# Tutorial of Simulation using Excel Spreadsheet

Using Excel, we can conduct simulation in two ways.

1. Conduct simple simulation in a spreadsheet.
2. Conduct complicated simulation using Visual Basic for Application (VBA) programming language.

This tutorial provides a minimum guide for a beginner to conduct simple simulation in a spreadsheet.

In Excel, we can use the built-in worksheet functions in a formula in a cell. Some basic functions commonly used in simulation are as follows.

1. Generate a random number (uniformly between 0 and 1):

   =RAND()

2. IF function

   =IF(logical_test,[value_if_true],[value_if_false])

   checks a condition in its first argument, and if the condition is true returns the first value; otherwise it returns the second value.
   - Example: =IF(RAND()<=0.5,0,1) returns 0 if the random number is smaller than 0.5; returns 1 otherwise.
   - Example: =IF(A1<=0.5,0,IF(AND(A1>0.5,A1<=0.8),1,2)) returns 0 if A1<=0.5, 1 if 0.5<A1<=0.8, and 2 if A1>0.8.
3. Generate a uniformly distributed integer value in an interval:

   =RANDBETWEEN(bottom,top)

4. Exponential distribution and normal distribution:

   EXPON.DIST(x,lambda,cumulative), NORMDIST(x,mean,standard_dev,cumulative)

   If cumulative == “TRUE”, returns the cdf; if cumulative == “FALSE”, returns the pdf.
5. Inverse cdf of normal distribution:

   NORM.INV(probability,mean,standard_dev)

   Given a value for probability, NORM.INV seeks that value x such that NORM.DIST(x, mean, standard_dev, TRUE) = probability.
6. There is no inverse cdf for exponential distribution. For some other distributions, like t distribution and binomial distribution, there exist pdf (pmf) / cdf function and inverse cdf function.
7. To generate a standard normal random variate:

   NORM.INV(RAND(),0,1)

8. To generate an exponential random variate with rate lambda:

   =-1/lambda*LN(RAND())

9. In a worksheet cell in Excel, we can also call a user-written VBA function. The user-written VBA functions can, in turn, call an internal VBA function such as Rnd().

***Note: Neither the worksheet function RAND() nor the VB function Rnd() should be used in professional work; they both have known deficiencies.***

**Example 1**

Monte Carlo Simulation: Estimate pi from Random Points

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | U1 | U2 | Distance from (0,0) | In circular sector? | n | 1000 |
| 2 | 0.280717 | 0.007399 | 0.280814279 | 1 | h | 783 |
| 3 | 0.041224 | 0.433094 | 0.435051387 | 1 | pi | 3.132 |
| 4 | 0.74929 | 0.411982 | 0.855081898 | 1 | | |
| 5 | 0.530758 | 0.835706 | 0.990003974 | 1 | | |
| 6 | 0.485722 | 0.922722 | 1.042757273 | 0 | | |
| 7 | 0.232218 | 0.260983 | 0.349337961 | 1 | | |
| 8 | 0.512707 | 0.046769 | 0.514835292 | 1 | | |
| 9 | 0.905181 | 0.818442 | 1.220327943 | 0 | | |
| 10 | 0.973512 | 0.330192 | 1.027984671 | 0 | | |

=SUM(D2:D1001)

=4*F2/F1

=RAND()

=SQRT(A?^2+B?^2)

=IF(C?<1,1,0)

*Note: "?" in formula represents the corresponding row number.*

**Example 2**

Discrete-Event System Simulation: $M/M/1$ Queue with $\lambda = 0.6, \mu = 1$

$$L = \frac{\rho}{1-\rho} = \frac{0.6}{1-0.6} = 1.5,\ L_Q = \frac{\rho^2}{1-\rho} = \frac{0.36}{1-0.6} = 0.9,\ W = \frac{1}{\mu-\lambda} = \frac{1}{0.4} = 2.5,\ W_Q = \frac{\rho}{\mu-\lambda} = \frac{0.6}{0.4} = 1.5.$$

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | lambda | 0.6 | mu | 1 | | | | | | | | |
| 2 | U1 | interarrival time | U2 | service time | Customer | Arrival Time | Time Service Begins | Departure Time | Waitimg Time | Sojourn Time | Wq | 1.523885 |
| 3 | 0.210886 | 2.594066353 | 0.02589 | 3.65390244 | 1 | 2.59406635 | 2.594066353 | 6.247968791 | 0 | 3.653902439 | W | 2.528611 |
| 4 | 0.736247 | 0.510316003 | 0.682781 | 0.38158049 | 2 | 3.10438236 | 6.247968791 | 6.629549285 | 3.143586436 | 3.525166929 | lambda | 0.594916 |
| 5 | 0.018733 | 6.629157722 | 0.327849 | 1.11520114 | 3 | 9.73354008 | 9.733540077 | 10.84874122 | 0 | 1.115201142 | Lq | 0.906584 |
| 6 | 0.661818 | 0.687941575 | 0.364453 | 1.00935856 | 4 | 10.4214817 | 10.84874122 | 11.85809978 | 0.427259567 | 1.436618125 | L | 1.504311 |
| 7 | 0.873194 | 0.225995707 | 0.281741 | 1.26676615 | 5 | 10.6474774 | 11.85809978 | 13.12486593 | 1.210622418 | 2.47738857 | | |
| 8 | 0.839983 | 0.290622405 | 0.759409 | 0.27521507 | 6 | 10.9380998 | 13.12486593 | 13.400081 | 2.186766165 | 2.461981235 | | |
| 9 | 0.792587 | 0.387422122 | 0.766577 | 0.26581985 | 7 | 11.3255219 | 13.400081 | 13.66590085 | 2.074559113 | 2.340378966 | | |
| 10 | 0.558416 | 0.971084659 | 0.334495 | 1.09513273 | 8 | 12.2966065 | 13.66590085 | 14.76103358 | 1.369294307 | 2.464427036 | | |
| 11 | 0.89452 | 0.185780522 | 0.328849 | 1.11215617 | 9 | 12.4823871 | 14.76103358 | 15.87318975 | 2.278646514 | 3.390802682 | | |

=-1/B$1*LN(A?)

=-1/D$1*LN(C?)

=F10+B11 =MAX(H10,F11) =G11+D11 =G11-F11 =H11-F11

=AVERAGE(I1002:I10002)
=AVERAGE(J1002:J10002)
=E10002/G10002
=L4*L2
=L4*L3