–20.00	78,286.39	1,448,204.87

illustrate this point, imagine that Henry never took withdrawals from his portfolio (Table 7.8).

The time value of money comes into play when withdrawals are taken. When Henry experienced negative returns early in retirement while taking withdrawals, he had less money in his portfolio to grow over time. To maintain his inflation-adjusted withdrawal rate, Henry needed a bull market at the beginning of retirement.

TABLE 7.8 Returns Analysis Without Withdrawals

Actual Return Sequence with No Withdrawals

Year	Return (%)	Ending Balance ($)
1	–20.00	800,000.00
2	–10.00	720,000.00
3	9.00	784,800.00
4	8.00	847,584.00
5	12.00	949,294.08
6	–10.00	854,364.67
7	–2.00	837,277.38
8	25.00	1,046,596.72
9	27.00	1,329,177.84
10	61.00	2,139,976.32
Average Return	**10.00%**	

Reverse Return Sequence with No Withdrawals

Year	Return (%)	End Balance ($)
1	61.00	1,610,000.00
2	27.00	2,044,700.00
3	25.00	2,555,875.00
4	–2.00	2,504,757.50
5	–10.00	2,254,281.75
6	12.00	2,524,795.56
7	8.00	2,726,779.20
8	9.00	2,972,189.33
9	–10.00	2,674,970.40
10	–20.00	2,139,976.32
Average Return	**10.00%**	

Henry's retirement plan is deterministic because it assumes that returns will be the same each and every year. What Henry and Mr. D didn't understand was that averaging 10 percent over time is very different than getting 10 percent each and every year. As Henry left the office, Mr. D wished he had a more dynamic retirement planning process—one that allowed for varying variables.

Stochastic Planning Using Monte Carlo Simulation

Monte Carlo is a stochastic tool that helps people think in terms of probability and not certainty. As opposed to using a deterministic process, financial planners can use Monte Carlo to simulate risk in investment returns. A financial plan's probability of success can be tested by simulating the variability of investment returns. Typically, to measure this variability, the expected mean and standard deviation of the portfolio's investment returns are used in a Monte Carlo model. What would Mr. D have told Henry had this approach been used?

Using Henry's same information but an expected return of 10 percent with a standard deviation of 17.5 percent, Mr. D can assign success probabilities for how long Henry's money will last. Henry has a 64 percent chance that his portfolio will last 30 years (Figure 7.18). If Henry is not comfortable with that success rate, then Mr. D can increase both expected return and standard deviation, or decrease withdrawals. Mr. D could change the return to 20 percent, but this is obviously not realistic. In Henry's case, it makes more sense to decrease the withdrawal rate. Assuming that Henry will be comfortable with a 70 percent chance of success, then Mr. D needs to lower the annual withdrawal to $55,000 (Figure 7.19).

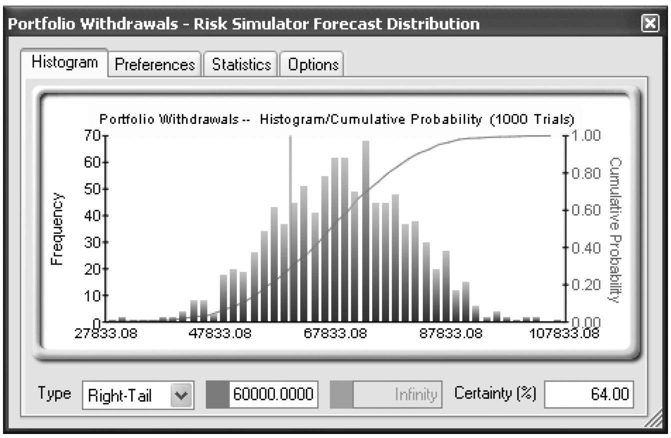

FIGURE 7.18 A 64 percent chance of portfolio survival at $60,000 withdrawals.

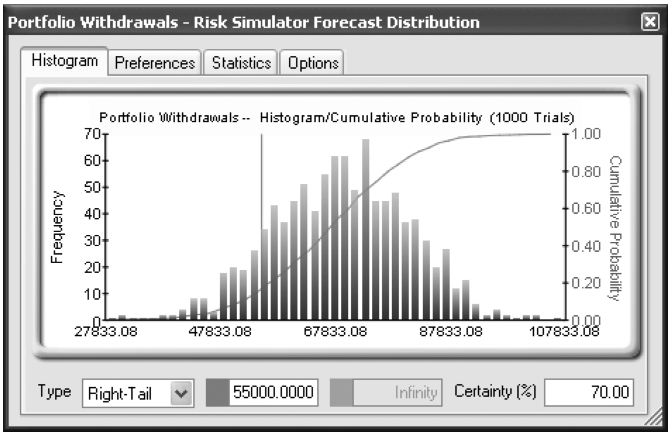

FIGURE 7.19 A 70 percent chance of portfolio survival at $55,000 withdrawals.

Expenses Lower Returns

It is truly a misuse of Monte Carlo and unfair to the client to illustrate a plan without fees if an advisory fee is to be charged. If Mr. Determinist charges Henry a 1 percent advisory fee, then this figure must be deducted from the annual return assumption, which will lower the plan's 30-year success probability to 54 percent. In Henry's case, the standard deviation will still be 17.5 percent, which is higher than a standard deviation of a portfolio that averages 9 percent. One can simply modify the Monte Carlo simulation to allow an advisory fee to be included by maintaining the return and standard deviation assumptions and deducting the advisory fee. For Henry's plan to still have a 70 percent success ratio after a 1 percent fee, he can withdraw an inflation-adjusted $47,000 annually, which is notably different from the $55,000 withdrawal rate before fees.

Success Probability

Monte Carlo educates the client about the trade-off between risk and return with respect to withdrawals. The risk is the success probability with which the client is comfortable. The return is the withdrawal rate. The financial planner should understand that a higher success rate amounts to lower withdrawals. A by-product of this understanding is that a higher success rate also increases the chance of leaving money in the portfolio at the client's death. In other words, Henry may be sacrificing lifestyle for an excessive probability of success. For Henry to have a 90 percent chance that his portfolio will

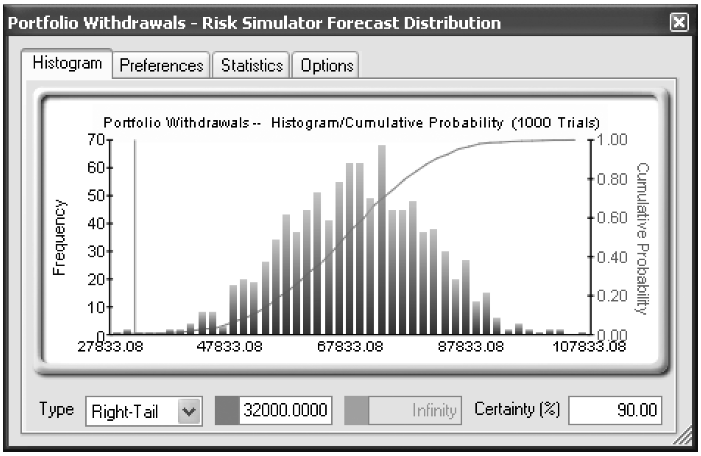

FIGURE 7.20 A 90 percent chance of portfolio survival at $32,000 withdrawals.

last 30 years, he needs to lower his withdrawals to $32,000 (Figure 7.20). An equally important interpretation of this result is that Henry has a 90 percent chance of dying with money in his portfolio. This is money he could have used for vacation, fancy dinners, gifts for his family, or circus tickets.

Success Tolerance

Going back to Henry's example of withdrawing $47,000 each year, if 5,000 simulation trials are run, a 70 percent success rate means that 3,500 times the plan worked. The 1,500 times the plan failed resulted in Henry being unable to take out $47,000 each and every year for 30 years. What is unclear about the 1,500 failures is how many of these resulted in a withdrawal amount marginally less than $47,000. If Henry takes out $47,000 for 29 years and then only withdraws $46,000 in the last year, is this a failure? Monte Carlo says yes. Most people are more flexible.

Establishing a success tolerance alleviates this problem. If Henry's goal is to take out $47,000 but he would be quite happy with $42,000, then he has a success tolerance of $5,000. This is the same as running a simulation using $42,000 with a zero success tolerance; however, the purpose of the success tolerance is to clearly illustrate to Henry the likelihood that a range of withdrawals will be achieved. By accounting for both the complexities of the market and the flexibility of human response to those complexities, Monte Carlo helps Henry understand, prepare for, and properly choose his risk tolerance.

Bear Markets and Monte Carlo

No matter what financial planning method is used, the reality is that a bear market early in retirement will drastically affect the plan. If Mr. D had used Monte Carlo when Henry first came to him and Henry took out $47,000 in Year 1 and $48,410 in Year 2, the portfolio balance at the end of the second year would have been $642,591. For the portfolio to last another 28 years and to preserve a 70 percent success rate, Henry must reduce his withdrawal amount to $31,500! The difficulty of this situation is obvious; however, Mr. D is in a position to help Henry make a decision about maintaining his standard of living versus increasing the chances of running out of money.

Table 7.9 illustrates running a Monte Carlo simulation at the end of each year to determine the withdrawal amount that preserves a 70 percent success rate for Henry's plan.

Like most people, Henry will not be enthusiastic about lowering his retirement salary by as much as 22 percent in any year. Without changing the return assumption, Henry's alternative is to accept a lower success rate. If Henry never adjusted his withdrawal rate from the initial $47,000, after 10 years his portfolio value would be $856,496 and his withdrawal would be $61,324 ($\$47{,}000 \times 1.03^9$). The success probability is 60 percent for a portfolio life of 20 years.

Other Monte Carlo Variables

Monte Carlo can simulate more than just investment returns. Other variables that are frequently simulated by financial planners using Monte Carlo include inflation and life expectancy.

TABLE 7.9 Simulation-Based Withdrawal Rates

Year	Return (%)	Beginning ($)	End Balance ($)	Monte Carlo Withdrawal ($)	Withdrawal Change (%)	Remaining Years
1	–20.00	1,000,000	762,400	47,000	0	29
2	–10.00	762,400	653,310	36,500	–22	28
3	9.00	653,310	676,683	32,500	–11	27
4	8.00	676,683	693,558	34,500	6	26
5	12.00	693,558	735,904	36,500	6	25
6	–10.00	735,904	627,214	39,000	7	24
7	–2.00	627,214	580,860	34,500	–12	23
8	25.00	580,860	685,137	32,750	–5	22
9	27.00	685,137	819,324	40,000	22	21
10	61.00	819,324	1,239,014	49,750	24	20

Inflation Since 1926, inflation has averaged approximately 3 percent annually with a standard deviation of 4.3 percent. In a plan with inflation-adjusted withdrawals, the change in inflation is significant. According to Ibbotson and Associates, inflation averaged 8.7 percent from the beginning of 1973 until the end of 1982. If such a period of inflation occurred at the beginning of retirement, the effect on a financial plan would be terrible.

Life Expectancy Using mortality tables, a financial planner can randomize the life expectancy of any client to provide a more realistic plan. According to the National Center for Health Statistics, the average American born in 2002 has a life expectancy of 77.3 years with a standard deviation of 10. However, financial planners should be more concerned with the specific probability that their clients will survive the duration of the plan.

Monte Carlo Suggestions

Financial plans created using Monte Carlo should not be placed on autopilot. As with most forecasting methods, Monte Carlo is not capable of simulating real-life adjustments that individuals make. As previously discussed, if a portfolio experienced severe negative returns early in retirement, the retiree can change the withdrawal amount. It is also important to realize that Monte Carlo plans are only as good as the input assumptions.

Distributions If Henry is invested in various asset classes, it is important for Mr. D to determine the distinct distribution characteristics of each asset class. The most effective approach to modeling these differences is by utilizing a distribution-fitting analysis in Risk Simulator.

Taxes Henry Tirement's situation involved a tax-deferred account and a pretax salary. For individuals with nontaxable accounts, rebalancing may cause taxes. In this case, a financial planner using Monte Carlo might employ a tax-adjusted return and a posttax salary might be used. The after-tax account balance should be used in the assumptions for clients with highly concentrated positions and a low tax basis who plan to diversify their investments.

Correlations It is important to consider any correlations between variables being modeled within Monte Carlo. Cross-correlations, serial correlations, or cross-serial correlations must be simulated for realistic results. For example, it may be shown that a correlation exists between investment returns and inflation. If this is true, then these variables should not be treated as independent of each other.