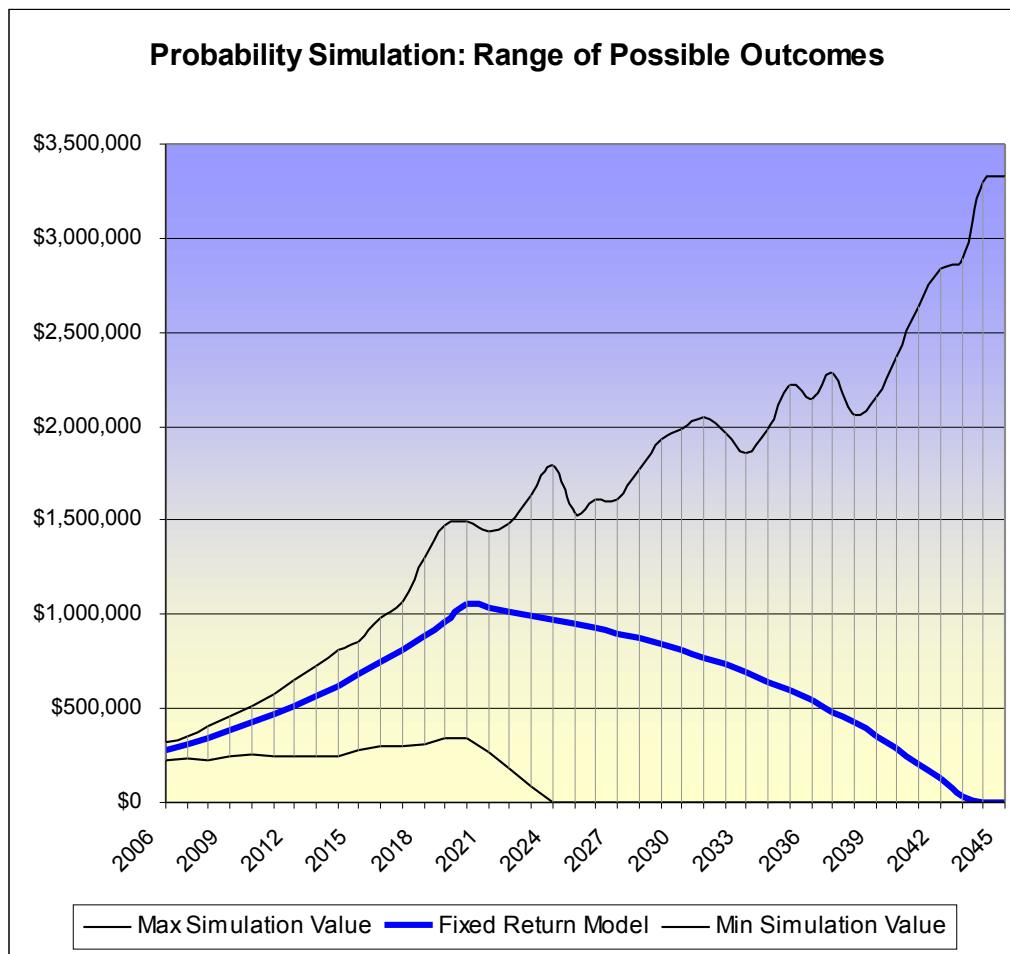


# Using Probability Simulation in Retirement Planning Models



## Abstract:

Probability simulation can help demonstrate the real risk often hidden in retirement planning models. Even a simple planning model can have a huge range of possible outcomes; this paper discusses techniques for using Monte Carlo simulation to identify risk and using interactive simulations to find best-case retirement models.

The spreadsheet used to generate the data and charts in this paper is available for download on our website. Use of the spreadsheet requires the RiskAMP Monte Carlo Add-in. To download the spreadsheet or a free trial of the RiskAMP Add-in, visit our site at <http://www.riskamp.com>.

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A basic retirement planning model includes periodic contributions prior to retirement, an expected return on retirement funds, and a periodic withdrawal following retirement. This model can be used to determine the level of contribution required, and the necessary returns, to support various levels of retirement income. However, a flat model often understates risk inherent in retirement planning. A Monte Carlo probability simulation can be used to expose and highlight this risk, and to demonstrate confidence in returns – that is, the likelihood that a given model will in fact support the desired retirement income.

## A Simple Retirement Plan

For the purposes of this paper, we use a simple retirement planning model with set characteristics (the model is contained in a spreadsheet which is available for download from our website). The model is based on the following parameters:

### Retirement Model Parameters

Starting Year	2006
Starting Balance	\$250,000
Expected Return	7.9%
Standard Deviation of Return	5.3%
Annual Contribution Until Retirement	\$10,000
Retirement Year	2021
Annual Withdrawal After Retirement	\$100,000

Note that this model is extremely simplistic; it omits, among other things, tax and insurance. In this model, a fixed contribution is made every year until retirement. Following retirement, a fixed withdrawal is made each year until the end of the model or the portfolio value falls to zero. The model calculates portfolio value until the year 2045; we assume that life expectancy falls within this range.

## Fixed Return Model

In the spreadsheet model, we first assume that the expected return – 7.9% – will hold for each period of the model. By retirement (2021), the portfolio value has grown to \$1,051,516. In this model, the portfolio value peaks at retirement, then declines; the portfolio can support a fixed retirement income of \$100,000 until 2044. In the last year of the model, 2045, the portfolio value has dropped to zero.

### Results of Fixed Returns Model

Value at Retirement	\$1,051,516
Closing Balance	\$0
Last Year with a Positive Balance	2044

## Probability Simulation

To create a probability simulation model, we start with random returns in each period. Instead of a fixed return of 7.9%, we generate random values using the expected return and standard deviation of the investment portfolio<sup>1</sup>. The portfolio values at retirement and at the end of the model are calculated based on compounding these random returns.

When the simulation is run, this process is repeated over and over and the results of each trial are stored. The simulation analysis is based on the characteristics of each of these trials. The results discussed here were generated using 1,000 trials of the simulation – meaning the model was run, based on randomly generated returns, 1,000 times.

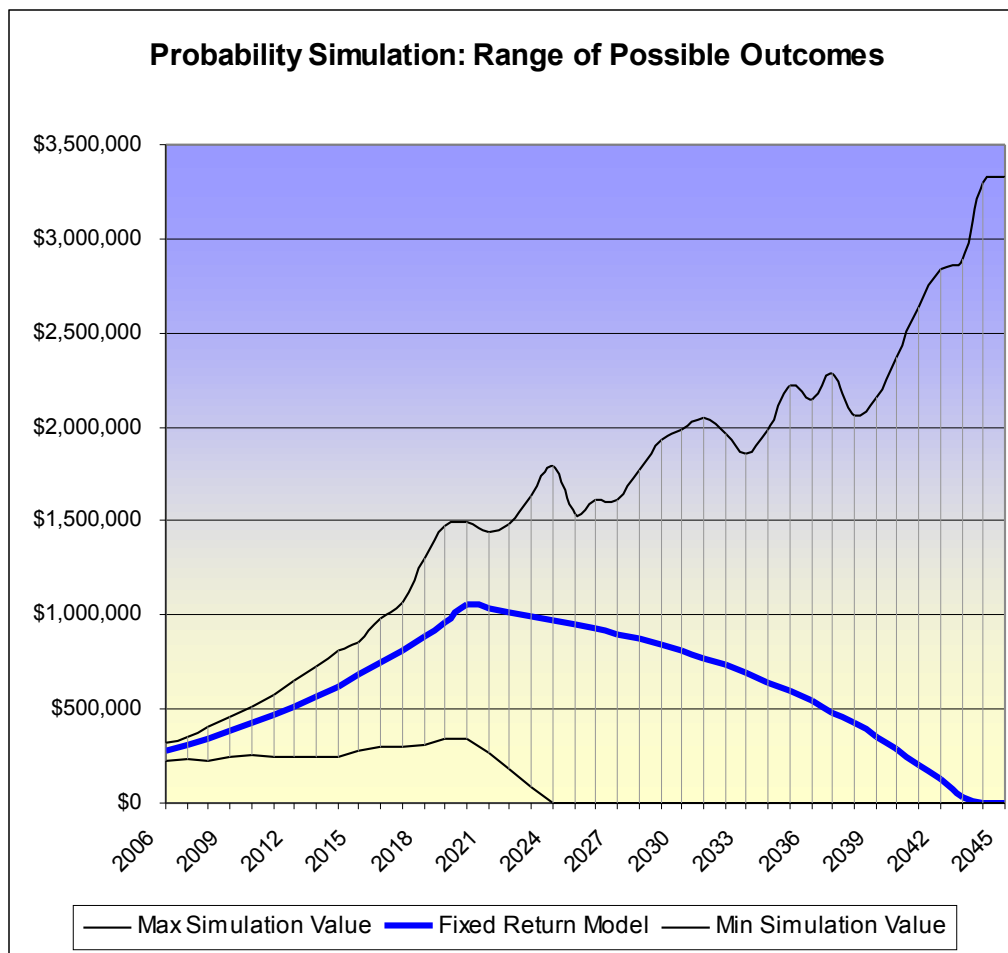


Figure 1: Range of possible outcomes

The shaded area of figure 1 shows the huge range of possible outcomes from the probability simulation (the heavy line represents the expected performance of a fixed-return model, as described above). At the end of the model, the portfolio value ranges from zero to over \$3,000,000. It should be immediately apparent that random chance can have a significant impact on the retirement portfolio.

<sup>1</sup> In this model, we assume a normally-distributed portfolio return.

## Analyzing a Probability Simulation

In the probability simulation, we run the scenario over and over again 1,000 times, generating different results. To analyze the simulation, we look at the number of times that the result was above or below some value. For example, in this simulation the final value of the portfolio was greater than zero 51 times out of 1,000; in the rest of the trials, the value dropped to zero. Therefore we can say that in the simulation, there was only a 5.1% chance that the portfolio value was positive at the end of the model (and therefore a 94.9% chance that the value dropped to zero).

The probability simulation cannot say with certainty that anything will or will not happen. Simulation is used to derive these probabilities, or confidence levels, so that we can understand the relative likelihood that an event will or will not occur.

We can also look at the average (mean) result, the minimum and maximum results, and so on. Figure 1, above, shows a shaded range of all the possible outcomes of the simulation. The chart is based on the minimum and maximum values of the portfolio at each year of the model. A more useful analysis will remove the highest and lowest values (the “outliers”) for a picture of likely outcomes.

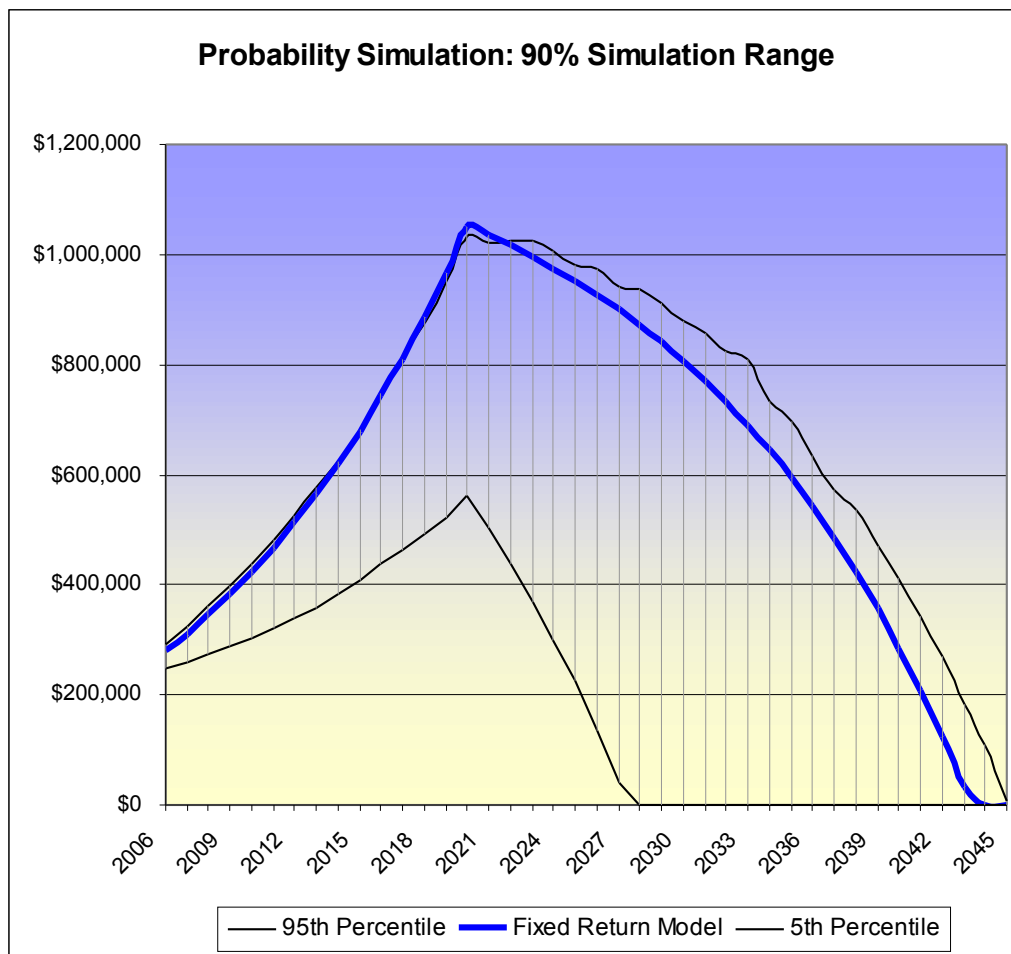
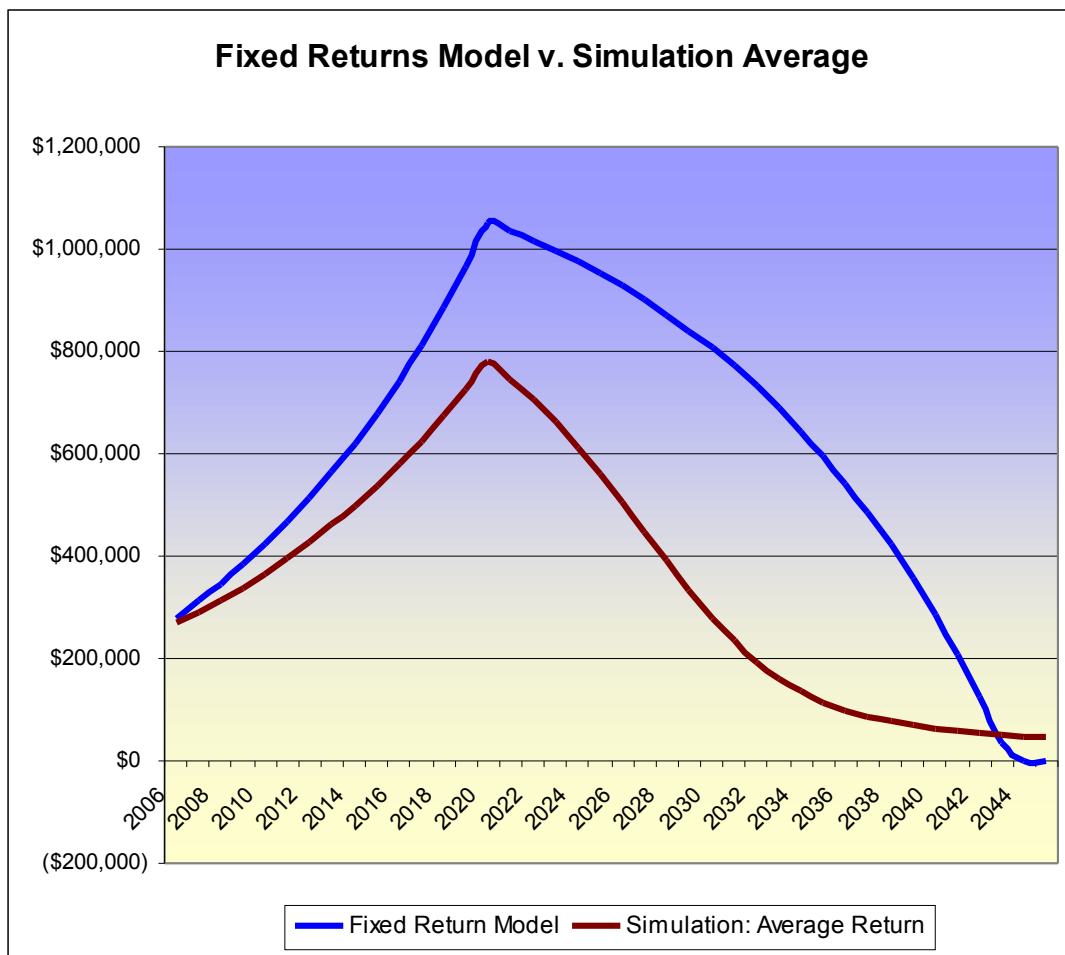


Figure 2: Middle 90% of possible outcomes

Figure 2 shows the range of outcomes with the top 5% (the best) and bottom 5% (the worst) outcomes

removed. In the simulation, 90% of possible outcomes fall within this range, so there is a 90% probability that any given outcome will fall in the range. This chart shows, however, that the vast majority of cases fall below the fixed return model. This illustrates the risk inherent in this model – only in a small fraction of the possible outcomes is the result equal to or better than that described by the fixed return model.

Taking the average results over all the trials of the simulation demonstrates that the probable outcome of the model is worse than the fixed returns model.



For some key values in the model, the average simulation results are as follows:

**Average Simulation Results<sup>2</sup>**

Value at Retirement	\$782,008
Closing Balance	\$46,605
Last Year with a Positive Balance	2033

<sup>2</sup> Because probability simulations are based on random data, the exact numbers returned in each simulation will be different. If you run a simulation on the spreadsheet used to generate these results, you will likely see a negligible difference. The more trials that are run, however, the more similar the final results will be.

Compare these results to the results of the fixed-returns simulation above. On average in the simulation, the portfolio value drops to zero in 2033 – more than 10 years earlier than in the fixed model. Depending on life expectancy, this could have a significant impact on retirement planning.

The average expected value at retirement in the simulation is \$782,008, compared to \$1,051,516 in the fixed-returns model. The reason for this is the compounding of interest in the portfolio prior to retirement. With a fixed rate, compounding and growth are assured. If the rate is variable, however, the portfolio value in the initial periods may be lower; and that lower value, after many periods of compounding, has an outsize effect on the portfolio value at the time of retirement.

Analysis of the simulation can look at data at any point in the retirement model. For example, we can test the model to see the likelihood that the portfolio value will be positive in any particular year:

#### **Probability of Positive Portfolio Value**

Retirement Year	2021
Likelihood of Positive Value in 2026	100%
Likelihood of Positive Value in 2031	69%
Likelihood of Positive Value in 2036	27%
Likelihood of Positive Value in 2041	11%

Therefore in the simulation, there is a 69% chance that the portfolio value will be positive in 2031, but only a 27% likelihood that the portfolio will have a positive value in 2036. Depending on life expectancy, we can use this analysis to assess the likelihood that the retirement model will succeed.

### **Interactive Simulation Modeling**

One of the primary benefits of using probability simulation in a spreadsheet model is the ability to alter the input parameters and re-run the simulation, to determine the effect of changes to the input parameters on the long-term simulation results. This interactive modeling can be used to create more effective models that have a greater probability of achieving a particular goal.

By changing the input parameters of the model and re-running the probability simulation, we can obtain very different results. In this model, for example, changing the retirement age from 2021 to 2024 – an additional three years work – changes the average value of the portfolio at retirement from \$782,008 to \$982,103 – an increase of 26%. The average closing balance changes from \$46,605 to \$412,854, a roughly 10-fold increase. The probability that the portfolio will have a positive balance in 2036 changes from 27% to 85%.

Changing the retirement date, the contribution, the withdrawal amount, or some combination of each input parameter, and testing the results with a probability simulation, can help identify risk in a retirement planning model and locate the optimal conditions for the retirement model. Probability analysis cannot guarantee a particular result, but it can be a very helpful tool in designing a retirement plan.

## **Long-term Planning**

Because retirement planning is a long-term process, the model can be revisited and retested periodically as time goes on. As real data is added to the model, the range of possible outcomes will become smaller and the simulation will be able to give a better projection of potential results. Revisiting this model in the first few years of the plan can provide an opportunity to make necessary changes to help ensure that the long-term goals of the plan are successful.