

Monte Carlo Simulation Using SimVoi

10

10.1 SIMVOI OVERVIEW

SimVoi is a Monte Carlo simulation add-in for Windows Excel 2010 & 2013 & 2016 & 2019 & 365 and Mac Excel 2016 & 2019 & 365.

SimVoi facilitates Monte Carlo simulation by providing:

- Seventeen random number generator functions
- Ability to set the seed for random number generation
- Automatic repeated sampling for simulation
- Frequency distributions of simulation results
- Histogram, cumulative, and bivariate charts
- Value of information for input assumptions of your model

Your spreadsheet model may include uncontrollable uncertainties as input assumptions. Examples are demand for a new product, uncertain variable cost of production, or competitor reaction. You can use simulation to determine the uncertainty associated with the model's output (annual profit). You assess the probabilities for the input assumptions, and SimVoi automates the simulation by trying hundreds or thousands of what-ifs consistent with your assessments.

SimVoi provides (1) random number generator functions as inputs for your model, (2) automates Monte Carlo simulation, (3) summarizes results in tables and charts, and (4) computes value of information.

To use SimVoi:

- (1) Refer to the separate “How To Install” PDF file for installation instructions.
- (2) Create a spreadsheet model.
- (3) Optionally use SensIt to identify critical inputs.
- (4) In each input cell of your model enter one of SimVoi's random number generator functions.
- (5) On the TreePlan ribbon, click the SimVoi button.
- (6) Specify the model output cell, information cells, and the number of what-if trials.
- (7) Interpret simulation results. SimVoi gives you tables, histograms, cumulative charts, bivariate charts, and value of information.

All of SimVoi's functionality is in the single SimVoi XLAM file. There is no separate setup file or help file. When you use SimVoi on a Windows computer, it does not create any Windows Registry entries (although Excel may use such entries to keep track of its add-ins).

10.2 USING SIMVOI FUNCTIONS

SimVoi adds seventeen random number generator functions to Excel:

```

RandBeta(alpha,beta,,[MinValue],[MaxValue])
RandBinomial(trials,probability_s)
RandBiVarNormal(mean1,stdev1,mean2,stdev2,correl12)
RandCumulative(value_cumulative_table)
RandDiscrete(value_discrete_table)
RandExponential(lambda)
RandInteger(bottom,top)
RandLogNormal(Mean,StDev)
RandNormal(mean,standard_dev)
RandPoisson(mean)
RandSample(population)
RandTriangular(minimum,most_likely,maximum)
RandTriBeta(minimum,most_likely,maximum,[shape])
RandTruncBiVarNormal(mean1,stdev1,mean2,stdev2,correl12,
[min1],[max1],[min2],[max2])
RandTruncLogNormal(Mean,StDev,[MinValue],[MaxValue])
RandTruncNormal(Mean,StDev,[MinValue],[MaxValue])
RandUniform(minimum,maximum)

```

You can use these functions as inputs to your model by typing in a worksheet cell. Or, in Windows Excel, from the Formulas ribbon, choose Insert Function and select the User Defined category. In Mac Excel, choose Formula Builder from the Formulas ribbon or choose Function from the Insert menu, search for Rand, and select from the User Defined list.

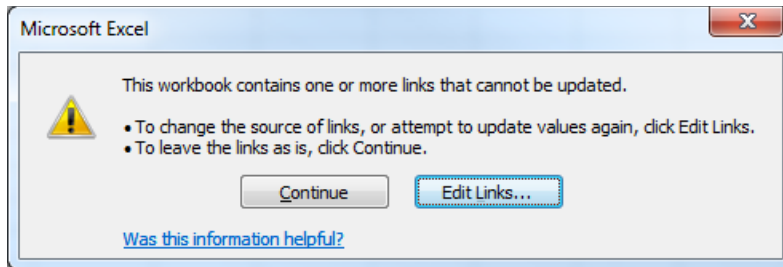
The SimVoi Rand functions include extensive error checking of arguments. After verifying that the functions are working properly, you can substitute the SimVoi Fast functions. These have minimal error checking and therefore run faster.

10.3 UPDATING LINKS TO SIMVOI FUNCTIONS

When you insert a SimVoi random number generator function in a worksheet cell, the function is linked to the folder location of the current SimVoi XLAM file. During the current Excel session, the formula bar shows only the name of the SimVoi function. When you save and close the workbook, Excel saves the complete path to the folder location of the SimVoi function. For example, after closing and reopening the workbook, the formula bar might show =`C:\MyAddIns\SimVoi-Addin.xlam`!RandNormal(100,10). This is standard behavior for Excel user defined functions like the ones contained in the SimVoi XLAM file.

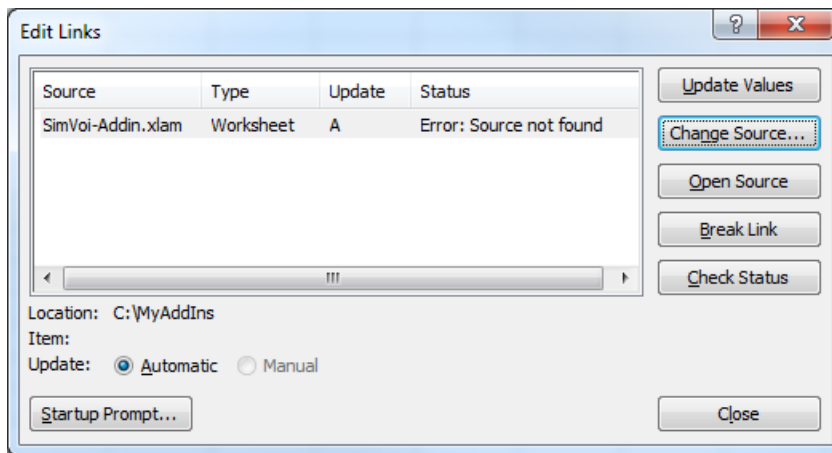
When you open the workbook, Excel looks for the SimVoi XLAM file using the saved path. If you deleted the SimVoi XLAM file or if you opened the workbook on another computer where the SimVoi XLAM file is not located at the same path, Excel cannot find the SimVoi XLAM file at the saved path location. Excel displays a dialog box like the one shown below.

Figure 10.1 Excel Warning To Update Links



Mac Excel will show a similar warning with an Update button and subsequent Edit Links button. If SimVoi is running, click the Edit Links button.

Figure 10.2 Excel Edit Links Dialog Box



To update the links, click the Change Source button. A file browser window will open. Navigate to the SimVoi XLAM file that is running. Select the file using the file browser, and click OK. Back in the Edit Links dialog box, click the Close button.

If you do not immediately update links when the file is opened, you can update the links later if SimVoi is running. To do so, in Windows Excel, choose Edit Links in the Queries & Connections group of the Data ribbon. In Mac Excel 365, from the topmost menu, choose Data > Edit Links, or choose Edit Links in the Connections group of the Data ribbon.

10.4 RANDOM NUMBER SEED

The "Random Number Seed" edit box on the SimVoi dialog box allows you to set the seed for SimVoi's random number generator functions. The seed must be an integer in the range 1 through 2,147,483,647. SimVoi's random number generator functions are completely independent of Excel's built-in RAND function.

Random numbers generated by the computer are actually pseudo-random. The numbers appear to be random, and they pass various statistical tests for randomness. But they are actually calculated by an algorithm where each random number depends on the previous random number. Such an algorithm generates a repeatable sequence. The seed specifies where the algorithm starts in the sequence.

A Monte Carlo simulation model usually has uncontrollable inputs (uncertain quantities using random number generator functions), controllable inputs (decision variables that have fixed values for a particular set of simulation iterations), and an output variable (a performance measure or operating characteristic of the system).

One use of the random number seed is to reduce variation. For example, a simple queuing system model may have an uncertain arrival pattern, a controllable number of servers, and total cost (waiting time plus server cost) as output. To evaluate a different number of servers, specify the same seed before generating the uncertain arrivals. The variation in total cost will depend primarily on the different number of servers, not on the particular sequence of random numbers that generates the arrivals.

10.5 EXAMPLE MODEL

In this example the analyst is interested in the uncertainty about cash flow for a software development project. It is difficult to express the uncertainty about cash flow directly, so the analyst has constructed a simple what-if spreadsheet model where the cash flow depends on assumptions about demand and costs. This analysis is based on a fixed price, but the other model inputs are uncertain.

Figure 10.3 Display of Example Model

	A	B	C	D	E	F	G	H	I
1	Software Decision Analysis								
2									
3	Controllable Input Variable								
4		Unit Price	\$79						
5	Uncertain Input Variables								
6		Units Sold	898	Truncated Normal	Mean=1000, StDev=200, Min=500, Max=1500				
7		Unit Variable Cost	\$8.36	Triangular	Min=\$6, Mode=\$8, Max=\$11				
8		Fixed Costs	\$12,000	Discrete	Value	Probability			
9	Output Variable				\$10,000	0.3			
10		Net Cash Flow	\$51,435		\$12,000	0.5			
11					\$15,000	0.2			

To show the use of several random number generator functions, we use the truncated normal, triangular density, and a discrete distribution. In your own initial analysis of a problem, you might choose to use the triangular density with estimates of the minimum, most likely, and maximum values for each input assumption.

Figure 10.4 Formulas of Example Model

	A	B	C
3	Controllable Input Variable		
4		Unit Price	\$79
5	Uncertain Input Variables		
6		Units Sold	=randtruncnormal(1000,200,500,1500)
7		Unit Variable Cost	=randtriangular(6,8,11)
8		Fixed Costs	=randdiscrete(F9:G11)
9	Output Variable		
10		Net Cash Flow	=C6*(C4-C7)-C8

After entering random number generator functions, recalculate the worksheet to verify that the functions and the output function Net Cash Flow are generating appropriate values. To recalculate, in Windows Excel press F9 repeatedly. In Mac Excel, hold down the Command key and press the = key repeatedly.

10.6 MONTE CARLO SIMULATION

After you specify random number generator functions as inputs to the model, to perform Monte Carlo simulation choose TreePlan (ribbon) > SimVoi (button). The SimVoi dialog box appears.

Figure 10.5 SimVoi Dialog Box for Example Simulation

The example model is in a worksheet named Model.

Select the Output Value Cell edit box, and point to a single cell on your worksheet. The output cell must contain a formula that depends (usually indirectly) on the model inputs determined by the random number generator functions. In the example, the Output Value Cell is C10 on the Model worksheet, so the edit box displays Model!\$C\$10.

Information Cells are any other cells that you want to monitor for simulation results. In the example, the range C6:C8 is selected. All Information Cells must be on a single worksheet, which may be different from the worksheet containing the Output Value Cell. To select multiple cells or multiple ranges, select the first cell or contiguous range of cells, and then hold down the Ctrl key (Windows) or Command key (Macintosh) while you select the other cells or ranges of cells.

Click the Monte Carlo Simulation Only option button, select the Number of Trials edit box, and type an integer value for the number of what-if trials. This value, sometimes called the sample size or number of iterations, specifies the number of times the worksheet will be recalculated to determine output values of your model. One row is needed for each trial, and several additional rows are used for labels, so the number of trials is limited to slightly more than one million in XLSX workbooks. In the example, the Number of Trials is 500.

If you specify one or more Information Cells, you can check the Bivariate Charts box to obtain correlations and charts. The correlations are based on the total Number of Trials, but you may specify a smaller Number of Points for Each Bivariate Chart if you think the scatter pattern may be obscured by a large number of points. In the example, the Number of Points for Each Bivariate Chart is 100.

If you want a cumulative relative frequency chart in addition to a histogram for each variable, check the Cumulative Charts box, and specify the Number of Points for Each Cumulative Chart. In the example, the number of points is 100.

Leave the Random Number Seed unchanged, or select the Random Number Seed edit box, and type a number between 1 and 2,147,483,647. Use an integer value without commas or other separators. In the example, the seed is 12345678.

For terse help, click the Help button. SimVoi will create a help worksheet in your current workbook.

To start the simulation, click the Simulate button. Be sure to wait until all calculations and charts are complete.

10.7 SIMULATION DATA

SimVoi creates a new worksheet in your Excel workbook named SimVoi.1 Simulation Data. Column A shows an integer for each trial 1 through the Number of Trials you specified. Column B shows the result in the Output Value Cell, and subsequent columns show results for each Information Cell.

SimVoi looks for text labels one or two cells to the left and one or two cells above the Output Value Cell and each Information Cell. If text is found, the text is shown in row 1; otherwise, the cell address is shown.

Figure 10.6 First Ten Trials of Simulation Data

	A	B	C	D	E
1	Trial	Net Cash Flow	Units Sold	Unit Variable Cost	Fixed Costs
2	1	\$48,155	854	\$8.58	\$12,000
3	2	\$70,683	1170	\$8.32	\$12,000
4	3	\$86,437	1371	\$7.20	\$12,000
5	4	\$66,834	1079	\$7.81	\$10,000
6	5	\$77,635	1283	\$9.13	\$12,000
7	6	\$61,920	1060	\$6.41	\$15,000
8	7	\$70,156	1125	\$7.72	\$10,000
9	8	\$90,185	1422	\$8.56	\$10,000
10	9	\$47,412	805	\$7.72	\$10,000
11	10	\$47,154	835	\$8.13	\$12,000

In columns to the right of the simulation results, SimVoi also displays the date, time, workbook name, and other information about the simulation.

Figure 10.7 SimVoi Summary Information on Simulation Data Sheet

	G	H	I
1	SimVoi Simulation Data		
2			
3	Date		(current date)
4	Time		(current time)
5			
6	Workbook		(file name)
7			
8	Number of Trials		500
9	Seed		12345678
10			
11	Output Value Worksheet		Model
12	Output Value Cell		\$C\$10
13	Output Value Label		Net Cash Flow
14			
15	Information Worksheet		Model
16	Information Cell		\$C\$6
17	Information Label		Units Sold
18			
19	Information Worksheet		Model
20	Information Cell		\$C\$7
21	Information Label		Unit Variable Cost
22			
23	Information Worksheet		Model
24	Information Cell		\$C\$8
25	Information Label		Fixed Costs

10.8 UNIVARIATE SUMMARY

SimVoi displays the Univariate Summary sheet for each simulation, regardless of which options are selected in the SimVoi dialog box. The top left of the sheet shows summary measures for the output variable and each of the information variables. The summary measures are based on Excel worksheet functions AVERAGE, STDEV, QUARTILE, and SKEW.

Figure 10.8 SimVoi Numerical Output for One-Output Example

	A	B	C	D	E
1	SimVoi Univariate Summary				
2					
3		Net Cash Flow	Units Sold	Unit Variable Cost	Fixed Costs
4	Mean	\$58,661	998	\$8.24	\$11,948
5	St. Dev.	\$13,662	191	\$1.01	\$1,746
6	Mean St. Error	\$611	9	\$0.05	\$78
7	Skewness	+0.146	+0.160	+0.300	+0.606
8					
9	Minimum	\$21,700	520	\$6.15	\$10,000
10	First Quartile	\$49,194	862	\$7.49	\$10,000
11	Median	\$58,210	995	\$8.14	\$12,000
12	Third Quartile	\$67,787	1125	\$8.89	\$12,000
13	Maximum	\$95,938	1485	\$10.79	\$15,000

Below the summary measures are selected percentiles, based on Excel's PERCENTILE worksheet function. The QUARTILE and PERCENTILE functions both use interpolation when necessary, so some values may be fractional, e.g., the first quartile or twenty fifth percentile in this example. Refer to Excel's online help for the interpolation method used by the PERCENTILE function.

Figure 10.9 Portion of Excel PERCENTILE Values

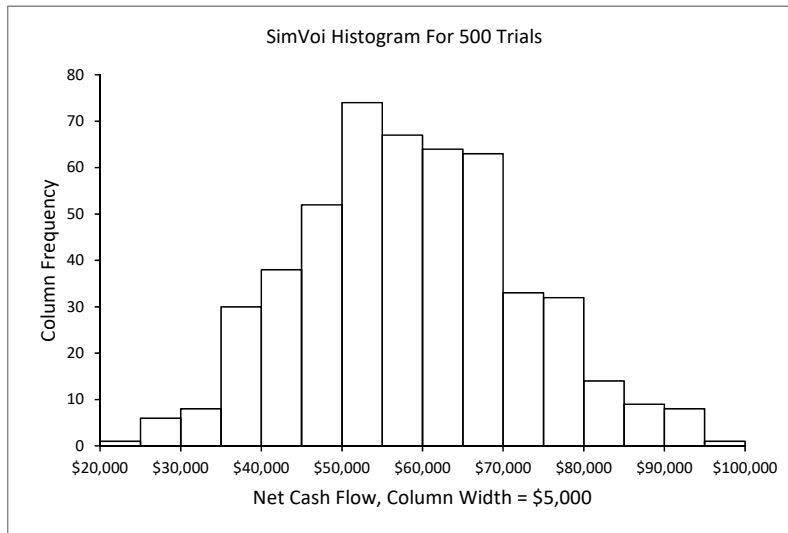
	A	B	C	D	E
16	Excel PERCENTILE				
17		Net Cash Flow	Units Sold	Unit Variable Cost	Fixed Costs
18	0.0%	\$21,700	520	\$6.15	\$10,000
19	0.5%	\$28,253	560	\$6.28	\$10,000
20	1.0%	\$28,448	585	\$6.35	\$10,000
21	2.5%	\$33,934	657	\$6.50	\$10,000
22	5.0%	\$36,675	701	\$6.70	\$10,000
23	10.0%	\$40,857	747	\$6.98	\$10,000
24	15.0%	\$43,876	805	\$7.15	\$10,000
25	20.0%	\$47,316	832	\$7.36	\$10,000
26	25.0%	\$49,194	862	\$7.49	\$10,000

For each variable SimVoi provides a five-column summary with histogram. The top section has simulation information and summary measures.

Figure 10.10 Portion of Univariate Summary for Each Variable

	H	I	J	K	L
1	SimVoi Univariate Summary			Mean	\$58,661
2	Date	(current date)		St. Dev.	\$13,662
3	Time	(current time)		Mean St. Error	\$611
4	Trials	500		Skewness	+0.146
5	Seed	12345678			
6	Workbook	(file name)		Minimum	\$21,700
7				First Quartile	\$49,194
8	Worksheet	Model		Median	\$58,210
9	Cell	\$C\$10		Third Quartile	\$67,787
10	Label	Net Cash Flow		Maximum	\$95,938

In the five-column range, the histogram is a combination chart, using an Excel column chart type for the vertical bars and an XY Scatter chart type for the horizontal axis.

Figure 10.11 Histogram

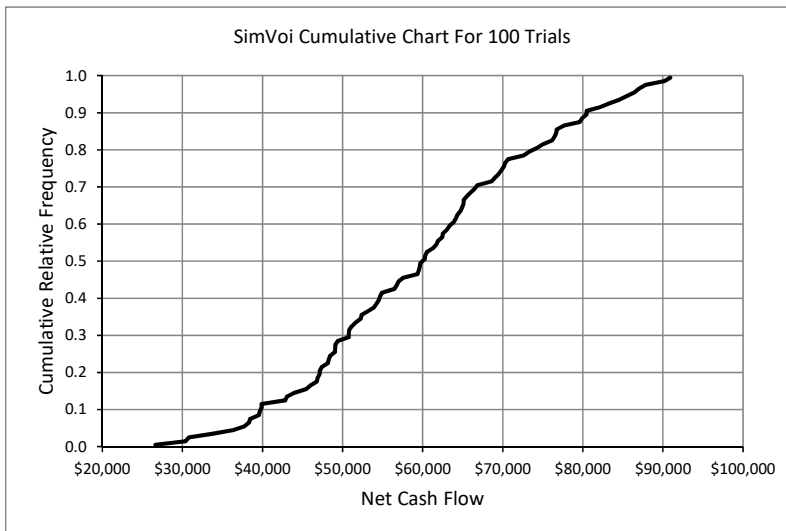
The histogram is based on the numerical values of the frequency distribution located below the histogram and optional cumulative distribution chart. The distribution is computed using Excel's array-entered FREQUENCY worksheet function.

Figure 10.12 Frequency Distribution

	H	I
49	Upper Limit	Frequency
50	\$20,000	0
51	\$25,000	1
52	\$30,000	6
53	\$35,000	8
54	\$40,000	30
55	\$45,000	38
56	\$50,000	52
57	\$55,000	74
58	\$60,000	67
59	\$65,000	64
60	\$70,000	63
61	\$75,000	33
62	\$80,000	32
63	\$85,000	14
64	\$90,000	9
65	\$95,000	8
66	\$100,000	1

If the Cumulative Charts box is checked on the SimVoi dialog box, the chart of cumulative relative frequency is shown below the histogram.

Figure 10.13 Cumulative Chart



The cumulative chart is based on the sorted values and the cumulative relative frequencies, located in columns to the right of the charts for the variables.

Figure 10.14 First Ten Values for Cumulative Charts

	AJ	AK	AL	AM	AN
1	Net Cash Flow	Units Sold	Unit Variable Cost	Fixed Costs	Cumul.Rel.Freq.
2	\$26,634	539	\$6.41	\$10,000	0.005
3	\$30,400	601	\$6.60	\$10,000	0.015
4	\$30,782	614	\$6.63	\$10,000	0.025
5	\$33,722	676	\$6.63	\$10,000	0.035
6	\$36,397	696	\$6.78	\$10,000	0.045
7	\$37,711	701	\$6.87	\$10,000	0.055
8	\$38,326	717	\$6.96	\$10,000	0.065
9	\$38,446	732	\$6.98	\$10,000	0.075
10	\$39,518	743	\$7.04	\$10,000	0.085
11	\$39,668	744	\$7.05	\$10,000	0.095

The cumulative relative frequencies start at $1/(2*N)$, where N is the number of trials, and increase by $1/N$. The rationale is that the lowest ranked value of the sample values from the simulation is an estimate of the population values in the range from 0 to $1/N$. The lowest ranked value is associated with the median of that range.

10.9 BIVARIATE SUMMARY

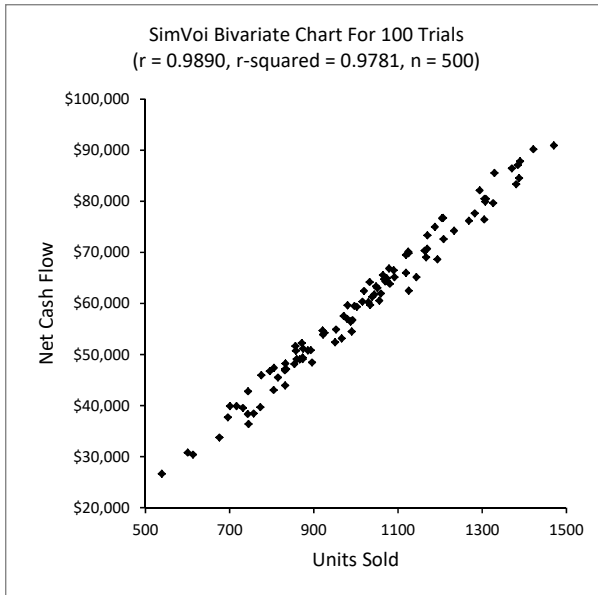
If there are Information Cells and the Bivariate Charts box is checked in the SimVoi dialog box, SimVoi creates a Bivariate Summary sheet. The top left area displays correlation coefficients, r , and coefficients of determination, r -squared, for each pair of variables, based on Excel's CORREL and RSQ worksheet functions.

Figure 10.15 Bivariate Numerical Results

	A	B	C	D	E
1	SimVoi Bivariate Summary				
2					
3					
4	Correlation Coefficient, r				
5	Excel CORREL, 500 Trials				
6		Net Cash Flow	Units Sold	Unit Variable Cost	Fixed Costs
7	Net Cash Flow	1.0000	0.9890	-0.0388	-0.1417
8	Units Sold	0.9890	1.0000	0.0342	-0.0145
9	Unit Variable Cost	-0.0388	0.0342	1.0000	-0.0144
10	Fixed Costs	-0.1417	-0.0145	-0.0144	1.0000
11					
12	Coefficient of Determination, r -squared				
13	Excel RSQ, 500 Trials				
14		Net Cash Flow	Units Sold	Unit Variable Cost	Fixed Costs
15	Net Cash Flow	1.0000	0.9781	0.0015	0.0201
16	Units Sold	0.9781	1.0000	0.0012	0.0002
17	Unit Variable Cost	0.0015	0.0012	1.0000	0.0002
18	Fixed Costs	0.0201	0.0002	0.0002	1.0000

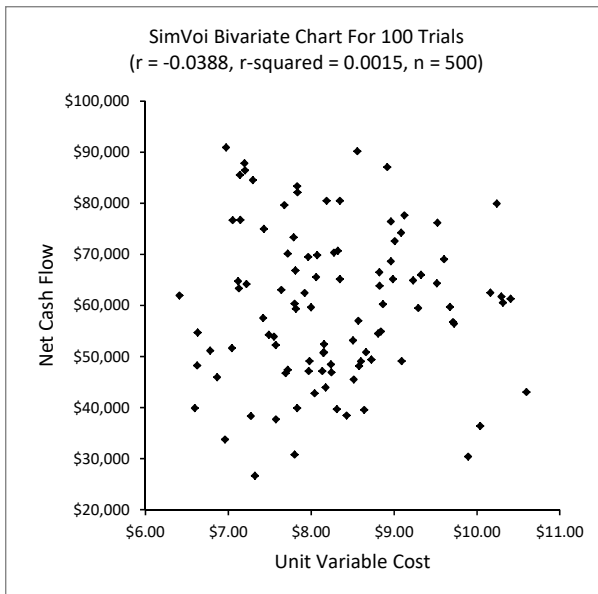
SimVoi creates an XY Scatter chart for each pair of variables. The chart is in the area to the right of the numerical tables for r and r -squared. The top row of bivariate charts have the output variable on the vertical axis.

Figure 10.16 Bivariate Chart With Strong Relationship



For the example, there is a very strong linear relationship between net cash flow and units sold. There is almost no relationship between net cash flow and unit variable cost.

Figure 10.17 Bivariate Chart With Essentially No Relationship



Each bivariate chart is based on data arranged in columns located to the right of the charts.

Figure 10.18 First Ten Trials for Bivariate Charts

	AP	AQ	AR	AS
1	Net Cash Flow	Units Sold	Unit Variable Cost	Fixed Costs
2	\$48,155	854	\$8.58	\$12,000
3	\$70,683	1170	\$8.32	\$12,000
4	\$86,437	1371	\$7.20	\$12,000
5	\$66,834	1079	\$7.81	\$10,000
6	\$77,635	1283	\$9.13	\$12,000
7	\$61,920	1060	\$6.41	\$15,000
8	\$70,156	1125	\$7.72	\$10,000
9	\$90,185	1422	\$8.56	\$10,000
10	\$47,412	805	\$7.72	\$10,000
11	\$47,154	835	\$8.13	\$12,000

The top ten trials of data for the bivariate charts is the same as the top ten trials on the Simulation Data sheet. The entire Simulation Data sheet may be deleted without affecting the display of the bivariate charts.

10.10 VALUE OF INFORMATION

Extending the Monte Carlo simulation example, the decision maker must decide between the software project and a fixed price job that would pay \$50,000 using the same commitment of time and related resources. Before choosing, the decision maker could gather some information to help resolve the uncertainty associated with the software project. Which information about the three uncertainties is most valuable, and how much should the decision maker be willing to pay for the information?

The analyst uses SimVoi's option for Value of Information to help answer the decision maker's questions.

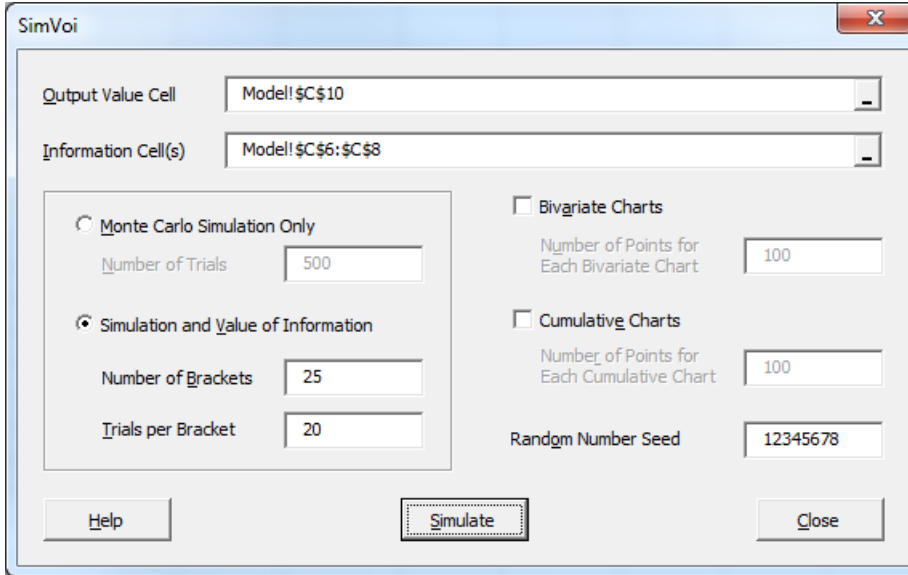
SimVoi is appropriate for this kind of analysis if the Output Value Cell is a monetary value and the Information Cells are uncertain inputs to the model.

The Number of Brackets box specifies the number of equally-probable ranges of values used to approximate the probability distributions for the value of information calculations.

The Trials per Bracket box specifies the number of trial used for approximating each of the brackets.

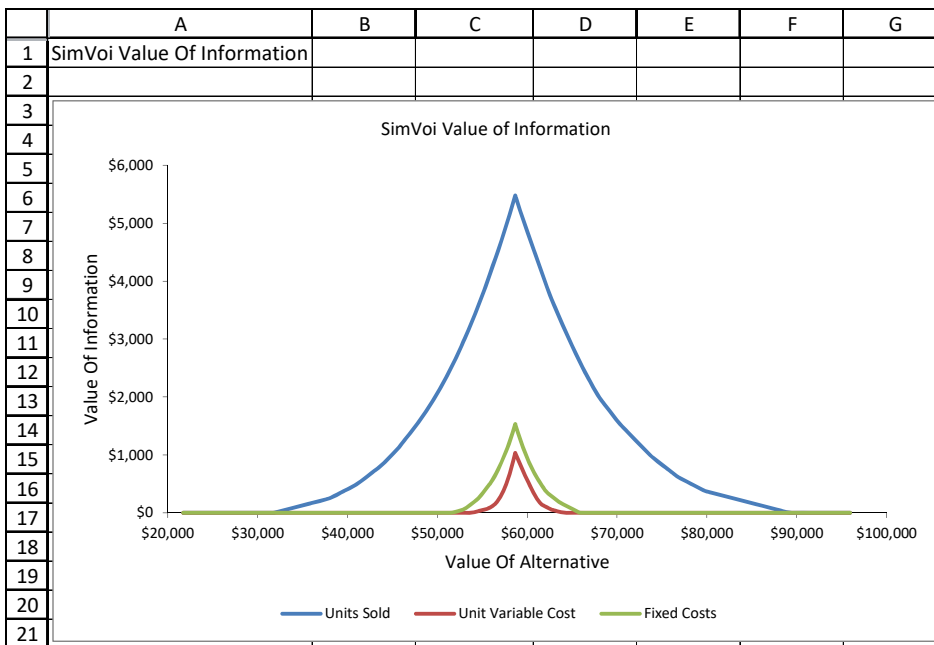
With 25 brackets and 20 trials per bracket, the simulation uses $25 \times 20 = 500$ trials. Using the same random number seed, 12345678, the simulation results will be the same as before. The histograms, cumulative charts, and bivariate charts will also be the same.

Figure 10.19 SimVoi Dialog Box for Simulation and Value of Information



SimVoi creates a chart showing the value of information for each Information Cell.

Figure 10.20 Chart for Value of Information for Each Information Variable



The chart shows how the value of information for the situation described by the model depends on the value of an alternative situation.

Referring to the Univariate Summary worksheet, the minimum value of simulation results for the software project is \$21,700. If an alternative project has an outcome value less than \$21,700, then clearly the software project is preferred, and there is no value for additional information about the three uncertain inputs of the software model.

Similarly, the maximum value of simulation results for the software project is \$95,938. If an alternative project has an outcome value greater than \$95,938, then clearly the alternative project is preferred, and there is no value for additional information about the three uncertain inputs of the software model.

If the alternative project has an outcome value between the two extremes of the software project, there may be some value of obtaining information about the uncertain assumptions used in the software model.

For the software example problem with an alternative project yielding \$50,000, there is a positive value associated with information about Units Sold. There is zero value for information about Unit Variable Cost and Fixed Costs.

When the value of the alternative is \$50,000, the exact value of information can be determined by using the What-If calculations in the Units Sold section of the Value Of Information worksheet.

Figure 10.21 Example of What-If for Units Sold

	J	K	L	M	N	O
24	What-If Input	\$50,000	Value Of Alternative			
25						
26		\$58,661	Average Value Of Simulation			
27		\$60,729	Average Value With Information, Units Sold			
28		\$58,661	Average Value Without Information			
29						
30	What-If Output	\$2,067	Value Of Information, Units Sold			
31						
32						
33		Conditional	Conditional		Data For Chart	
34		Average Value	Average Value		Value Of	Value Of
35	Bracket	Of Simulation	With Information		Alternative	Information
36	1	\$89,201	\$89,201		\$21,700	\$0
37	2	\$79,779	\$79,779		\$21,849	\$0
38	3	\$76,814	\$76,814		\$21,997	\$0
39	4	\$73,781	\$73,781		\$22,146	\$0
40	5	\$70,249	\$70,249		\$22,294	\$0

If you enter \$50,000 into the What-If Input cell for Value Of Alternative and recalculate the worksheet, the What-In Output cell shows \$2,067. This is the most you should pay for perfect information about Units Sold.

Another important use of value of information is sensitivity analysis. Instead of looking at the effects of varying input values or probability, value of information combines both into its measure. By examining the chart, it is easy to see that information about Units Sold is much more valuable than information about Unit Variable Cost or Fixed Costs.

SimVoi determines value of information by first sorting the simulation results for an Information Cell and associated Output Value Cell. SimVoi uses the Information Cell data as the sort key and

sorts from highest value down to lowest value. The Trial number is included to make it easy to verify the calculations.

Figure 10.22 Top Ten Rows of Sorted Data for Conditional EMV

	AN	AO	AP
3		Sort Key	
4	Trial	Units Sold	Net Cash Flow
5	322	1485	\$90,700
6	43	1471	\$90,922
7	188	1469	\$92,973
8	239	1469	\$93,967
9	206	1465	\$91,794
10	236	1462	\$95,938
11	114	1460	\$93,300
12	320	1445	\$92,665
13	136	1430	\$88,405
14	8	1422	\$90,185

Without any additional information, the average value of the simulation model is \$58,661, i.e., the mean of Net Cash Flow shown on the Univariate Summary worksheet.

In this example, the Number of Brackets is 25 and the Trials per Bracket is 20. In the sorted data the first 20-row bracket is rows 5:24. When Units Sold is in the range 1349 to 1485, the associated Net Cash Flow values range from \$83,313 to \$95,938 with average value \$89,201. SimVoi uses the name Conditional Average Value of Simulation for this average, and the value is displayed below the What-If area on the worksheet. If we know that Units Sold is in this high range, average value of the simulation is \$89,201. The second bracket is rows 25:44 with conditional average value \$79,779. And so on, down to the twenty-fifth bracket in rows 485:504 with conditional average value \$31,784.

If we know that Units Sold is in a particular bracket, we compare the conditional average value of the simulation with the value of the alternative, and we choose the highest. The third column below the What-If area contains MAX functions, and the result is Conditional Average Value With Information.

The average of the Conditional Average Value With Information values is the Average Value With Information, Units Sold, shown in the What-If area. Also shown is the Average Value Without Information, i.e., the maximum of the Average Value Of Simulation and the Value Of Alternative. The Value of Information is the difference between the Average Value With Information and the Average Value Without Information.

When the value of the alternative is \$50,000, the value of information is \$2,067. The value of information is highest if the value of the alternative is the same as the average value of the simulation model, i.e., $\$64,139 - \$58,661 = \$5,478$.

The data for the chart is computed using approximately 500 equally-spaced values between the minimum and maximum of the Net Cash Flow values from the simulation, including the value of Average Value Of Simulation.

10.11 RANDOM NUMBER GENERATOR FUNCTIONS

RandBeta

Returns a random value from a beta distribution.

Syntax

RandBeta(alpha,beta,[minimum_value],[maximum_value])

The required arguments alpha and beta determine the shape of the probability density function and correspond to arguments of the same name used by the Excel family of beta functions. The optional arguments correspond to lower bound A and upper bound B in the Excel beta functions.

Remarks

If any argument is nonnumeric, RandBeta returns the #VALUE! error value.

If alpha \leq 0 or beta \leq 0, RandBeta returns the #NUM! error value.

If you omit values for minimum_value and maximum_value, RandBeta returns values with minimum_value = 0 and maximum_value = 1.

Example

The charts show the distribution for RandBeta with shape parameter values of 4 and 2, minimum_value 2 and maximum_value 10.

Figure 10.23 RandBeta Example Probability Density Function

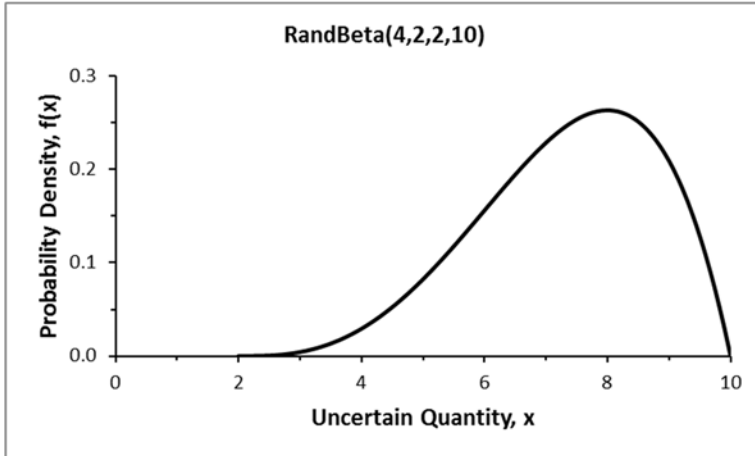
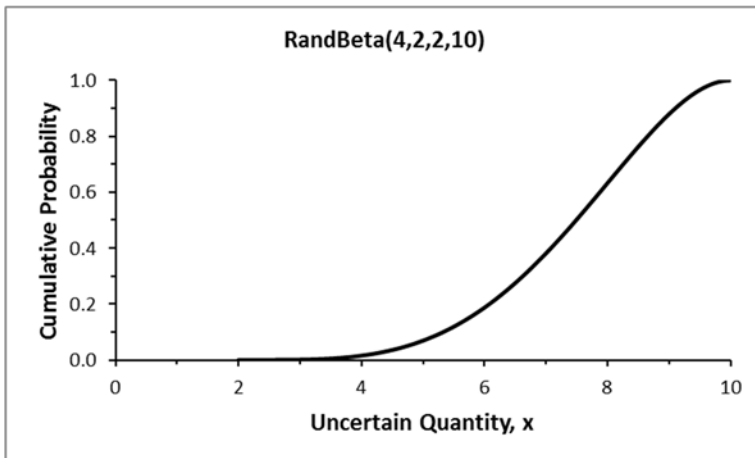


Figure 10.24 RandBeta Example Cumulative Probability Function



RandBinomial

Returns a random value from a binomial distribution. The binomial distribution can model a process with a fixed number of trials where the outcome of each trial is a success or failure, the trials are independent, and the probability of success is constant. RandBinomial counts the total number of successes for the specified number of trials. If n is the number of trials, the possible values for RandBinomial are the non-negative integers $0, 1, \dots, n$.

Syntax

RandBinomial(trials,probability_s)

Trials (often denoted n) is the number of independent trials.

Probability_s (often denoted p) is the probability of success on each trial.

Remarks

Returns #N/A if there are too few or too many arguments.

Returns #NAME! if an argument is text and the name is undefined.

Returns #NUM! if trials is non-integer or less than one, or probability_s is less than zero or more than one.

Returns #VALUE! if an argument is a defined name of a cell and the cell is blank or contains text.

Example

A salesperson makes ten unsolicited calls per day, where the probability of making a sale on each call is 70 percent. The uncertain total number of sales in one day is =RandBinomial(10,0.7)

Figure 10.25 RandBinomial Example Probability Mass Function

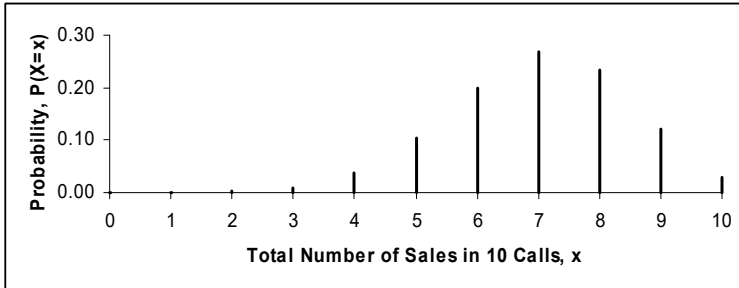
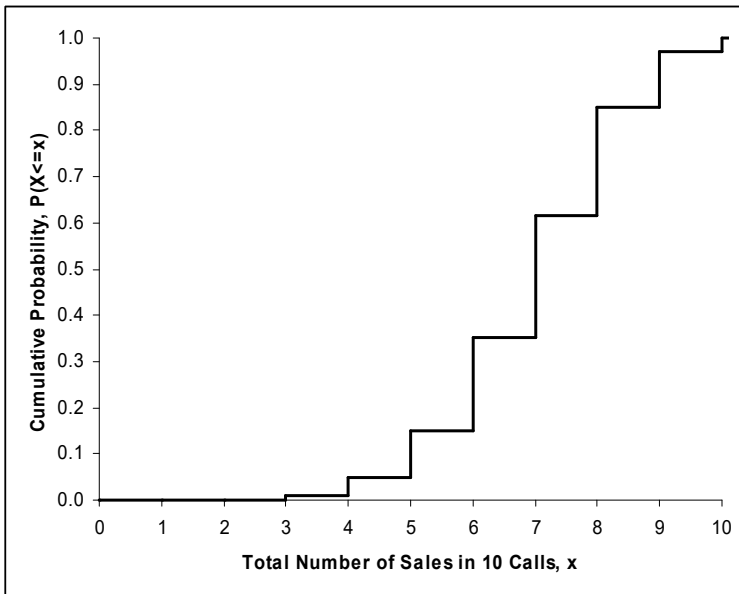


Figure 10.26 RandBinomial Example Cumulative Probability Function



Related Functions

FastBinomial: Same as RandBinomial without any error checking of the arguments.

CritBinom(trials,probability_s,RAND()): Excel's inverse of the cumulative binomial, or CritBinom(trials,probability_s,RandUniform(0,1)) to use the SimVoi Seed feature.

RandBiVarNormal

Returns two random values from a bivariate normal distribution with specified means, standard deviations, and correlation.

To use this random number generator function, select two adjacent cells on the worksheet. Type =RandBiVarNormal followed by numerical values for the five arguments or references to cells containing the values, separated by commas, enclosed in starting and ending parentheses. After typing the ending parentheses, do not press Enter. Instead, hold down the Control and Shift keys while you press Enter, thus "array entering" the function.

Syntax

RandBiVarNormal(mean1,stdev1,mean2,stdev2,correl12)

Remarks

Returns #REF! if the array function is not entered into two adjacent cells.

Returns #NUM! if a standard deviation is negative or the correlation is outside the range between -1 and +1.

Returns #VALUE! if an argument is not numeric.

Example

Select two adjacent cells, type

=RandBiVarNormal(100,10,50,5,0.5)

Hold down Control and Shift while you press Enter.

Related Function

FastBiVarNormal: Same as RandBiVarNormal without any error checking of the arguments. The two adjacent cells must be in the same row.

RandCumulative

Returns a random value from a piecewise-linear cumulative distribution. This function can model a continuous-valued uncertain quantity, X , by specifying points on its cumulative distribution. Each point is specified by a possible value, x , and a corresponding left-tail cumulative probability, $P(X \leq x)$. Random values are based on linear interpolation between the specified points.

Syntax

RandCumulative(value_cumulative_table)

Value_cumulative_table must be a reference, or the defined name of a reference, for a two-column range, with values in the left column and corresponding cumulative probabilities in the right column.

Remarks

Returns #N/A if there are too few or too many arguments.

Returns #NAME! if the argument is text and the name is undefined.

Returns #NUM! if the first (top) cumulative probability is not zero, if the last (bottom) cumulative probability is not one, or if the values or cumulative probabilities are not in ascending order.

Returns #REF! if the number of columns in the table reference is not two.

Returns #VALUE! if the argument is not a reference, if the argument is a defined name but not for a reference, or if any cell of the table contains text or is blank.

Example

A corporate planner thinks that minimum possible market demand is 1000 units, median is 5000, and maximum possible is 9000. Also, there is a ten percent chance that demand will be less than 4000 and a ten percent chance it will exceed 7000. The values, x , and cumulative probabilities, $P(X \leq x)$, are entered into spreadsheet cells A2:B6.

Figure 10.27 RandCumulative Example Spreadsheet Data

	A	B
1	x	$P(X \leq x)$
2	1000	0.0
3	4000	0.1
4	5000	0.5
5	7000	0.9
6	9000	1.0

The function is entered into another cell: =RandCumulative(A2:B6)

Related Function

FastCumulative: Same as RandCumulative without any error checking of the arguments.

Figure 10.28 RandCumulative Example Probability Density Function

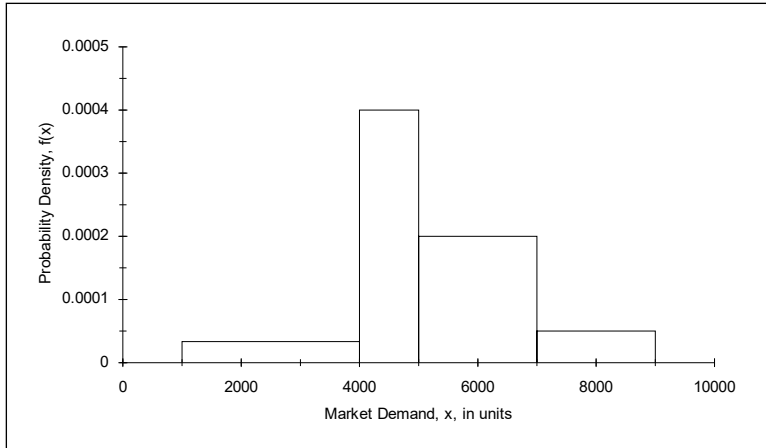
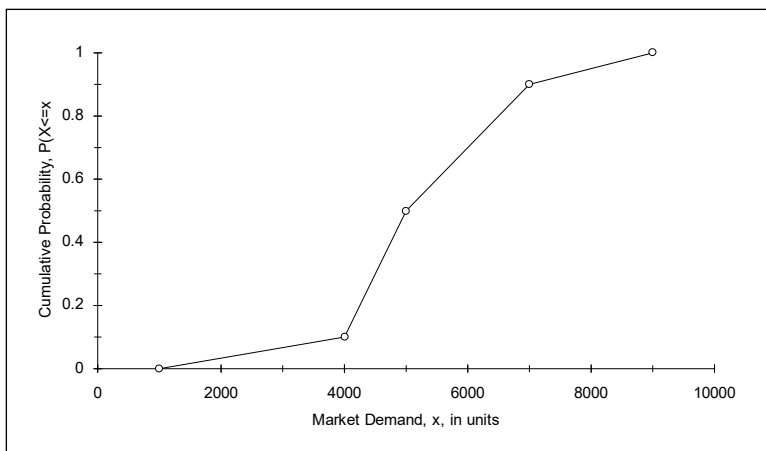


Figure 10.29 RandCumulative Example Cumulative Probability Function



RandDiscrete

Returns a random value from a discrete probability distribution. This function can model a discrete-valued uncertain quantity, X , by specifying its probability mass function. The function is specified by each possible discrete value, x , and its corresponding probability, $P(X=x)$.

Syntax

RandDiscrete(value_discrete_table)

Value_discrete_table must be a reference, or the defined name of a reference, for a two-column range, with values in the left column and corresponding probability mass in the right column.

Remarks

Returns #N/A if there are too few or too many arguments.

Returns #NAME! if the argument is text and the name is undefined.

Returns #NUM! if a probability is negative or if the probabilities do not sum to one.

Returns #REF! if the number of columns in the table reference is not two.

Returns #VALUE! if the argument is not a reference, if the argument is a defined name but not for a reference, or if any cell of the table contains text or is blank.

Example

A corporate planner thinks that uncertain market revenue, X , can be approximated by three possible values and their associated probabilities: $P(X=10000) = 0.25$, $P(X=12000) = 0.50$, and $P(X=15000) = 0.25$. The values and probabilities are entered into spreadsheet cells A2:B4.

Figure 10.30 RandDiscrete Example Spreadsheet Data

	A	B
1	x	$P(X=x)$
2	\$10,000	0.25
3	\$12,000	0.50
4	\$15,000	0.25

The function is entered into another cell: =RandDiscrete(A2:B4)

Related Function

FastDiscrete: Same as RandDiscrete without any error checking of the arguments.

Figure 10.31 RandDiscrete Example Probability Mass Function

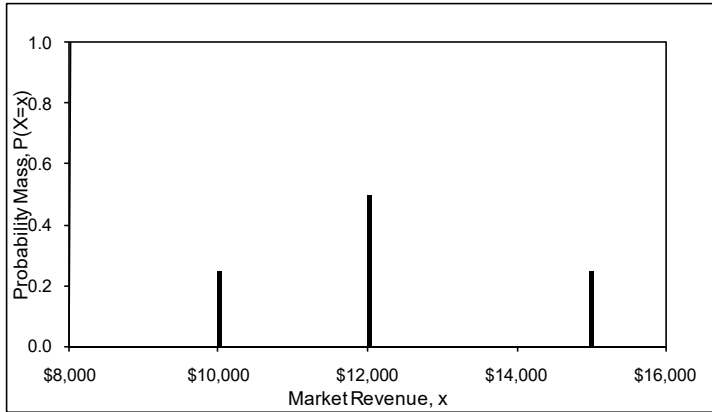
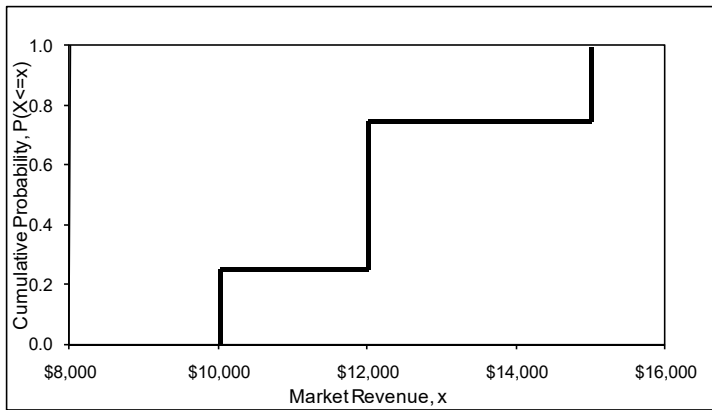


Figure 10.32 RandDiscrete Example Cumulative Probability Function



RandExponential

Returns a random value from an exponential distribution. This function can model the uncertain time interval between successive arrivals at a queuing system or the uncertain time required to serve a customer.

Syntax

RandExponential(lambda)

Lambda is the mean number of occurrences per unit of time.

Remarks

Returns #N/A if there are too few or too many arguments.

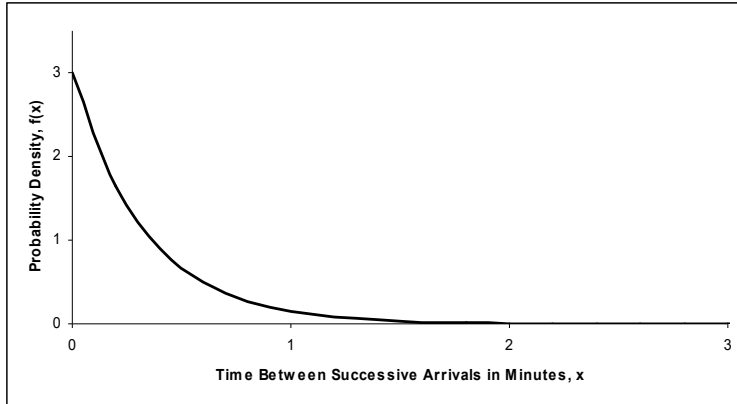
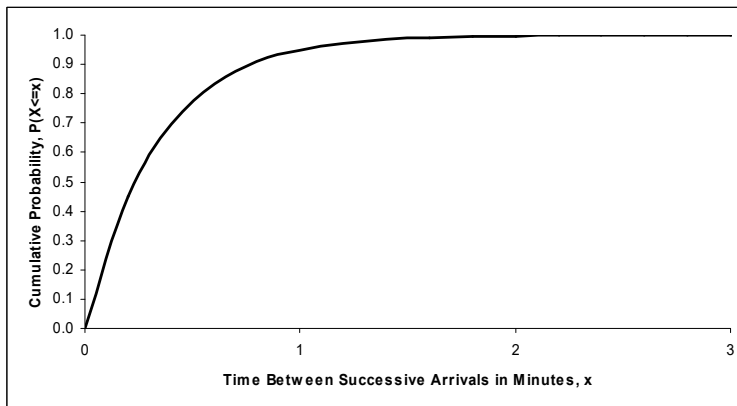
Returns #NAME! if the argument is text and the name is undefined.

Returns #NUM! if lambda is negative or zero.

Returns #VALUE! if the argument is a defined name of a cell and the cell is blank or contains text.

Examples

Cars arrive at a toll plaza with a mean rate of 3 cars per minute. The uncertain time between successive arrivals, measured in minutes, is =RandExponential(3). The average value returned by repeated recalculation of RandExponential(3) is 0.333.

Figure 10.33 RandExponential Example Probability Density Function**Figure 10.34** RandExponential Example Cumulative Probability Function

A bank teller requires an average of two minutes to serve a customer. The uncertain customer service time, measured in minutes, is $\text{=RandExponential}(0.5)$. The average value returned by repeated recalculation of $\text{RandExponential}(0.5)$ is 2.

Related Functions

FastExponential: Same as RandExponential without any error checking of the arguments.

$-\text{LN}(\text{RAND}())/\text{lambda}$: Excel's inverse of the exponential, or

$-\text{LN}(\text{RandUniform}(0,1))/\text{lambda}$ to use the SimVoi Seed feature.

RandPoisson: Counts number of occurrences for a Poisson process.

RandInteger

Returns a uniformly distributed random integer between two integers you specify.

Syntax

`RandInteger(bottom,top)`

Bottom is the smallest integer RandInteger will return.

Top is the largest integer RandInteger will return.

Remarks

Returns #N/A if there are too few or too many arguments.

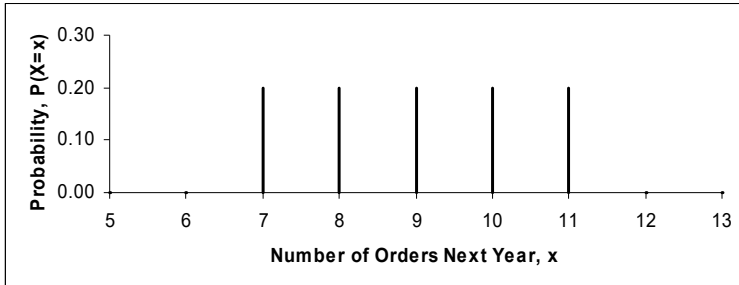
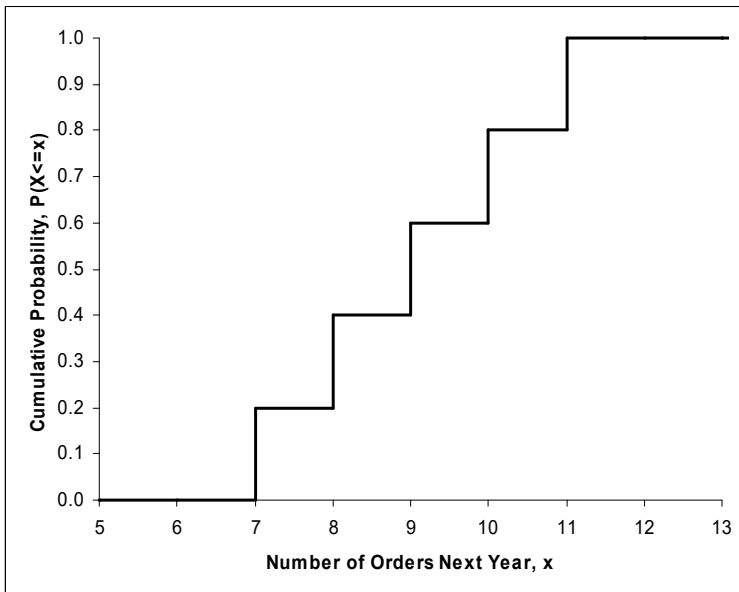
Returns #NAME! if an argument is text and the name is undefined.

Returns #NUM! if top is less than or equal to bottom.

Returns #VALUE! if bottom or top is not an integer or if an argument is a defined name of a cell and the cell is blank or contains text.

Example

The number of orders a particular customer will place next year is between 7 and 11, with no number more likely than the others. The uncertain number of orders is `=RandInteger(7,11)`.

Figure 10.35 RandInteger Example Probability Mass Function**Figure 10.36** RandInteger Example CumulativeProbability Function**Related Function**

FastInteger: Same as RandInteger without any error checking of the arguments.

RandBetween(bottom,top): Excel's function for uniformly distributed integers, without SimVoi's capability of setting the seed.

RandLogNormal

Returns a random value from a lognormal distribution.

Syntax

RandLogNormal(mean,standard_dev)

RandNormal

Returns a random value from a normal distribution. This function can model a variety of phenomena where the values follow the familiar bell-shaped curve, and it has wide application in statistical quality control and statistical sampling.

Syntax

RandNormal(mean,standard_dev)

Mean is the arithmetic mean of the normal distribution.

Standard_dev is the standard deviation of the normal distribution.

Remarks

Returns #N/A if there are too few or too many arguments.

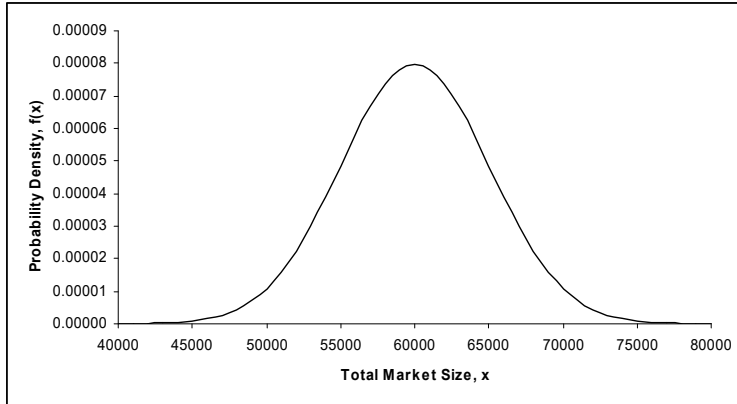
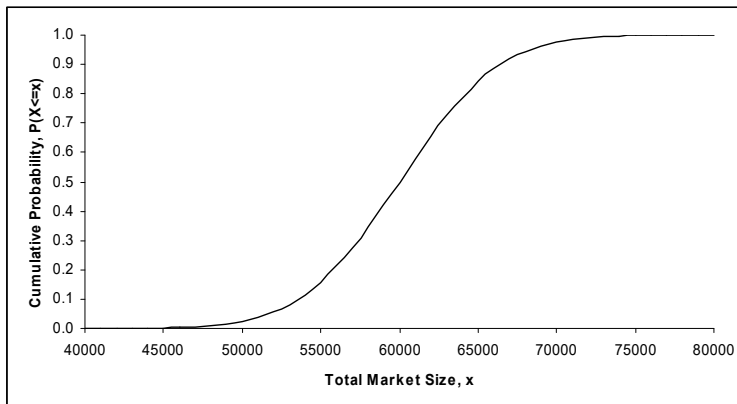
Returns #NAME! if an argument is text and the name is undefined.

Returns #NUM! if standard_dev is negative.

Returns #VALUE! if an argument is a defined name of a cell and the cell is blank or contains text.

Example

The total market for a product is approximately normally distributed with mean 60,000 units and standard deviation 5,000 units. The uncertain total market is =RandNormal(60000,5000).

Figure 10.37 RandNormal Example Probability Density Function**Figure 10.38** RandNormal Example Cumulative Probability Function**Related Function**

FastNormal: Same as RandNormal without any error checking of the arguments.

NormInv(RAND(),mean,standard_dev): Excel's inverse of the normal, or
NormInv(RandUniform(0,1),mean,standard_dev) to use the SimVoi Seed feature.

RandPoisson

Returns a random value from a Poisson distribution. This function can model the uncertain number of occurrences during a specified time interval, for example, the number of arrivals at a service facility during an hour. The possible values of RandPoisson are the non-negative integers, 0, 1, 2,

Syntax

RandPoisson(mean)

Mean is the mean number of occurrences per unit of time.

Remarks

Returns #N/A if there are too few or too many arguments.

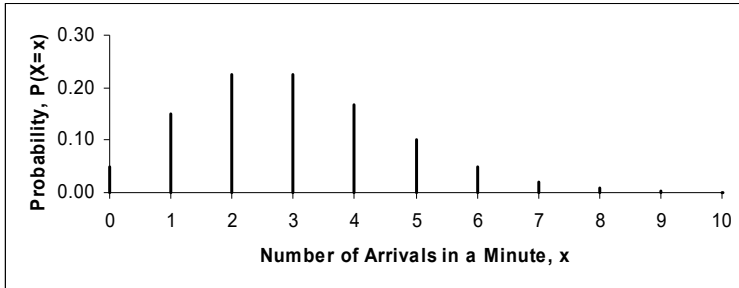
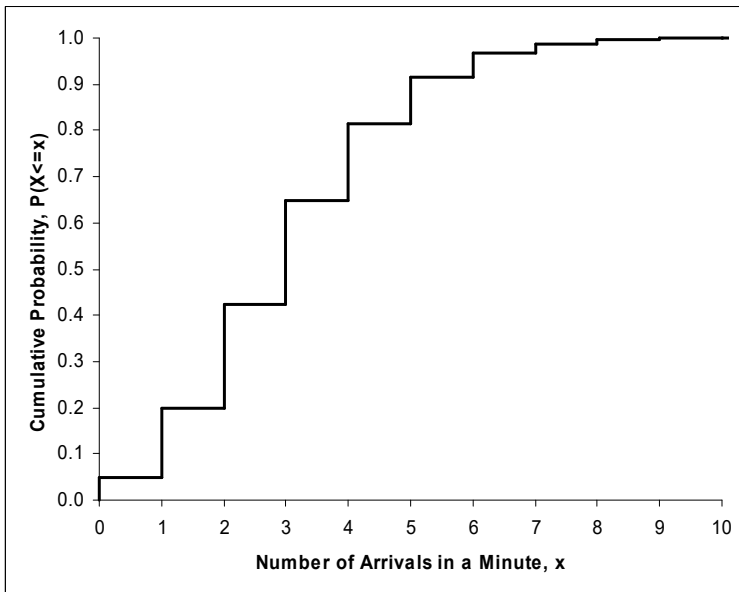
Returns #NAME! if the argument is text and the name is undefined.

Returns #NUM! if mean is negative or zero.

Returns #VALUE! if mean is a defined name of a cell and the cell is blank or contains text.

Examples

Cars arrive at a toll plaza with a mean rate of 3 cars per minute. The uncertain number of arrivals in a minute is =RandPoisson(3). The average value returned by repeated recalculation of RandPoisson(3) is 3.

Figure 10.39 RandPoisson Example Probability Mass Function**Figure 10.40** RandPoisson Example CumulativeProbability Function**Example**

A bank teller requires an average of two minutes to serve a customer. The uncertain number of customers served in a minute is $\text{RandPoisson}(0.5)$. The average value returned by repeated recalculation of $\text{RandPoisson}(0.5)$ is 0.5.

Related Functions

FastPoisson: Same as RandPoisson without any error checking of the arguments.

RandExponential: Describes time between occurrences for a Poisson process.

RandSample

Returns a random sample without replacement from a population.

To use this random number generator function, select a number of cells equal to the sample size, either in a single column or in a single row. Type =RandSample(followed by a reference to the cells containing the population values, enclosed in parentheses. After typing the ending parentheses, do not press Enter. Instead, hold down the Control and Shift keys while you press Enter, thus "array entering" the function.

Syntax

RandSample(population)

The population argument is a reference to a range of values in a single column.

Remarks

Returns #N/A if the population range is not part of a single column.

Returns #REF! if the function is not entered into two adjacent cells.

Example

Type population values into cells A2:A6. For a sample of size 3, select cells B2:B4, and type =RandSample(A2:A6) but don't press Enter. Hold down Control and Shift while you press Enter. Press F9 to recalculate for a different sample.

	A	B
1	Population Data	Sample
2	29	73
3	73	57
4	13	29
5	44	
6	57	

Related Functions

FastColumnSample: Same as RandSample for two adjacent cells in the same column, without any error checking of arguments.

FastRowSample: Same as RandSample for two adjacent cells in the same row, without any error checking of arguments.

RandTriangular

Returns a random value from a triangular probability density function. This function can model an uncertain quantity where the most likely value (mode) has the largest probability of occurrence, the minimum and maximum possible values have essentially zero probability of occurrence, and the probability density function is linear between the minimum and the mode and between the mode and the maximum. This function can also model a ramp density function where the minimum equals the mode or the mode equals the maximum.

Syntax

RandTriangular(minimum,most_likely,maximum)

Minimum is the smallest value RandTriangular will return.

Most_likely is the most likely value RandTriangular will return.

Maximum is the largest value RandTriangular will return.

Remarks

Returns #N/A if there are too few or too many arguments.

Returns #NAME! if an argument is text and the name is undefined.

Returns #NUM! if minimum is greater than or equal to maximum, if most_likely is less than minimum, or if most_likely is greater than maximum.

Returns #VALUE! if an argument is a defined name of a cell and the cell is blank or contains text.

Example

The minimum time required to complete a particular task that is part of a large project is 2 hours, the most likely time required is 4 hours, and the maximum time required is 10 hours.

The function returning the uncertain time required for the task is entered into a cell:
=RandTriangular(4,6,10).

The probability density chart shows the difference between the RandTriangular function with its two linear segments and the smoother RandTriBeta function.

Related Function

FastTriangular: Same as RandTriangular without any error checking of arguments.

Figure 10.41 RandTriangular Example Probability Density Function

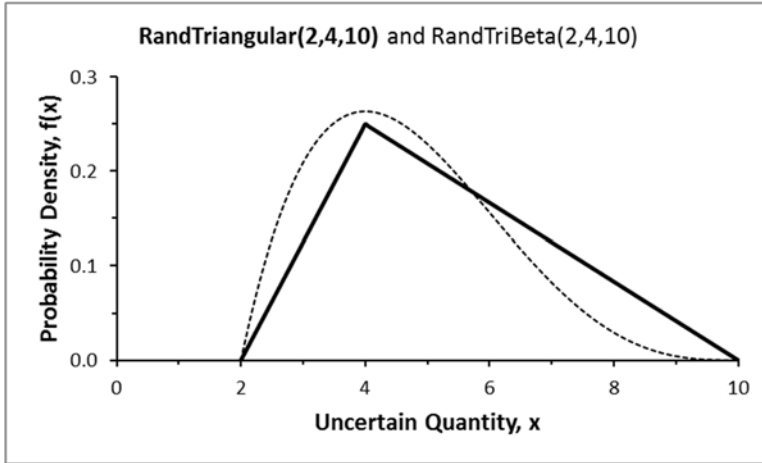
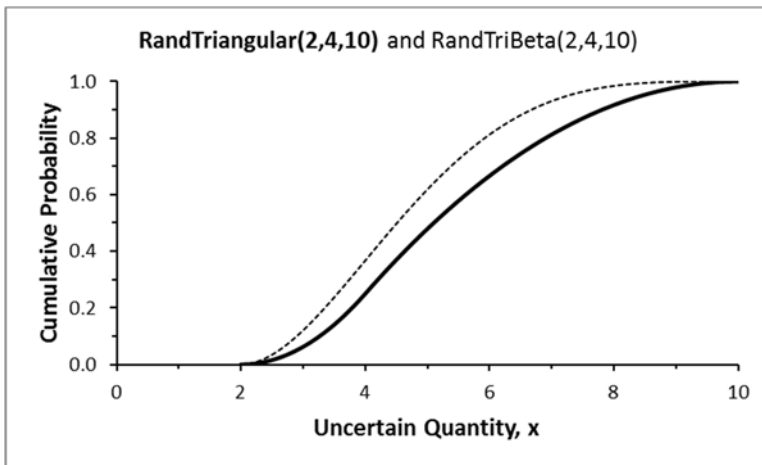


Figure 10.42 RandTriangular Example Cumulative Probability Function



RandTriBeta

Returns a random value from a beta probability density function. This function can model an uncertain quantity where the most likely value (mode) has the largest probability of occurrence, and the minimum and maximum possible values have essentially zero probability of occurrence. The probability density function is a smooth curve between the minimum and the maximum with its highest point at the mode.

Syntax

`RandTriBeta(minimum,most_likely,maximum,shape)`

Minimum is the smallest value RandTriBeta will return.

Most_likely is the most likely value RandTriBeta will return.

Maximum is the largest value RandTriBeta will return.

Shape is an optional parameter which determines the peakedness of the density function. If a value for Shape is omitted, RandTriBeta uses the value Shape = 4.

Remarks

Returns #N/A if there are too few or too many arguments.

Returns #NAME! if an argument is text and the name is undefined.

Returns #NUM! if minimum is greater than or equal to maximum, if most_likely is less than minimum, or if most_likely is greater than maximum.

Returns #VALUE! if an argument is a defined name of a cell and the cell is blank or contains text.

Related Function

FastTriBeta: Same as RandTriBeta without any error checking of arguments.

Example

The minimum time required to complete a particular task that is part of a large project is 2 hours, the most likely time required is 4 hours, and the maximum time required is 10 hours.

The function returning the uncertain time required for the task is entered into a cell: =
RandTriBeta(2,4,10).

The charts show the shapes of RandTriBeta(2,4,10) where the solid line uses the default shape value 4. The flatter dotted line shows RandTriBeta(2,4,10,2), and the peaked dashed line shows RandTriBeta(2,4,10,6).

Figure 10.43 RandTriBeta Example Probability Density Function

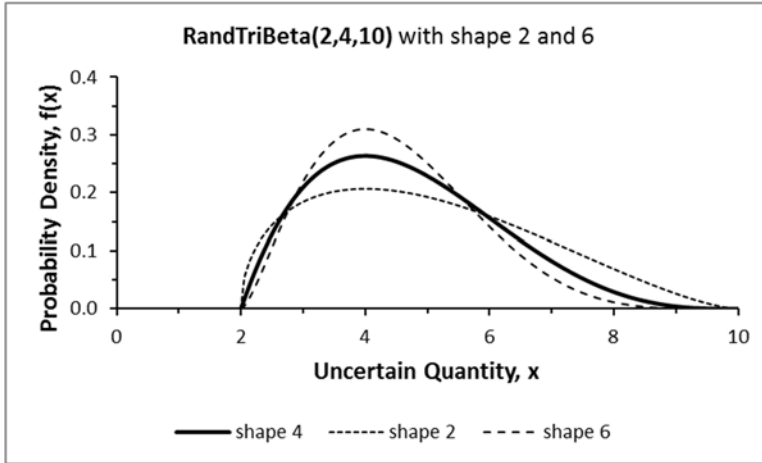
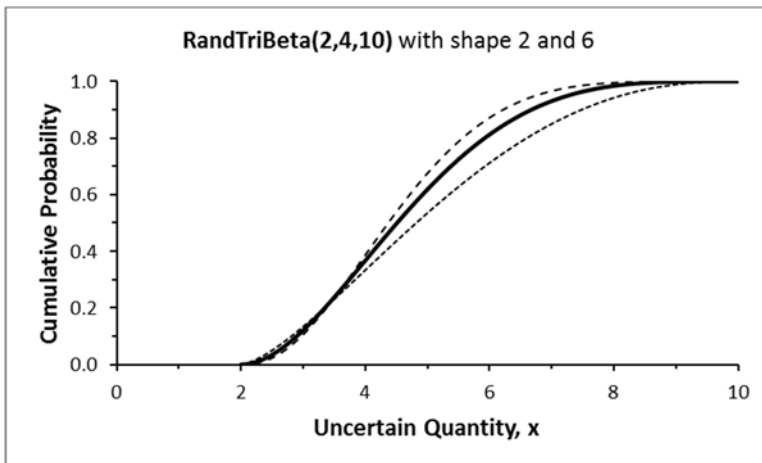


Figure 10.44 RandTriBeta Example Cumulative Probability Function



RandTruncBiVarNormal

Returns a pair of random values from a bivariate normal probability density function with specified correlation, where each marginal distribution is truncated.

Syntax

`RandTruncBiVarNormal(mean1,stdev1,mean2,stdev2,correl12,[min1],[max1],[min2],[max2])`

RandTruncLogNormal

Returns a random value from a truncated log normal probability density function. This function can model an uncertain quantity with a positively-skewed density function where extreme values in the tails of the distribution are not desired. Subranges of the truncated UQ have the same relative probabilities as the same subranges of the original log normal distribution.

Syntax

RandTruncLogNormal(Mean,StDev,MinValue,MaxValue)

Mean and StDev are the parameters for the original log normal distribution.

MinValue is the smallest value RandTruncLogNormal will return.

MaxValue is the largest value RandTruncLogNormal will return.

MinValue and MaxValue are optional arguments.

Remarks: Same as RandTruncNormal

RandTruncNormal

Returns a random value from a truncated normal probability density function. This function can model an uncertain quantity with a bell-shaped density function where extreme values in the tails of the distribution are not desired. Subranges of the truncated UQ have the same relative probabilities as the same subranges of the original normal distribution.

Syntax

RandTruncNormal(Mean,StDev,MinValue,MaxValue)

Mean and StDev are the parameters for the original normal distribution.

MinValue is the smallest value RandTruncNormal will return.

MaxValue is the largest value RandTruncNormal will return.

MinValue and MaxValue are optional arguments.

Remarks

Returns #N/A if a value between MinValue and MaxValue is not found after 10,000 attempts.

Returns #NUM! if MinValue is greater than or equal to MaxValue.

Returns #VALUE! if an argument cannot be interpreted as a numeric value.

Related Function

FastTruncNormal: Same as RandTruncNormal, but with error checking only for maximum of 10,000 attempts.

Example

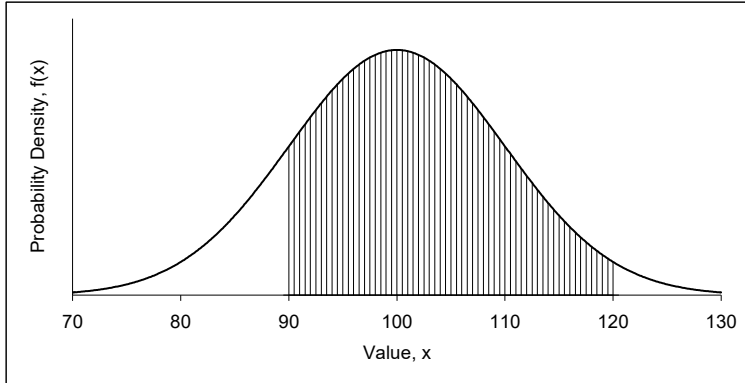
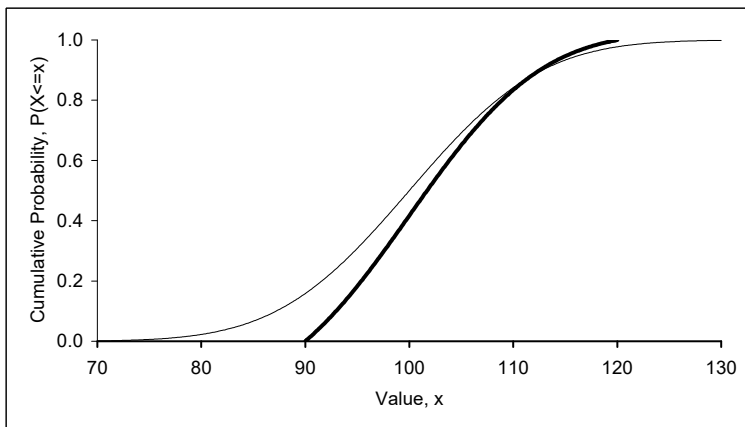
An uncertain quantity has a normal distribution with mean = 100 and standard deviation = 10, but values are restricted between 90 and 120.

The function returning the uncertain quantity is entered into a cell: = RandTruncNormal (100,10,90,120).

Figure 10.45 shows the original normal density function with mean = 100 and standard deviation = 10. The density function is rescaled so that the total area under the curve between 90 and 120 is equal to one. The corresponding cumulative distributions are shown in Figure 10.46.

For example, with the original normal density function, $P(100 \leq X \leq 110) = 0.341$, and $P(110 \leq X \leq 120) = 0.136$. The ratio of $P(100 \leq X \leq 110)$ to $P(110 \leq X \leq 120)$ is $0.341/0.136 = 2.512$. Thus, a value in the range 100 to 110 is approximately 2.5 times as likely as a value in the range 110 to 120.

With the truncated normal density function, $P(100 \leq X \leq 110) = 0.417$, and $P(110 \leq X \leq 120) = 0.166$. The ratio of $P(100 \leq X \leq 110)$ to $P(110 \leq X \leq 120)$ is $0.417/0.166 = 2.512$. Thus, a value in the range 100 to 110 is still approximately 2.5 times as likely as a value in the range 110 to 120.

Figure 10.45 RandTruncNormal Probability Density Function**Figure 10.46** RandTruncNormal Cumulative Probability Function

RandUniform

Returns a uniformly distributed random value between two values you specify. As a special case, RandUniform(0,1) is the same as Excel's built-in RAND() function.

Syntax

RandUniform(minimum,maximum)

Minimum is the smallest value RandUniform will return.

Maximum is the largest value RandUniform will return.

Remarks

Returns #N/A if there are too few or too many arguments.

Returns #NAME! if an argument is text and the name is undefined.

Returns #NUM! if minimum is greater than or equal to maximum.

Returns #VALUE! if an argument is a defined name of a cell and the cell is blank or contains text.

Example

A corporate planner thinks that the company's product will garner between 10% and 15% of the total market, with all possible percentages equally likely in the specified range. The uncertain market proportion is =RandUniform(0.10,0.15).

Figure 10.47 RandUniform Example Probability Density Function

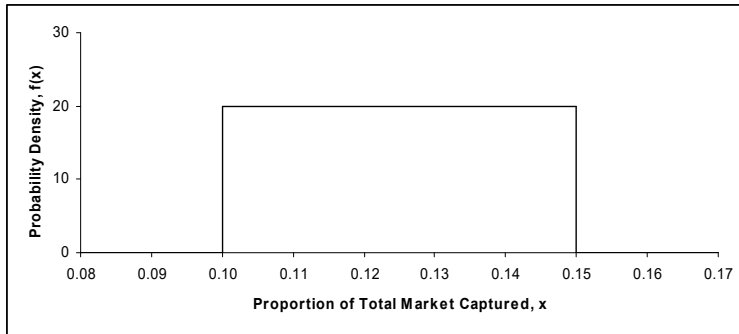
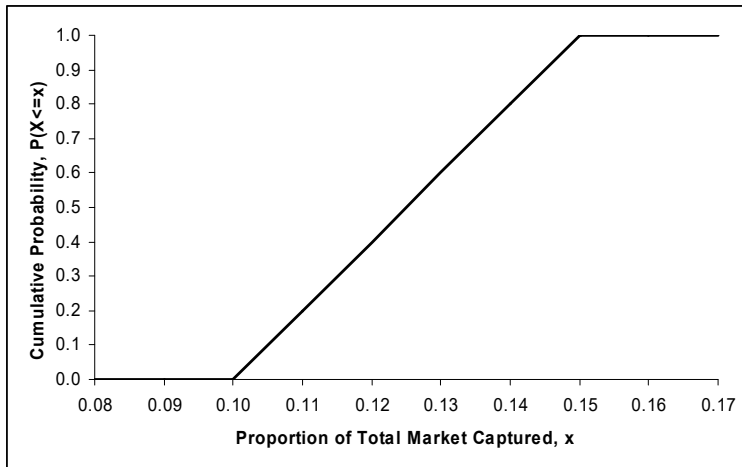


Figure 10.48 RandUniform Example Cumulative Probability Function



Related Function

FASTUNIFORM: Same as RandUniform without any error checking of the arguments.

10.12 SIMVOI TECHNICAL DETAILS

SimVoi's random number generator functions are based on a uniformly distributed random number function called RandSeed which is not directly accessible by the user. RandSeed returns a random value x in the range $0 < x \leq 1$. Internally, decimal values for RandSeed are calculated by dividing a uniformly distributed random integer by 2,147,483,647, which is RandSeed's period. Random integers in the range 1 through 2,147,483,647 are generated using the well-documented Park-Miller algorithm, where each random integer depends on the previous random integer.

When SimVoi starts, the initial integer seed depends on the system clock. Unlike Excel's RAND() function, you can use SimVoi at any time to specify an integer seed in the range 1 through 2,147,483,647, which is used as the previous random integer for the sequence of random numbers generated by the SimVoi functions.

In the SimVoi dialog box, the Random Number Seed edit box changes the seed only for the SimVoi functions; it does not have any effect on Excel's built-in RAND() function.

Each of SimVoi's random number generator functions uses RandSeed as a building block.

RandBeta(alpha,beta, [MinValue],[MaxValue]) uses RandSeed as the cumulative probability in Excel's built-in BETAINV function.

RandBinomial(trials,probability_s) uses RandSeed as the cumulative probability in Excel's built-in CRITBINOM function.

RandBiVarNormal(mean1,stdev1,mean2,stdev2,correl12) uses two values of RandNormal to obtain correlated normal values.

RandCumulative(value_cumulative_table) uses the value of RandSeed, R , searches to find the adjacent cumulative probabilities that bracket R , and interpolates on the linear segment of the cumulative distribution to find the corresponding value.

RandDiscrete(value_discrete_table) compares RandSeed with summed probabilities of the input table until the sum exceeds the RandSeed value, and then returns the previous value from the input table.

RandExponential(lambda) uses the value of RandSeed, R , as follows. If the exponential density function is $f(t) = \lambda \cdot \text{EXP}(-\lambda \cdot t)$, the cumulative is $P(T \leq t) = 1 - \text{EXP}(-\lambda \cdot t)$. Associating R with $P(T \leq t)$, the inverse cumulative is $t = -\text{LN}(1-R)/\lambda$. Since R and $1-R$ are both uniformly distributed between 0 and 1, SimVoi uses $-\text{LN}(R)/\lambda$ for the returned value.

RandInteger(bottom,top) returns $\text{bottom} + \text{INT}(\text{RandSeed} \cdot (\text{top} - \text{bottom} + 1))$.

RandLogNormal(Mean,StDev) transforms Mean and StDev, uses RandSeed and the transformed values in SimVoi's RandNormal function, and transforms the normal result to obtain the log normal value.

RandNormal(mean,standard_dev) uses two RandSeed values in the well-documented Box-Muller method.

RandPoisson(mean) compares RandSeed with cumulative probabilities of Excel's built-in POISSON function until the probability exceeds the RandSeed value, and then returns the previous value.

`RandSample(population)` uses `RandSeed` for each of the cells that were selected when the function was array-entered, avoiding population values that have already been selected, thus providing sampling without replacement.

`RandTriangular(minimum,most_likely,maximum)` uses `RandSeed` once. The triangular density function has two linear segments, so the cumulative distribution has two quadratic segments. The returned value is determined by interpolation on the appropriate quadratic segment.

`RandTriBeta(minimum,most_likely,maximum,[shape])` uses several formulas to transform min-mode-max into the beta function alpha and beta parameters and then uses `RandSeed` as the cumulative probability in Excel's built-in `BETAINV` function.

`RandTruncBiVarNormal(mean1,stdev1,mean2,stdev2,correl12,[min1],[max1],[min2],[max2])` uses values of `RandBiVarNormal` until normal values are found between the pairs of min and max values or until it has made 10,000 attempts.

`RandTruncLogNormal(Mean,StDev,MinValue,MaxValue)` uses values of `RandNormal` until a log normal value is found between `MinValue` and `MaxValue` or until it has made 10,000 attempts.

`RandTruncNormal(Mean,StDev,MinValue,MaxValue)` uses values of `RandNormal` until a value is found between `MinValue` and `MaxValue` or until it has made 10,000 attempts.

`RandUniform(minimum,maximum)` returns $\text{minimum} + \text{RandSeed} * (\text{maximum} - \text{minimum})$.
`RandUniform(0,1)` is equivalent to Excel's built-in `RAND()` function.

`SimVoi` includes a Fast... version of each of the seventeen functions, e.g., `FastBinomial`, `FastCumulative`, etc. The Fast... functions are identical to the `Rand...` functions except there is no error checking of arguments.