

# Monte Carlo Simulation Using RiskSim

## Add-In for Microsoft Excel

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## Introduction

RiskSim is a Monte Carlo Simulation add-in for Microsoft Excel 5, 95, 97, 98, 2000, and 2001 for Windows and Macintosh.

RiskSim provides random number generator functions as inputs for your model, automates Monte Carlo simulation, and creates charts. Your spreadsheet model may include various uncontrollable uncertainties as input assumptions (e.g., demand for a new product, uncertain variable cost of production, competitor reaction), and you can use simulation to determine the uncertainty associated with the model's output (e.g., annual profit). RiskSim automates the simulation by trying hundreds of what-ifs consistent with your assessment of the uncertainties.

To use RiskSim, you

- (1) create a spreadsheet model
- (2) optionally use SensIt to identify critical inputs
- (3) enter one of RiskSim's nine random number generator functions in each input cell of your model
- (4) choose Tools | Risk Simulation from Excel's menu
- (5) specify the model output cell and the number of what-if trials
- (6) interpret RiskSim's histogram and cumulative distribution charts.

RiskSim facilitates Monte Carlo simulation by providing:

- Nine random number generator functions
- Ability to set the seed for random number generation
- Automatic repeated sampling for simulation
- Frequency distribution of simulation results
- Histogram and cumulative distribution charts

## Using RiskSim Functions

RiskSim adds nine random number generator functions to Excel. You can use these functions as inputs to your model by typing in a worksheet cell or by using the Function Wizard. From the Insert menu choose Function, or click the Function Wizard button. RiskSim's functions are listed in a User Defined category. The nine functions are:

- RANDBINOMIAL(trials,probability\_s)
- RANDCUMULATIVE(value\_cumulative\_table)
- RANDDISCRETE(value\_discrete\_table)
- RANDEXPONENTIAL(lambda)
- RANDINTEGER(bottom,top)
- RANDNORMAL(mean,standard\_dev)
- RANDPOISSON(mean)

RANDTRIANGULAR(minimum,most\_likely,maximum)  
RANDUNIFORM(minimum,maximum)

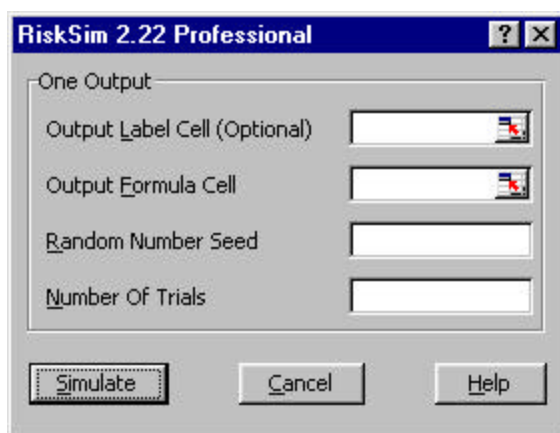
RiskSim's RAND... functions include extensive error checking of arguments. After verifying that the functions are working properly, you may want to substitute RiskSim's FAST... functions which have minimal error checking and therefore run faster. From the Edit menu choose Replace; in the Replace dialog box, type =RAND in the "Find What" edit box, type =FAST in the "Replace with" edit box, and click the Replace All button.

## Excel Error Message

When you insert a RiskSim random number generator function in a worksheet cell, the function is linked to RiskSim.xla. When you save the workbook, Excel saves the complete path to the function in RiskSim.xla. When you open the workbook, Excel looks for RiskSim.xla using the saved path. If Excel cannot find RiskSim.xla at the saved path location (e.g., if you deleted RiskSim.xla or if you opened the workbook on another computer where RiskSim.xla isn't located at the same path), Excel displays a dialog box: "This document contains links. Re-establish links?" Click No. The workbook will be opened, but any cell containing a reference to a RiskSim function will display the #REF!, #NAME?, or other error code. To fix the links, be sure that RiskSim.xla is open (e.g., File | Open | RiskSim.xla), choose Edit | Links | Change Source, and locate the RiskSim.xla file that is open.

## Monte Carlo Simulation

After specifying random number generator functions as inputs to your model, from the Tools choose Risk Simulation | One Output.



Optionally, select the "Output Label Cell" edit box, and point or type a reference to a cell containing the name of the model output (for example, a cell whose contents is the text label "Net Profit").

Select the "Output Formula Cell" edit box, and point to a single cell on your worksheet or type a cell reference. The output cell of your model must contain a formula that depends, usually indirectly, on the model inputs determined by the random number generator functions.

Select the "Random Number Seed" edit box, and type a number between zero and one. (If you want to change the seed without performing a simulation, enter zero in the "Number of iterations" edit box.)

Select the "Number Of Trials" edit box, and type an integer value (for example, 100 or 500). 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.

## **Random Number Seed**

The "Random Number Seed" edit box on the RiskSim dialog box allows you to set the seed for RiskSim's random number generator functions. These functions depend on RiskSim's own uniform random number function that is completely independent of Excel's built-in RAND().

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).

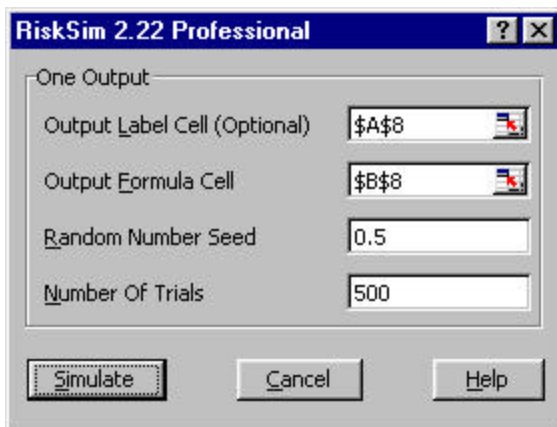
For example, a simple queuing system model may have an uncertain arrival pattern, a controllable number of servers, and total cost (waiting time plus server cost) as output. To evaluate a different number of servers, you would specify the same seed before generating the uncertain arrivals. Then the variation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

## One-Output Example

In this example the decision maker has described his subjective uncertainty using normal, triangular, and discrete probability distributions.

	A	B	C	D	E	F	G	H
1	Software Decision Analysis							
2								
3	Unit Price	\$29		Price is controllable and constant.				
4	Units Sold	739		Normal	Mean = 700, StDev = 100			
5	Unit Variable Cost	\$8.05		Triangular	Min = \$6, Mode = \$8, Max = \$11			
6	Fixed Costs	\$12,000		Discrete	Value	Probability		
7					\$10,000	0.25		
8	Net Cash Flow	\$3,485			\$12,000	0.50		
9					\$15,000	0.25		

	A	B
1	Software Decision Analysis	
2		
3	Unit Price	\$29
4	Units Sold	=INT(RANDNORMAL(700,100))
5	Unit Variable Cost	=RANDTRIANGULAR(6,8,11)
6	Fixed Costs	=RANDDISCRETE(E7:F9)
7		
8	Net Cash Flow	=B4*(B3-B5)-B6



The image shows the 'RiskSim 2.22 Professional' dialog box. It has a title bar with a question mark and a close button. The main area is titled 'One Output' and contains four input fields: 'Output Label Cell (Optional)' with the value '\$A\$8', 'Output Formula Cell' with the value '\$B\$8', 'Random Number Seed' with the value '0.5', and 'Number Of Trials' with the value '500'. Each input field has a small icon to its right. At the bottom, there are three buttons: 'Simulate', 'Cancel', and 'Help'.

## RiskSim Output

When you click the Simulate button, RiskSim creates a new worksheet in your Excel workbook named "RiskSim Summary 1." A summary of your inputs and the output is shown in cells L1:R9 with the accompanying histogram and cumulative distribution charts.

	L	M	N	O	P	Q	R																						
1	RiskSim - One Output - Summary					Mean	\$2,454																						
2	Date	(current date)				St. Dev.	\$2,794																						
3	Time	(current time)				Mean St. Error	\$125																						
4	Workbook	risksamp.xls				Minimum	-\$5,455																						
5	Worksheet	Simulation				First Quartile	\$536																						
6	Output Cell	\$B\$8				Median	\$2,458																						
7	Output Label	Net Cash Flow				Third Quartile	\$4,416																						
8	Seed	0.5				Maximum	\$10,236																						
9	Trials	500				Skewness	0.0028																						
10																													
11	<div><div>RiskSim Histogram, (current date), (current time)</div><table><caption>Histogram Data (Approximate)</caption><thead><tr><th>Net Cash Flow Interval (Upper Limit)</th><th>Frequency</th></tr></thead><tbody><tr><td>-\$6,000</td><td>0</td></tr><tr><td>-\$4,000</td><td>5</td></tr><tr><td>-\$2,000</td><td>22</td></tr><tr><td>0</td><td>72</td></tr><tr><td>\$2,000</td><td>122</td></tr><tr><td>\$4,000</td><td>128</td></tr><tr><td>\$6,000</td><td>105</td></tr><tr><td>\$8,000</td><td>38</td></tr><tr><td>\$10,000</td><td>10</td></tr><tr><td>\$12,000</td><td>2</td></tr></tbody></table></div>							Net Cash Flow Interval (Upper Limit)	Frequency	-\$6,000	0	-\$4,000	5	-\$2,000	22	0	72	\$2,000	122	\$4,000	128	\$6,000	105	\$8,000	38	\$10,000	10	\$12,000	2
Net Cash Flow Interval (Upper Limit)								Frequency																					
-\$6,000								0																					
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28																													
29																													
30	<div><div>RiskSim Cumulative Chart, (current date), (current time)</div><table><caption>Cumulative Chart Data (Approximate)</caption><thead><tr><th>Net Cash Flow</th><th>Cumulative Probability</th></tr></thead><tbody><tr><td>-\$6,000</td><td>0.00</td></tr><tr><td>-\$4,000</td><td>0.05</td></tr><tr><td>-\$2,000</td><td>0.25</td></tr><tr><td>0</td><td>0.45</td></tr><tr><td>\$2,000</td><td>0.70</td></tr><tr><td>\$4,000</td><td>0.85</td></tr><tr><td>\$6,000</td><td>0.95</td></tr><tr><td>\$8,000</td><td>0.99</td></tr><tr><td>\$10,000</td><td>1.00</td></tr><tr><td>\$12,000</td><td>1.00</td></tr></tbody></table></div>							Net Cash Flow	Cumulative Probability	-\$6,000	0.00	-\$4,000	0.05	-\$2,000	0.25	0	0.45	\$2,000	0.70	\$4,000	0.85	\$6,000	0.95	\$8,000	0.99	\$10,000	1.00	\$12,000	1.00
Net Cash Flow								Cumulative Probability																					
-\$6,000								0.00																					
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\$10,000								1.00																					
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The histogram is based on the frequency distribution in columns I:J. The cumulative distribution is based on the sorted output values in column C and the cumulative probabilities in column D.

	A	B	C	D	E	F	G	H	I	J
1	Trial	Net Cash Flow	Sorted	Cumulative		Percent	Percentile		Upper Limit	Frequency
2	1	\$1,653	-\$5,455	0.0010		0%	-\$5,455		-\$6,000	0
3	2	\$2,804	-\$4,267	0.0030		5%	-\$1,996		-\$4,000	3
4	3	\$2,280	-\$4,185	0.0050		10%	-\$1,132		-\$2,000	22
5	4	\$761	-\$3,898	0.0070		15%	-\$637		\$0	72
6	5	-\$1,817	-\$3,675	0.0090		20%	\$77		\$2,000	122
7	6	-\$692	-\$3,582	0.0110		25%	\$536		\$4,000	128
8	7	\$623	-\$3,569	0.0130		30%	\$923		\$6,000	105
9	8	\$5,575	-\$3,562	0.0150		35%	\$1,331		\$8,000	38
10	9	\$1,389	-\$3,547	0.0170		40%	\$1,823		\$10,000	9
11	10	\$445	-\$3,275	0.0190		45%	\$2,063		\$12,000	1
12	11	\$2,573	-\$3,207	0.0210		50%	\$2,458			0
13	12	\$5,055	-\$3,137	0.0230		55%	\$2,756			
14	13	\$1,430	-\$3,135	0.0250		60%	\$3,138			
15	14	\$4,529	-\$3,063	0.0270		65%	\$3,644			
16	15	\$701	-\$3,036	0.0290		70%	\$4,104			
17	16	-\$903	-\$3,008	0.0310		75%	\$4,416			
18	17	\$3,900	-\$2,968	0.0330		80%	\$4,867			
19	18	\$7,282	-\$2,950	0.0350		85%	\$5,412			
20	19	\$9,901	-\$2,774	0.0370		90%	\$5,897			
21	20	\$285	-\$2,649	0.0390		95%	\$7,109			
22	21	\$3,833	-\$2,485	0.0410		100%	\$10,236			
23	22	\$4,369	-\$2,370	0.0430						
24	23	\$1,991	-\$2,319	0.0450						
25	24	-\$11	-\$2,219	0.0470						
26	25	\$1,100	-\$2,195	0.0490						
27	26	-\$1,100	-\$1,986	0.0510						
28	27	-\$5,455	-\$1,969	0.0530						

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

Column B contains the original sampled output values.

Columns F:G show percentiles based on Excel's PERCENTILE worksheet function. Refer to Excel's online help for the interpolation method used by the PERCENTILE function.

The summary measures in columns Q:R are also based on Excel worksheet functions: AVERAGE, STDEV, QUARTILE, and SKEW.

## 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,...,n.

**RANDBINOMIAL 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.

### RANDBINOMIAL 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.

### RANDBINOMIAL Example

A salesperson makes ten unsolicited calls per day, where the probability of making a sale on each call is 30 percent. The uncertain total number of sales in one day is =**RANDBINOMIAL**(10,0.3)

### RANDBINOMIAL Related Function

**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 RiskSim Seed feature.



## 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.

RANDCUMULATIVE 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.

### RANDCUMULATIVE 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.

### RANDCUMULATIVE Example

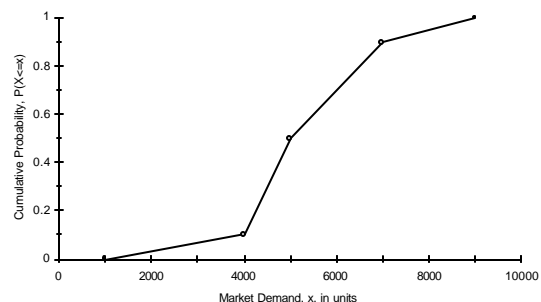
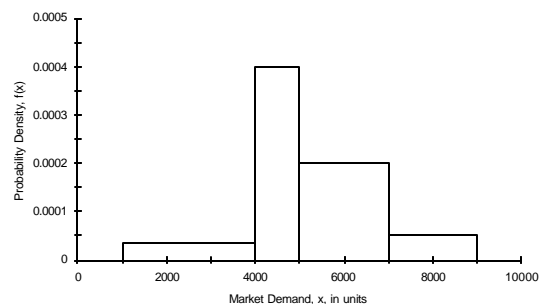
A corporate planner thinks that minimum possible market demand is 1000 units, median is 5000, and maximum possible is 9000. Also, there is a ten percent chance that demand will be less than 4000 and a ten percent chance it will exceed 7000. The values,  $x$ , and cumulative probabilities,  $P(X \leq x)$ , are entered into spreadsheet cells A1:B5.

	A	B
1	1000	0.0
2	4000	0.1
3	5000	0.5
4	7000	0.9
5	9000	1.0

The function is entered into another cell: `=RANDCUMULATIVE(A1:B5)`

### RANDCUMULATIVE Related Function

**FASTCUMULATIVE:** Same as RANDCUMULATIVE without any error checking of the arguments.



## 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,  $P(X=x)$ .

RANDDISCRETE 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.

### RANDDISCRETE 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.

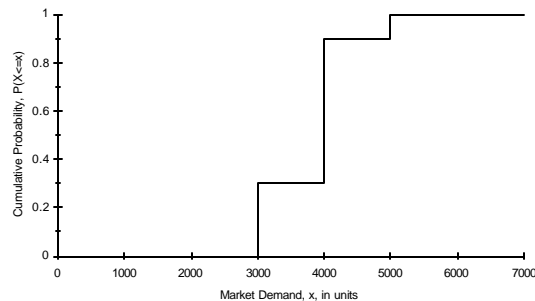
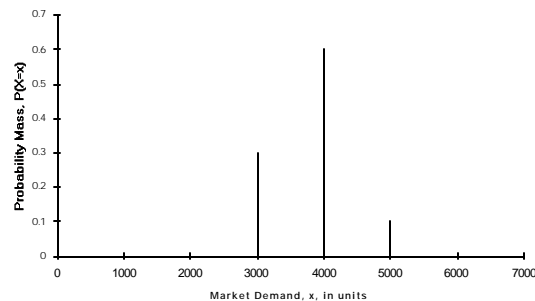
Returns #VALUE! if the argument is not a reference, if the argument is a defined name but not for a reference, or if any cell of the table contains text or is blank.

### RANDDISCRETE Example

A corporate planner thinks that uncertain market demand,  $X$ , can be approximated by three possible values and their associated probabilities:  $P(X=3000) = 0.3$ ,  $P(X=4000) = 0.6$ , and  $P(X=5000) = 0.1$ . The values and probabilities are entered into spreadsheet cells A1:B3.

	A	B
1	3000	0.3
2	4000	0.6
3	5000	0.1

The function is entered into another cell: `=RANDDISCRETE(A1:B3)`



### RANDDISCRETE Related Function

FASTDISCRETE: Same as RANDDISCRETE without any error checking of the arguments.

## 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.

RANDEXPONENTIAL Syntax: RANDEXPONENTIAL(lambda)

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

RANDEXPONENTIAL 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.

RANDEXPONENTIAL 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.

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

RANDEXPONENTIAL Related Functions

FASTEXPONENTIAL: Same as RANDEXPONENTIAL without any error checking of the arguments.

–LN(RAND())/lambda: Excel's inverse of the exponential, or

–LN(RANDUNIFORM(0,1))/lambda to use the RiskSim Seed feature.

RANDPOISSON: Counts number of occurrences for a Poisson process.

## RandInteger

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

RANDINTEGER Syntax: RANDINTEGER(bottom,top)

Bottom is the smallest integer RANDINTEGER will return.

Top is the largest integer RANDINTEGER will return.

### RANDINTEGER 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.

### RANDINTEGER 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).

### RANDINTEGER Related Function

FASTINTEGER: Same as RANDINTEGER without any error checking of the arguments.

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

## 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.

RANDNORMAL Syntax: `RANDNORMAL(mean,standard_dev)`

Mean is the arithmetic mean of the normal distribution.

Standard\_dev is the standard deviation of the normal distribution.

### RANDNORMAL 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.

### RANDNORMAL 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)`.

### RANDNORMAL 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 RiskSim 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, ... .

RANDPOISSON Syntax: RANDPOISSON(mean)

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

### RANDPOISSON 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.

### RANDPOISSON 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.

A bank teller requires an average of two minutes to serve a customer. The uncertain number of customers served in a minute is =RANDPOISSON(0.5). The average value returned by repeated recalculation of RANDPOISSON(0.5) is 0.5.

### RANDPOISSON Related Functions

FASTPOISSON: Same as RANDPOISSON without any error checking of the arguments.

RANDEXPONENTIAL: Describes time between occurrences for a Poisson process.

## 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.

**RANDTRIANGULAR 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.

### RANDTRIANGULAR Remarks

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

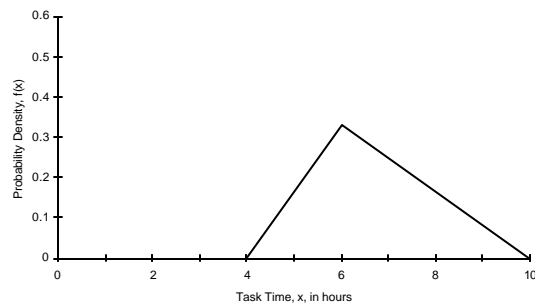
Returns #NAME! if an argument is text and the name is undefined.

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.

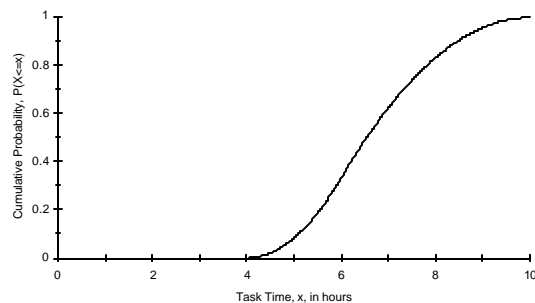
### RANDTRIANGULAR Example

The minimum time required to complete a particular task that is part of a large project is 4 hours, the most likely time required is 6 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).



### RANDTRIANGULAR Related Function

**FASTTRIANGULAR:** Same as RANDTRIANGULAR without any error checking of arguments.

## 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.

RANDUNIFORM Syntax: RANDUNIFORM(minimum,maximum)

Minimum is the smallest value RANDUNIFORM will return.

Maximum is the largest value RANDUNIFORM will return.

### RANDUNIFORM 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.

### RANDUNIFORM 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).

### RANDUNIFORM Related Function

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



## Technical Details

RiskSim's random number generator functions are based on a uniformly distributed random number function called RandSeed which is not directly accessible by the user. Each value of RandSeed is calculated by multiplying 9821 times the previous value of RandSeed, adding 0.211327, and taking the fractional part. This algorithm is the same as the one used by Excel 4's built-in RAND() function.

When RiskSim starts, the previous random number for RandSeed is set to 0.5. The first time a random number is calculated, the resulting value is 0.711327. Unlike Excel's RAND() function, you can use RiskSim at any time to specify the previous random number (the seed) for the sequence of random numbers generated by the RiskSim functions.

In the Risk Simulation dialog box, the "Random number seed" edit box changes the seed only for the RiskSim functions; it does not have any effect on Excel's built-in RAND() function.

Each of RiskSim's random number generator functions use RandSeed as a building block.

RANDBINOMIAL(trials,probability\_s) uses RandSeed as the cumulative probability in Excel's built-in CRITBINOM function.

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, RiskSim uses  $-\text{LN}(R)/\lambda$  for the returned value.

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

RANDNORMAL(mean,standard\_dev) uses RandSeed as the cumulative probability in Excel's built-in NORMINV function.

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.

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.

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

RiskSim includes a FAST... version of each of the nine functions, e.g., FASTBINOMIAL, FASTCUMULATIVE, etc. The FAST... functions are identical to the RAND... functions except there is no error checking of arguments.

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