



# Data Tables & Monte Carlo Simulations in Excel – A Comprehensive Guide

Posted on May 6th, 2010 in [Analytics](#) , [Charts and Graphs](#) , [Featured](#) , [Hui](#) , [Learn Excel](#) , [Posts by Hui](#) , [simulation](#) - 80 comments

*This is a Guest Post by [Hui](#), an Excel Ninja and One of the Moderators of our Forums. Please note that this post is unusually large by Chandoo.org standards.*

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If anybody asks me what is the best function in excel I am drawn between [Sumproduct](#) and Data Tables, Both make handling large amounts of data a breeze, the only thing missing is the Spandex Pants and Red Cape!

How often have you thought of or been asked "I'd like to know what our profit would be for a number of values of an input variable" or "Can I have a graph of Profit vs Cost vs ..."

This post is going to detail the use of the Data Table function within Excel, which can help you answer that question and then so so much more.

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## INTRODUCTION

*How often have you thought "I'd like to know what our profit would be for a +/- 10, 20 and 30 % variance in the costs" ?*

This post is going to detail the use of the Data Table function within Excel, which can help you answer that question.

The Data Table function is a function that allows a table of what if questions to be posed and answered simply, and is useful in simple what if questions, sensitivity analysis, variance analysis and even Monte Carlo (Stochastic) analysis of real life model within Excel.

The Data Table function should not be confused with the [Insert Table function](#).

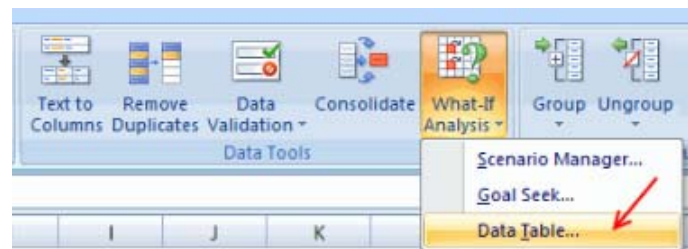
## DATA TABLE BASICS

The Data Table function is hidden away in different locations within different versions of Excel but apart from the menu location the functionality is the same throughout.

### Where is the Data Table Function

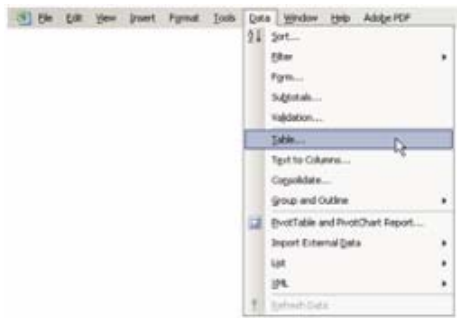
#### Excel 2007/10

In Excel 2007 & 2010 go to the Data Tab, What If Analysis panel and select Data Table

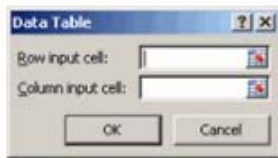


#### Excel 97-03

In Excel up to 2003 go to the Data Menu and select Table...



Both Excel 97-03 and 2007/10 then bring up the same **Data Table** dialog box.



... and this simple dialog box is all empowering ?

Yes !

### Blue Sky Mine Co

For demonstration of the Data Table function I am going to use a simple profit model of a Gold Mine, "The Blue Sky Mine Co". This is a fictitious mine but provides a simple model which we can use the data Table function to analyse.

It consists of 6 input variables and a simple cost and revenue model to produce a profit.

#### Blue Sky Gold Mine Co

	Input	
Ore Tonnes	1,000,000	t
Gold Grade	1.68	g/t Au
Gold price	1,200	U\$/Oz Au
Exchange Rate	0.92	A\$/U\$
Mine Unit Cost	40	\$/t
Process Unit Cost	25	\$/t
Total Cost	65,000,000	A\$
Revenue	70,452,018	A\$
<b>Profit</b>	<b>5,452,018</b>	<b>A\$</b>

In our Blue Sky Gold Mine Co model, we can see that if we mine and treat 1,000,000 t of gold ore containing 1.68 g/t gold, we will make A\$ 5.452M profit. But what if the inputs change ?

### 1 WAY DATA TABLES

Lets make a 1 Way Table with our Blue Sky Gold Mine Co example.

*This is shown in the attached Excel Workbook on the "1 Way" Tab or 1 Way Example*

## Blue Sky Gold Mine Co

	Input	
Ore Tonnes	1,000,000	t
Gold Grade	1.68	g/t Au
Gold price	1,200	U\$/Oz Au
Exchange Rate	0.92	A\$/U\$
Mine Unit Cost	40	\$/t
Process Unit Cost	25	\$/t
Total Cost	65,000,000	A\$
Revenue	70,452,018	A\$
<b>Profit</b>	<b>5,452,018</b>	<b>A\$</b>

In our Blue Sky Gold Mine profit calculation example, we can see that if we mine and treat 1,000,000 t of gold ore containing 1.68 g/t gold, we will make A\$ 5.452M profit. But what if the grade is more or less than that value of 1.68 g/t ? After all it is only a geological estimate.

This is what the Data Table function is made for.

Next to the model add a couple of columns as shown in blue

**Note:** Throughout this post you will see the use of 1E6 in formulas which is simpler to write than 1,000,000.

## Blue Sky Gold Mine Co

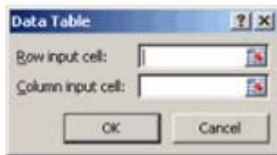
	Input	Gold Grade	Profit
Ore Tonnes	1,000,000 t		\$m
Gold Grade	1.68 g/t Au		<b><math>\text{=+Profit/1E6}</math></b>
Gold price	1,200 U\$/Oz Au	1.50	
Exchange Rate	0.92 A\$/U\$	1.55	
Mine Unit Cost	40 \$/t	1.60	
Process Unit Cost	25 \$/t	1.65	
Total Cost	65,000,000 A\$	1.70	
Revenue	70,452,018 A\$	1.75	
Profit	5,452,018 A\$	1.80	
		1.85	
		1.90	
		1.95	
		2.00	
		2.05	
		2.10	

The first column is a list of values that will be applied to each iteration of the Column Input Cell

The Top Cell of the second Column contains a formula which will retrieve the answer you want to watch, in this case Profit. It will be displayed as M\$.

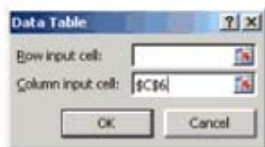
Now select the entire Blue Area and Select Data Table

This is the Data Table input screen.



The tricky/confusing part here is that in our example we are changing the input value to our Gold Mine Profit model using a Column of Numbers, so enter \$C\$6 in the Column Input Cell, Leave the Row Input Cell blank.

	A	B	C	E	F	G	H
1							
2		<b>Blue Sky Gold Mine Co</b>					
3							
4			<b>Input</b>		<b>Gold Grade</b>		<b>Profit</b>
5		Ore Tonnes	1,000,000 t				\$m
6		Gold Grade	1.68 g/t Au				=+Profit/1E6
7							
8		Gold price	1,200 US\$/Oz Au				
9		Exchange Rate	0.92 A\$/US				
10							
11		Mine Unit Cost	40 \$/t				
12		Process Unit Cost	25 \$/t				
13							
14		Total Cost	65,000,000 A\$				
15							
16		Revenue	70,452,018 A\$				
17							
18		<b>Profit</b>	<b>5,452,018 A\$</b>				
19							
20							
21							
22							
23							
24							

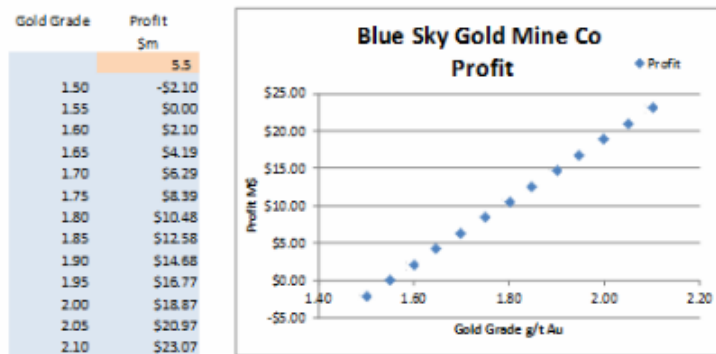


Click OK

You can now see a Table of Profit Values for each Grade Value.

			Gold Grade	Profit
	<b>Input</b>			\$m
Ore Tonnes	1,000,000 t			5.5
Gold Grade	1.68 g/t Au			
			1.50	-\$2.10
			1.55	\$0.00
Gold price	1,200 US\$/Oz Au		1.60	\$2.10
Exchange Rate	0.92 A\$/US		1.65	\$4.19
			1.70	\$6.29
Mine Unit Cost	40 \$/t		1.75	\$8.39
Process Unit Cost	25 \$/t		1.80	\$10.48
			1.85	\$12.58
Total Cost	65,000,000 A\$		1.90	\$14.68
			1.95	\$16.77
Revenue	70,452,018 A\$		2.00	\$18.87
			2.05	\$20.97
<b>Profit</b>	<b>5,452,018 A\$</b>		2.10	\$23.07

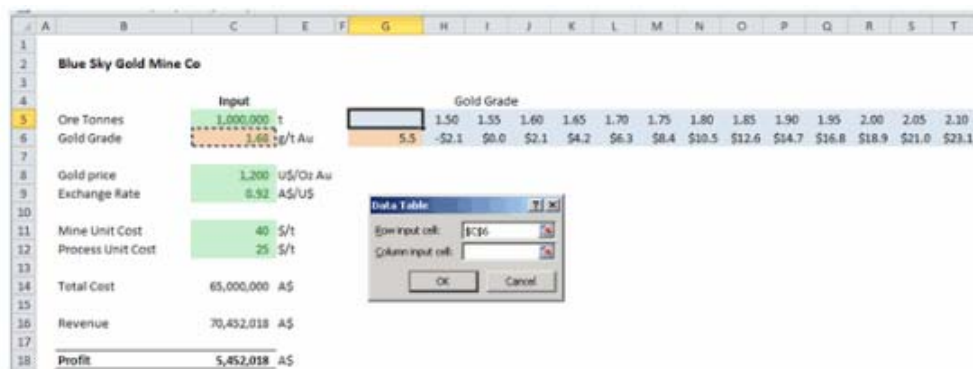
The variance in the Profit can easily be graphed against the Gold Grade and we can now see that if the Gold Grade is below about 1.55 g/t Au we will not make a profit and conversely if it is above 2.0 g/t Au we will make a large profit.



Before we move onto 2 Way Data Tables it is worth exploring small variations on One Way Tables.

### What if my Data is in Rows?

Had our input data been arranged horizontally in Rows, we could have used a Row Input Cell to process the data.



### What if I want to vary the inputs by a certain Percentage ?

Another Scenario is often where you want to vary an input by a Fixed Percentage.

This is easily done using Data Tables

Setup the input cells with the percentage variations you want to examine, noting that the values don't have to be evenly spread.

Setup a Temporary Input Cell, This will hold the Percentage Variance briefly whilst calculations are happening. Set a default value of 0 (zero)

Change your Main Input Cell, Gold Grade in our case, to Multiply the fixed answer by 1+ the temp Input Cell.

Run the Data Table with a **Column Input Cell**, which will refer to the **Temp Input Cell**.

	A	B	C	E	F	G	H
1							
2		<b>Blue Sky Gold Mine Co</b>		0		Temp Input Cell	
3					Gold Grade	Profit	
4			<b>Input</b>			\$m	
5		Ore Tonnes	1,000,000 t				\$5.5
6		Gold Grade	=1.68*1+E2	g/t Au	-50%	-\$15.5	
7					-25%	-\$5.0	
8		Gold price	1,200	US\$/Oz Au	-10%	\$1.3	
9		Exchange Rate	0.92	A\$/U\$	-5%	\$3.4	
10					0%	\$5.5	
11		Mine Unit Cost	40	\$/t	5%	\$7.5	
12		Process Unit Cost	25	\$/t	10%	\$9.6	
13					25%	\$15.9	
14		Total Cost	65,000,000	A\$	50%	\$26.4	
15					100%	\$47.4	
16		Revenue	70,452,018	A\$			
17							
18		<b>Profit</b>	<b>5,452,018</b>	<b>A\$</b>			
19							

## 2 WAY DATA TABLES

So the Boss comes in and asks, what Happens if the Gold Grade changes as well as the A\$/U\$ Exchange Rate?

You guessed it, Two Way tables to the rescue.

This is shown in the attached Excel Workbook on the "2 Way" Tab or [2 Way Example](#)

Two way data Tables work the same as One Way Data Tables except that you can vary 2 parameters at once.

With Two Way Data Tables you need to setup a Column of data for one Input and a Row of data for the second Input. The answer is returned at the intersection of the Row and Column.

Here we have setup a Column of Gold Grades ranging from 1.5 to 2.1 g/t Au and a Row of Exchange rates =varying from 0.70 to 1.00 A\$/U\$

	A	B	C	E	F	G	H	I	J	K	L
1											
2		<b>Blue Sky Gold Mine Co</b>									
3											
4			<b>Input</b>				Exchange Rate				
5		Ore Tonnes	1,000,000 t					0.70	0.80	0.90	1.00
6		Gold Grad	1.68 g/t Au				=C18/1E6				
7											
8		Gold price	1,200	US\$/Oz Au							
9		Exchange	0.92	A\$/U\$							
10											
11		Mine Unit	40	\$/t							
12		Process U	25	\$/t							
13											
14		Total Cost	65,000,000	\$							
15											
16		Revenue	70,452,018	\$							
17											
18		<b>Profit</b>	<b>5,452,018</b>	<b>\$</b>							
19											
20											
21											
22											

Note at the intersection of the Row and Column there is a Reference to the variable you want to monitor in this case profit.

**Blue Sky Gold Mine Co**

**Input**

Ore Tonnage: 1,000,000 t

Gold Grade: 1.68 g/t Au

Gold price: 1,200 US\$/Oz Au

Exchange: 0.92 A\$/US\$

Mine Unit: 40 \$/t

Process Unit: 25 \$/t

Total Cost: 65,000,000 \$

Revenue: 70,452,018 \$

Profit: 5,452,018 \$

**Exchange Rate**

	5.5	0.70	0.80	0.90	1.00
1.50	17.67	7.34	-	0.70	-
1.55	20.43	9.75	-	1.44	-
1.60	23.18	12.16	-	3.59	-
1.65	25.94	14.57	-	5.73	-
1.70	28.70	16.98	-	7.87	-
1.75	31.45	19.40	-	10.02	-
1.80	34.21	21.81	-	12.16	-
1.85	36.96	24.22	-	14.31	-
1.90	39.72	26.63	-	16.45	-
1.95	42.48	29.04	-	18.59	-
2.00	45.23	31.45	-	20.74	-
2.05	47.99	33.86	-	22.88	-
2.10	50.74	36.27	-	25.02	-

**Data Table**

Row input cell: \$C\$9

Column input cell: \$C\$5

OK Cancel

You can now see the variance in Profit for variations in Gold Grade and Exchange Rate.

### What about varying by Percentages?

Once again we can re-arrange the input variables to examine percentage changes in the inputs via a Temporary Input Cell.

**Blue Sky Gold Mine Co**

**Input**

Ore Tonnage: 1,000,000 t

Gold Grade:  $=1.68 * 1 + F6$  g/t Au

Gold price: 1,200 US\$/Oz Au

Exchange:  $=0.92 * 1 + F9$  A\$/US\$

Mine Unit: 40 \$/t

Process Unit: 25 \$/t

Total Cost: 65,000,000 \$

Revenue: 70,452,018 \$

Profit: 5,452,018 \$

**Exchange Rate**

	5.5	-25%	-10%	0%	10%	25%
-25%	17.34	2.28	-	5.03	-	10.91
-10%	25.98	9.34	-	1.26	-	5.24
0%	31.74	14.04	-	5.45	-	1.46
10%	37.50	18.75	-	9.65	-	2.33
25%	46.14	25.81	-	15.94	-	1.36

**Data Table**

Row input cell: \$F\$9

Column input cell: \$F\$6

OK Cancel

## MONITORING MULTIPLE VARIABLES

So you have a complex model and want to monitor a number of input and output variables at once. No problems, Data Tables to the rescue.

In this example we are varying one input variable but monitoring 3 Output variables, 2 input variables and then doing a calculation all as part of the Data Table.

This is shown in the attached Excel Workbook on the "Monitor Multi variables" Tab or [Monitor Multi Variables Example](#)

Blue Sky Gold Mine Co		Variables to Monitor					
Input		Total Cost	Revenue	Profit	Gold Grade	Gold Price	Cost/Oz Au
Ore Tonnes	1,000,000 t	=C14/166	=C16/166	=C18/166	=C6	=C8	=C14/(C5*C6/31.1035)
Gold Grade	1.68 g/t Au	1.40	65.0	58.7	- 6.3	1.4	1,200
		1.50	65.0	62.9	- 2.1	1.5	1,200
Gold price	1,200 US\$/Oz Au	1.60	65.0	67.1	2.1	1.6	1,200
Exchange Rate	0.92 A\$/US\$	1.70	65.0	71.3	6.3	1.7	1,200
Mine Unit Cost	40 \$/t	1.80	65.0	75.5	10.5	1.8	1,200
Process Unit Cost	25 \$/t	1.90	65.0	79.7	14.7	1.9	1,200
		2.00	65.0	83.9	18.9	2.0	1,200
Total Cost	65,000,000 \$						
Revenue	70,452,018 \$						
Profit	5,452,018 \$						

The first 3 columns, Total Cost, Revenue and Profit are output variables even though Total Cost doesn't change, we can still monitor it to make sure our model is working correctly

The next 2 columns, Gold Grade and Gold Price are input variables even though only Gold Grade is being varied.

The last column Cost per Oz is not calculated as part of the model (ok sometimes we forget don't we), but it can be calculated on the fly as part of the Data Table.

The result is:

Blue Sky Gold Mine Co		Variables to Monitor					
Input		Total Cost	Revenue	Profit	Gold Grade	Gold Price	Cost/Oz Au
Ore Tonnes	1,000,000 t	65.0	70.5	5.5	1.7	1,200	1,200
Gold Grade	1.68 g/t Au	1.40	65.0	58.7	- 6.3	1.4	1,200.0
		1.50	65.0	62.9	- 2.1	1.5	1,200.0
Gold price	1,200 US\$/Oz Au	1.60	65.0	67.1	2.1	1.6	1,200.0
Exchange Rate	0.92 A\$/US\$	1.70	65.0	71.3	6.3	1.7	1,200.0
Mine Unit Cost	40 \$/t	1.80	65.0	75.5	10.5	1.8	1,200.0
Process Unit Cost	25 \$/t	1.90	65.0	79.7	14.7	1.9	1,200.0
		2.00	65.0	83.9	18.9	2.0	1,200.0
Total Cost	65,000,000 \$						
Revenue	70,452,018 \$						
Profit	5,452,018 \$						

## MULTIWAY DATA TABLES

But I hear you thinking, "If Data Tables are so good why can I only Change 2 variables at Once? I want to change more! ".

No Problems

Data Tables in fact allow you to Change any Number of input variables at once and monitor any number of input and output variables. It does however require a slight of hand.

This is shown in the attached Excel Workbook on the "Multi Way Tables" Tab or [Multiway Table Example](#)

First things first,

Setup a table of what scenarios you want to examine:

Scenario No.	Desc	Ore Tonnes	Gold Grade	Gold Price	Ex Rate	Mine Cost	Process Cost
1	Base case	1,000,000	1.68	1200	0.92	40	25
2	High Tonnes	1,200,000	1.68	1200	0.92	40	25
3	Low Tonnes	800,000	1.68	1200	0.92	40	25
4	High Grade	1,000,000	1.90	1200	0.92	40	25
5	Low Grade	1,000,000	1.68	1200	0.92	40	25
6	High Ex Rate	1,000,000	1.50	1200	1.00	40	25
7	Low Ex Rate	1,000,000	1.68	1200	0.85	40	25
8	High Cost	1,000,000	1.68	1200	0.92	50	35
9	Low Cost	1,000,000	1.68	1200	0.92	30	20
10	Hi Gold Price	1,000,000	1.68	1400	0.92	40	25
11	Low Gold Price	1,000,000	1.68	1000	0.92	40	25
12	Worst Case	800,000	1.58	1000	1.00	50	35

Setup the Data Table area to monitor Inputs, Outputs and Calculated Fields

**Variables to Monitor**

Scenario No.	Descrp Ore Tonnes (MT)	Gold Grade g/t Au	Gold Price A\$/Oz	Ex Rate A\$/US	Total Cost M\$	Cost/Oz A\$/Oz Au	Revenue M\$	Profit M\$
1	=F2	=C5/1e6	=C6	=C7/C8	=C9	=C14/1e6	=C14/(C5*C6/31.1035)	=C18/1e6
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

Note that the Input Data Column will be used to select the Scenario No.

Also note that we have setup F2 to retrieve the Scenarios Name.

And in H6 we will put the Scenario name into the Data Table, who said Data Tables were only for Numbers!

Next Link the Model to the scenario

	A	B	C	D	E
1					
2		<b>Blue Sky Gold Mine Co</b>		Scenario	1
3					
4					
5		Ore Tonnes	=VLOOKUP(\$E\$2,\$Q\$7:\$X\$18,3)	t	
6		Gold Grade	=VLOOKUP(\$E\$2,\$Q\$7:\$X\$18,4)	g/t Au	
7					
8		Gold price	=VLOOKUP(\$E\$2,\$Q\$7:\$X\$18,5)	US/Oz Au	
9		Exchange Rate	=VLOOKUP(\$E\$2,\$Q\$7:\$X\$18,6)	A\$/US	
10					
11		Mine Unit Cost	=VLOOKUP(\$E\$2,\$Q\$7:\$X\$18,7)	\$/t	
12		Process Unit Cost	=VLOOKUP(\$E\$2,\$Q\$7:\$X\$18,8)	\$/t	
13					
14		Total Cost		85,000,000	\$
15					
16		Revenue		70,452,018	\$
17					
18		Profit		5,452,018	\$
19					
20					

And run the Data Table

	A	B	C	D	E	F	G	H	I	J	K	L
1												
2		<b>Blue Sky Gold Mine Co</b>		Scenario	1	Base case						
3												
4												
5		Ore Tonnes	1,000,000	t								
6		Gold Grade	1.68	g/t Au								
7												
8		Gold price	1,200	US/Oz Au								
9		Exchange Rate	0.92	A\$/US								
10												
11		Mine Unit Cost	40.00	\$/t								
12		Process Unit Cost	25.00	\$/t								
13												
14		Total Cost		85,000,000	\$							
15												
16		Revenue		70,452,018	\$							
17												
18		Profit		5,452,018	\$							
19												
20												
21												
22												
23												
24												
25												

		Description	Ore Tonnes (MT)	Gold Grade g/t Au	Gold Price A\$/Oz	Ex Rate A\$/US
1		Base case	1.00	1.68	1,304	0.92
2		High Tonnes	1.20	1.68	1,304	0.92
3		Low Tonnes	0.80	1.68	1,304	0.92
4		High Grade	1.00	1.80	1,304	0.92
5		Low Grade	1.00	1.60	1,304	0.92
6		High Ex Rate	1.00	1.50	1,200	1.00
7		Low Ex Rate	1.00	1.60	1,412	0.85
8		High Cost	1.00	1.68	1,304	0.92
9		Low Cost	1.00	1.68	1,304	0.92
10		Hi Gold Price	1.00	1.68	1,522	0.92
11		Low Gold Price	1.00	1.68	1,087	0.92
12		Worst Case	0.80	1.58	1,000	1.00

Column Input Data

Scenario No.	Input
1	Base case
2	High Tonnes
3	Low Tonnes
4	High Grade
5	Low Grade
6	High Ex Rate
7	Low Ex Rate
8	High Cost
9	Low Cost
10	Hi Gold Price
11	Low Gold Price
12	Worst Case

Note how the Description Column is populated with the Scenario's Name (Text values)

So now when your boss asks you what effect the price of ... has on the budget, you know where to turn.

## MONTE CARLO SIMULATIONS IN EXCEL

Monte Carlo simulation (or analysis) as its name suggests puts an element of gambling into the scenarios, or more correctly allows you to measure the effect of variability on input parameters.

This is done by running scenarios against your model hundreds or thousands of times and changing the inputs each time and then measuring the effects at the end of the runs.

And Data Tables can do that? Absolutely!

**First some statistics.**

Everything in life has variability, from the size of Zebra’s Strips, The height of people and the Arrival times of trains, the time that people read this post, the time that it takes people to read this post.

Most things are variable around a central or mean (average) value. The spread of variability is commonly known as the distribution.

Distributions can have many names and shapes, but common ones are

- **Normal**: Bell shaped around a mean
- **Uniform**: All values have an even chance of selection
- **Exponential**: Low or High values have a much higher probability that the other values

In life most distributions are Normal in nature indicating that the distribution is Bell shaped around a mean with a known method of describing the variability around this.

Excel has 2 functions that produce Random numbers, Rand() and Randbetween(). These 2 functions both have a Uniform Distribution, that is any value between the minimum and maximum values will have the same probability of being chosen.

We can convert a uniform distribution to a Normal distribution by some simple maths (simple to do, not simple to explain).

**=norminv(rand() , mean, standard\_dev)**

**Example =NORMINV(rand() , 100, 10)**

Will generate a distribution of random numbers centred on 100 with a spread having a bell shaped curve with a standard deviation of 10. This means that the function will produce a number with a 99.7% probability of being between 70 and 130 and on average will have a mean of 100.

### Monte Carlo simulations

So how can I use this and Data Tables to do Monte Carlo simulations.

Before we go any further the author wants to explicitly state that he is not suggesting that the use of Normal Distributions for the variables modeled below is appropriate, except for the purpose of demonstration of the principles behind Monte Carlo Modelling.

As with all models you need to have a good understanding of the distribution of inputs before you start playing with simulations or of which Monte Carlo is but one type. ie: Rubbish In Rubbish Out.

We can model an input variable, in this case Exchange rate with a distribution instead of a fixed value and then run the model a number of times and see what impact the variation has on the output.

This is shown in the attached Excel Workbook on the “Monte Carlo (Simple)” Tab or [Monte Carlo \(Simple\) Example](#)

Blue Sky Gold Mine Co			Variable to Monitor		
	Input		input	output	
			Ex Rate	Profit	
Ore Tonnes	1,000,000	t	0.92	5.45	
Gold Grade	1.68	g/t Au	=NORMINV(RAND(),0.92,0.02)	0.90	7.15
			=NORMINV(RAND(),0.92,0.02)	0.90	7.23
Gold price	1,200	US/Oz Au	=NORMINV(RAND(),0.92,0.02)	0.94	3.85
Exchange Rate	0.92	A\$/US	=NORMINV(RAND(),0.92,0.02)	0.91	6.23
			=NORMINV(RAND(),0.92,0.02)	0.90	7.07
Mine Unit Cost	40	\$/t	=NORMINV(RAND(),0.92,0.02)	0.94	3.92
Process Unit Cost	25	\$/t	=NORMINV(RAND(),0.92,0.02)	0.94	3.91
			=NORMINV(RAND(),0.92,0.02)	0.95	2.90
Total Cost	65,000,000	\$	=NORMINV(RAND(),0.92,0.02)	0.90	6.93
			=NORMINV(RAND(),0.92,0.02)	0.94	4.02
Revenue	70,452,018	\$	=NORMINV(RAND(),0.92,0.02)	0.88	8.69
			=NORMINV(RAND(),0.92,0.02)	0.91	6.29
Profit	5,452,018	\$	=NORMINV(RAND(),0.92,0.02)	0.90	7.20

The formula =NORMINV(RAND(),0.92,0.02), will generate a Random Exchange Rate with a distribution based on a mean on 0.92 A\$/U\$ and a spread of approximately 6 cents each way ie: there will be a 99.7% probability of the exchange rate being between 0.86 and 0.98 A\$/U\$.

## Blue Sky Gold Mine Co

### Variables to Monitor

		input output		
Input		Ex Rate	Profit	
Ore Tonnes	1,000,000 t	0.92	5.45	Average H6:H1005 5.7134
Gold Grade	1.68 g/t Au	0.92	0.90	
		0.92	0.90	
Gold price	1,200 U\$/Oz Au	0.93	0.94	
Exchange Rate	0.92 A\$/U\$	0.92	0.91	
		0.91	0.90	
Mine Unit Cost	40 \$/t	0.92	0.94	
Process Unit Cost	25 \$/t	0.90	0.94	
		0.93	0.95	
Total Cost	65,000,000 \$	0.86	0.90	
		0.94	0.94	
Revenue	70,452,018 \$	0.91	0.88	
		0.93	0.91	
Profit	5,452,018 \$	0.93	0.90	7.20

Copying the formula down from H6 to H1005 will allow our data table to generate 1000 iterations of the model each with a randomly generated Exchange Rate.

In the model above, you can see that for a Base case exchange rate of 0.92 the profit is \$M 5.452, however after running 1000 simulations the profit is actually \$M 5.7134. More important is that you can now run statistics on the model to tell what is the probability of the profit being greater than 0.00 based on variance in the exchange rate etc.

**Note 1:** You will note that in the above data table that the Input Column (darker blue) has the formula for calculating a random input grade from a distribution. =NORMINV(RAND(),0.92,0.02)

This is a Volatile Formula , ie: It recalculates every time the worksheet changes.

What this means for the worksheet is that when the Data Table goes to Calculate Row 2 of the Data Table it will recalculate the Input value for Row 1.

On Calculation of Row 2, It doesn't change the Table Values for Row 1, just the Input Column value.

So after 1,000 calculations of the Data Table, the Input Column values will have no relationship to the data from the original Calculations stored in the Data Table body area.

To make up for this we also add an Input variable to the Data Table.

Doing this allows the Data Table to capture and store both the Input variable and corresponding Output variable in the Data Table's Body.

**Note 2:** Always run at least 1000 iterations of Monte Carlo models. This is to ensure that you have a statistical chance of getting sufficient outliers (extreme values) to make the variance analysis meaningful. This is important because as the number of iterations increases the variance of the average output decreases.

Press F9 a few times and watch the average H6:H1005 change.

Try changing the Data table from 1,000 rows to 10, 20 or 100,000 rows. As the number of iterations increases the variance in the average of the output decreases.

## Advanced Monte Carlo Simulations

We can now put our knowledge of Data Tables and Monte Carlo Simulation to the test by varying 4 input variables at the same time.

This is shown in the attached Excel Workbook on the "Monte Carlo (Advanced)" Tab or [Monte Carlo \(Adv\) Example](#)

In the example below we have inserted distributions for 4 input variables.

Ore Tonnes	Mean 1,000,000 tonnes	Standard Deviation of 100,000 tonnes
Gold Grade	Mean 1.68 g/t Au	Standard Deviation of 0.1 g/t Au
Gold Price	Mean 1,200 U\$/Oz	Standard Deviation of 100 U\$/Oz
Exchange rate	Mean 0.92 A\$/U\$	Standard Deviation of 0.02 A\$/U\$

Blue Sky Gold Mine Co			Variables to Monitor					
Input			Run No.	Ex Rate	Gold price	Ore Tonnes	Gold Grade	Profit.
				AS/US	US/Oz Au	Mt	g/t Au	MS
Ore Tonnes	=NORMINV(RAND(),1000000,100000)	t	1	=C9	=C8	=C5/1e6	=C6	=C18/1e6
Gold Grade	=NORMINV(RAND(),1.68,0.1)	g/t Au	2					
Gold price	=NORMINV(RAND(),1200,100)	US/Oz Au	3					
Exchange Rate	=NORMINV(RAND(),0.92,0.02)	AS/US	4					
Mine Unit Cost	40	\$/t	5					
Process Unit Cost	25	\$/t	6					
Total Cost	55,791,670	\$	9					
Revenue	57,722,129	\$	10					
Profit	1,930,458	\$	13					

And setup a data Table for the 4 Input Variables and main output variable, Profit.

A	B	C	D	E	F	G	H	I	J	K	L	M
1	Blue Sky Gold Mine Co					Variables to Monitor						
2						Run No.	Ex Rate	Gold price	Ore Tonnes	Gold Grade	Profit	
3							A\$/US	US/Oz Au	Mt	g/t Au	M\$	
4	Input											
5	Ore Tonnes	942,479	t			0.92	963	0.94	1.94	-3.3	Average H6:H1005	
6	Gold Grade	1.74	g/t Au			1	0.90	1,234	0.91	1.76	10.1	
7						2	0.91	1,140	1.10	1.67	2.5	
8	Gold price	963	US/Oz Au			3	0.93	1,243	0.88	1.63	4.3	
9	Exchange Rate	0.92	A\$/US			4	0.89	1,136	0.98	1.66	3.1	
10						5	0.89	1,201	1.07	1.75	11.7	
11	Mine Unit Cost	40	\$/t			6	0.92	1,095	1.03	1.62	-2.9	
12	Process Unit Cost	25	\$/t			7	0.90				-1.9	
13						8	0.91				-0.5	
14	Total Cost	61,251,108	\$			9	0.93				6.2	
15						10	0.91				3.6	
16	Revenue	55,497,627	\$			11	0.91				-2.0	
17						12	0.92				6.7	
18	Profit	- 5,753,481	\$			13	0.91	1,133	0.99	1.57	-2.5	

**Note:** When this model is run through the Data Table, note that the Row or Column input cells can be set to anywhere. The Model is not using the value of the Input Cell (Row or Column) and isn't even using the Run No (Column F) for the model, the data table is simply being used to run lots of iterations of the model, with the variability coming from the Random Numbers in the 4 input cells.

## ITERATED FUNCTIONS INCLUDING FRACTALS

At a meeting in early 2005, the company I was working for was looking at an integrated Scheduling & Budgeting system.

The salesman gave a great demo except that the system would take approx. 30 mins to calculate our budget as opposed to a half a second in Excel.

Complaining I mentioned that our current, Excel based, system could do the job in seconds.

And he returned stating that "the system was doing a lot of things Excel couldn't do".

I responded "but Excel can do anything"

and he immediately shot back that "Excel can't do a Mandelbrot"

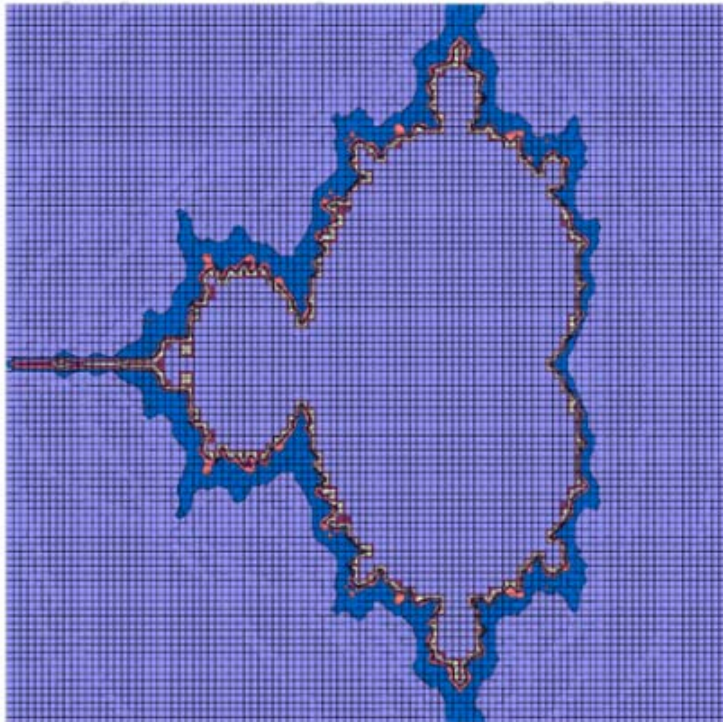
To which I responded "Yes it can"

And he responded "Not without VB Code"

Without too much thinking I responded that I would accept the Challenge.

The attached file, which is described below is my response.

### Excel Mandelbrot



The attached file is an implementation of the classic Mandelbrot implemented in Excel without the use of VBA code.

A Mandelbrot is a graphical display of the simple equation  $Z_{n+1} = Z_n^2 + c$ , where  $Z$  is a complex number ( $x + iy$ ).

Which is described at [http://en.wikipedia.org/wiki/Mandelbrot\\_set](http://en.wikipedia.org/wiki/Mandelbrot_set)

This can be solved in the real X-Y domain using:

$$X_{new} = X_{old}^2 - Y_{old}^2 + X_{Orig} \text{ and}$$

$$Y_{new} = 2 * Y_{old} * X_{old} + Y_{Orig}$$

Study of iterated functions reveals that these functions will either converge on an answer or diverge once a boundary has been breached

In the case of the Mandelbrot, this function diverges after the function  $Z^2 > 4$

So to construct a Mandelbrot a program needs simply to

1. Loop from Xmin to Xmax in small steps and
2. Loop from Ymin to Ymax in small steps and
3. For every X, Y Point in the above 2 loops, solve the above equations until the answer is  $> 4$
4. Color the screen according to how many iterations it took to diverge or not

Simple...

Except that Excel doesn't have any looping functions unless you use VBA Code

The calculation of the solution for any X, Y starting point is simple enough using a series of Rows and Columns where each Cells is the starting iteration of the solution for each various X, Y co-ordinate.

This is shown in the Calculations page in the Xnew, Ynew, Xold, Yold, Rsq and Count columns.

The iterations are simply done in the Xnew and Ynew columns

For each iteration we check that the  $Z^2$  value hasn't diverged ( $\text{not} > 4$ ) ( $X_{new}^2 + Y_{new}^2$ )

And keep track of how many iterations it took to diverge, the Count Column

The above 5 lines I refer to below as the Calculator.

-2	Power	2		
3	Iterations	50		
-1	Escape	4		
2	X Orig	-1.278		
	Y Orig	0.068		

Y new	X old	Y old	Rsq	Count
	0.00	0.00	0.0	1
0.00	-1.28	0.07	1.6	2
0.07	0.35	-0.11	0.1	3
-0.11	-1.17	-0.01	1.4	4
-0.01	0.08	0.08	0.0	5
0.08	-1.28	0.08	1.6	6
0.08	0.35	-0.14	0.1	7

The trick to working out how to do this for a X-Y Grid was the use of the Table Function to send the starting positions to the Calculator and return the Count for that location.

This is the large Yellow Area.

	X-Coordinates -->				
26	-2.00	-1.97	-1.94	-1.91	-1.88
-1.00	2	2	2	2	2
-0.98	2	2	2	2	2
-0.96	2	2	2	2	2
-0.94	2	2	2	2	2
-0.92	2	2	2	2	2
-0.90	2	2	2	2	2
-0.88	2	2	2	2	2
-0.86	2	2	2	2	2

The Large yellow area (Data Table Area) is flanked on the Top and Left by the X and Y co-ordinates for a grid encompassing the area which we want to plot.

The Table Function extracts the Top and Left values and puts them in the X Orig and Y Orig positions of the calculator.

The Calculator returns the Count of the Divergence of the Calculator to the H2 position (Top Left corner of the Grid) and that value is stored at the Grid Location.

								XCoordinates →			
X Min	-2	Power	2			2	-2.00	-1.97	-1.94	-1.91	-1.88
X Range	3	Iterations	50			-1.00	2	2	2	2	2
Y Min	-1	E scape				-0.93	2	2	2	2	2
Y Range	2	X Orig	-1.04			-0.86	2	2	2	2	2
		Y Orig	-0.92			-0.84	2	2	2	2	2
						-0.92	2	2	2	2	2
X new	Y new	X old	Y old	Rsqr	Count	-0.90	2	2	2	2	2
		0.00	0.00	0.0	1	-0.88	2	2	2	2	2
0.00	0.00	-1.94	-0.92	4.6	2	-0.86	2	2	2	2	2
		#VALUE!	#VALUE!		3	-0.84	2	2	2	2	2
		#VALUE!	#VALUE!		4	-0.82	2	2	2	2	2
					5	-0.80	2	2	2	2	2
					6	-0.78	2	2	2	2	2
					7	-0.76	2	2	2	2	2
					8	-0.74	2	2	2	2	2
					9	-0.72	2	2	2	2	2
					10	-0.70	2	2	2	2	2

The Data Table repeats this for each position in the X-Y Grid.

An Excel Surface Chart can then Chart the Large Yellow area in effect creating a Traditional Mandelbrot plot by joining up adjacent areas of equal value (Contouring).

The Chart can also be displayed as a 3D-Surface rather than a Contour Chart for a dramatic effect.

Zooming In can be added by adding code that allows the user to say Right click in the Large Yellow area and the code will then take the Co-ordinates and Zoom in by a fixed factor

Zooming Out can be added by adding code that allows the user to say Double click in the Large Yellow area and the code will then take the Co-ordinates and Zoom out by a fixed factor

## DOWNLOAD EXAMPLE WORKBOOKS

Download the complete example workbooks described above and practice data tables on your own.

- [Click here to download](#) Gold Mine Monte Carlo Simulations & Data Tables workbook. [[XL 2003 version here](#)]
- [Click here to download](#) Excel Mandelbrot workbook.

**Note:** A few people have said the above files either Hang or Freeze there PC's. This is probably because they have a number of large Data Tables within them.

I have uploaded each Tab as a separate Excel 2007 file, see below:

1. [1 Way.xlsx](#)
2. [2 Way.xlsx](#)
3. [Monitor Multi Variables.xlsx](#)
4. [Multiway Table.xlsx](#)
5. [Monte Carlo Simple \(updated\)](#)
6. [Monte Carlo \(Adv\).xlsx](#)

In the Example Files some of the Data Tables have been removed and there are instructions on how to re-instate them included in the file.

## FINAL THOUGHTS

### Speed

If you start adding a number of Data Tables to Complex Models you will rapidly cause even the fastest machines to grind to a halt.

### VBA

The best way around the above speed issue is to setup a number of Data Tables for whatever analysis you wish to undertake. Then as you run each analysis copy the Data Table Data Area, The area between the Rows and Columns and paste it as values over itself. Then move onto the next data table and run it.

This allows the Data Tables to be quickly recalculated if required.

This process can be automated via 3 lines of VBA code for each Data Table.

```
'Calculate Data Table in F5:H18, using Column Input cell C9
Range("F5:H18").Table.ColumnInput:=Range("C9")

'Copy Data Area as Values
Range("G6:H18").Copy
Range("G6:H18").PasteSpecial Paste:=xlPasteValues

'Repeat Above for each Data Table

'Deselect Current Range
Application.CutCopyMode = False
```

### Cell Contents

If you look at a cell in a Data Table you will see something like:

- {=TABLE(,E5)}: for a Column Input Cell
- {=TABLE(E4,)}: for a Column Input Cell
- {=TABLE(E4,E5)}: for a Row and Column Input Cell

Although these appear like Array Formula, they cannot be manually set.

So setting up a data table and typing =TABLE(,E5) Ctrl Shift Enter, only produces an error message.

## Further Reading & References

- <http://www.exceluser.com/explore/statsnormal.htm>
- <http://www.vertex42.com/ExcelArticles/mc/GeneratingRandomInputs.html>
- <http://www.itl.nist.gov/div898/handbook/eda/section3/eda366.htm>
- [http://en.wikipedia.org/wiki/Mandelbrot\\_set](http://en.wikipedia.org/wiki/Mandelbrot_set)
- <http://chandoo.org/wp/2011/06/20/analyse-data-like-a-super-hero/>

## Added by Chandoo

This post is by far one of the most comprehensive posts on Chandoo.org. And each of the 3100+ words in it show the passion and knowledge that **Hui** has. Thank you so much Hui for sharing this wealth of knowledge with our members. I have learned a lot of interesting and useful things from this article.

If you have enjoyed this article, *please say thanks to [Hui](#)*.

### Trackbacks & Pingbacks

- Pingback by [More on data tables and Monte Carlo « Excel Tips Monster](#) on May 20, 2010 @ 9:12 pm

- Pingback by [Excel Hiding Error Messages Quick Tip | Chandoo.org - Learn Microsoft Excel Online](#) on October 28, 2010 @ [8:43 am](#)
- Pingback by [Introduction to Project Finance Modeling in Excel | Chandoo.org - Learn Microsoft Excel Online](#) on February 8, 2011 @ [8:56 am](#)
- Pingback by [Using Excel's Random Functions to setup Dummy Data | Chandoo.org - Learn Microsoft Excel Online](#) on May 4, 2011 @ [8:38 am](#)
- Pingback by [Data Tables & Monte Carlo Simulations in Excel \(Update\) | Chandoo.org - Learn Microsoft Excel Online](#) on May 19, 2011 @ [8:01 am](#)
- Pingback by [Data Analysis using Linest and the Data Table function . | Chandoo.org - Learn Microsoft Excel Online](#) on June 23, 2011 @ [3:05 am](#)
- Pingback by [Scenario Analysis for the Project Valuation \[Financial Modeling\] | Chandoo.org - Learn Microsoft Excel Online](#) on July 26, 2011 @ [8:46 am](#)
- Pingback by [A Challenge from Hui | Chandoo.org - Learn Microsoft Excel Online](#) on October 3, 2011 @ [9:02 am](#)
- Pingback by [Day 63: Excel 2-way data table – WHAT I BELIEVE](#) on October 29, 2011 @ [10:15 pm](#)

#### Comments

##### 1) [ross](#) [May 6, 2010](#)

Hi

Looks like a grate post, I'll need to give some time over to reading it fully, thanks Hui,  
Ross

##### 2) [oldchippy](#) [May 6, 2010](#)

Hats off to Hui,

Can't say i've ever used that in Excel before, but thanks for the introduction

##### 3) [Martin](#) [May 6, 2010](#)

Hui,

definitively, another post to print for the travel back home...Without all your knowledge, I am a convinced that Excel can do everything, but in my case it's more a question of faith, rather than knowledge...

Thanks for sharing, and thanks Chandoo for giving him the space !

Rgds,

Martin

##### 4) [Jon Peltier](#) [May 6, 2010](#)

Excellent post describing a powerful yet unknown/underused feature of Excel.

##### 5) [Taf](#) [May 6, 2010](#)

1st of all thanks to Hui!

And great bost, maybe the most usefull i've seen here so far. I already knew of excels capabilities in this area but often couldn't find it well described before...

Thanks for the crytal clear explanation!

##### 6) [Bill Norton](#) [May 6, 2010](#)

Very thorough use of the tables functions! I wonder though, wouldn't creating a Pivot table after the fact make rearranging these various scenarios a lot easier?

Also, have you tried using the Analysis ToolPack for the Monte Carlo simulations? I'm curious if it has any similar functionality (it's disabled for some bizarre reason at my place of work).

##### 7) [Ihm](#) [May 6, 2010](#)

Nice post, funny – there was a very similar discussion about monte carlo and mandelbrot a few days back, don't know if that's just coincidence?

See: <http://www.excelhero.com/blog/2010/03/monte-carlo-pi.html>

The linked workbook is in hi-res so takes a little while, but is worth the wait – maybe someone can help speed it up? (eg using IF(ISNA(...) in the iterations runs about 1/3 quicker)

As mentioned there, to improve performance of Monte Carlo, you need to find ways to reduce the variation. In fact, since convergence is order root n, every additional digit of precision requires 100 times more computations! Lori

##### 8) [Hui](#) [May 7, 2010](#)

@ All, Thanx for the words of appreciation.

@ LHM, although the Monte Carlo system is in use in both examples, Excel Hero is using the weight of numbers to zero in on an answer and yes the more iterations you do the more accurate it is, as it is a definite formula that gets you closer to the answer the more you feed into it.

In Monte Carlo analysis of variability you never get the right answer, regardless of how many iterations you do. What you do need to do is do enough iterations that the results are statistically accurate. Generally for a Normal Distribution you need a minimum of 30 points to define a statistical population which will be representative of the real population.

Because you are generally interested on the probability of the results of the simulation being above/below a certain range, you are more interested in the outliers, than the mean. This means that you need enough outliers to be presented to be a representative population of outliers. For a Normal distribution where  $\pm 3$  Standard Deviations is 99.7% of the population if you then want 30 samples in the remainder 0.3% you need  $30 \times 100/0.3$  or about 10,000 iterations to guarantee a sufficient sample of outliers. This is starting to become a large number and most people run in the 1-10,000 iteration range and then check that sufficient outliers have been presented.

#### 9) Kanti Chiba May 7, 2010

Hui & Chandoo,

This was a very instructive post learned a great deal from it.

I split out the High and Low in the scenario description and created a high and low field to hold a percentage and then linked the scenario data to these fields so that I could change what High and Low meant. If you wanted to test for +10% for high you would put 10% in the High field, or if you wanted to test for a low of 8% you could put -8% in the low field.

The possibilities are endless.

Thanks once again for the post

#### 10) Chris May 7, 2010

Hui et. al.,

I don't really see the advantage of doing this in data tables and not running the iterations in vba? Certainly it isn't any faster.

Seriously speaking MC Valuation need a few thousand iterations, i don't think you'll like to do that within the sheet. I'd prefer looping it in VBA for smaller projects, for larger ones you need to switch to oracles crystal ball or sth similar.

Never the less, i really liked the application of advanced excel methods.

Thy

#### 11) Hui... May 8, 2010

@Chris

I ran the Multi Way Tables example with 4 inputs and 5 output variables with 1,000,000 iterations in the Data Table in about 8 seconds

Using VBA to do 100,000 iterations took about 230 seconds

I Deleted all the other sheets to speed it up in both cases

Excel easily handles 100,000+ iterations on modestly complex models with ease

I try and use the native functions of Excel as opposed to VBA as much as possible, they are just so much faster.

The low iteration count in the example models were for demonstration purposes only.

#### 12) Abhishek May 13, 2010

just one word for this "AWESOME"

#### 13) Lucasini May 20, 2010

Hui, great post, you and Chandoo really qualify as an "Excel " & POWER(Ninja,99) – someday I will get there.

I have to say that I agree with your "Excel can do -almost- anything" statement, I prove it everyday in my workplace.

In all my years of working with Excel I've learned an important lesson, the very first and ultimate principle that determines the approach to take with an Excel problem: Whatever you can do with the built in Excel functions would run faster and better than if you do the same thing with macros. The problem is that the common mortal doesn't know what tools he can use, or how to use them.

I have to admit that I don't use the Data Table feature but I like'd your way to do the fractal iterations!

There is another way to make iterations in Excel... you can use one of the most powerful but concealed feature (and often considered only as an error warning): circular references. Of course, you have to make more complex formulas, you have to be careful with the physical placement of your variables and calculations, but you can write really complex models with it!

Great work, keep the good posts coming!!!!

P.D.: Sorry about my english, It's not my native language!

#### 14) John N June 30, 2010

Stunning!

#### 15) Gene K June 30, 2010

Hui, great article with a lot of insight. I will need more time to get everything out of it, but I have learned a great deal already. Thanks.

16) **Kwesi** July 4, 2010

All of the inputs in my workbook are on a different sheet. When I try to create a data table I get the error message " Input Cell Reference Is Not Valid ". Is there a workaround?

17) **Hui...** July 5, 2010

Kwesi

Setup an input area on the same sheet as where the data Tables will go

Link the real inputs to these values

Run the data tables on these values

It is a shame that you can't use named ranges here to get around this issue, like you can elsewhere where inter-sheet formulas can't be used.

18) **Dilishan** July 10, 2010

Hi..

Montecarlo simulation using excel is amazing. I really appreciate you for sharing the knowledge.

I have this question for you.

Let us say I am trying to figure out the variation in profit for variable A. Using the method suggested I can run the montecarlo simulation. I want to draw a graph at each iteration (X axis- Different units of variable A), (Y axis – Different profit levels which corresponds to different variable units.)

So once the iterations are over a chart will be drawn where this could be used as an efficient frontier.

Please let me know whether it will be possible. If this can be done we all have to agree that Excel can do wonders.

Many thanks in advance for your support

19) **Hui...** July 13, 2010

Dilishan

You have 2 easy options here :

1. Scatter Chart – As you have a table of Input Values and results next to it in the actual Data Table, it is a few clicks to chart the data as a scatter chart. You should see more symbols near the mean value and less as you get towards the outliers.

2. Cummulative Column Chart – The most common method of Charting Distributions is a Column Chart and associated Cummulative Line Chart (like <http://i26.tinypic.com/34yo20k.png> ) .

This will require you to setup an area where you have a list of result containers, ie: If your results go from 0 to 100, you may want to setup containers every 5, 0-4.99, 5-9.99,10-14.99 etc and then use a sumifs or sumproduct to count how many times these results are in the Solution part of the Data Table.

20) **Ankit** July 18, 2010

i wanted to knw the procedure of sum the numeric value in one sentence

21) **Hui...** July 19, 2010

Ankit

You can do something like:

=Sum(1,2,4,10) which will give you the answer of 17

or

=Sum(A1, A3, A5, A10) which will add up the values in those cells

or

=Sum(A1:A5) will add up all the values in the Range A1:A4

or a combination of the above

=Sum(2,4,A5, A7) which will add 6 (2 + 4 ) to the values in A5 + A7

22) **Chris** July 21, 2010

Fantastic article, just helped me save hours of work!

23) **Gary** September 26, 2010

Great article. Microsoft should be paying royalties!

Thanks.

24) **junius** October 29, 2010

Excellent post. You should check out <http://tukhi.com>. One of the examples in the Mosteller workbook plays the game of craps!

25) **James** November 10, 2010

this is pretty cool.

anyone know how to make a data table of a data table?

i.e. i want to run a model for N period where each period is dependent upon the previous period while varying multiple input variables.

then i want an outer loop running the above model for M iterations to find the optimal settings for the input variables based on summary statistics found for each iteration

when i try a data table referencing another data table the referenced data table does not change, so i only get iterations for 1 set of input variables

26) **Sesky** [November 16, 2010](#)

One of the best articles I have ever read on Excel.  
Thank you very much Hui.

27) **Rutgerius** [November 16, 2010](#)

Hello, please can I know how you created the Large yellow area (Data Table Area)?

Thanks  
Rut

28) **Bill** [November 16, 2010](#)

Is there any way to unsubscribe from comment posts? I think my last comment was a year ago....

29) **Chandoo** [November 16, 2010](#)

@Bill.. you can unsubscribe from the email alert you get. There should be a link to managing your profile in that mail.

30) **Hui...** [November 17, 2010](#)

@Rutgerius  
The large yellow area is the Data Table area  
You only need to populate the Top Row and Left Column  
Then Use the Data Table command to fill it.  
Select Cells D2:DE103 and goto Data Table  
Select cells for the Row and Column Inputs as described in the text above

31) **schizophrenia** [November 17, 2010](#)

hi,i need some help with the data table.Could please explain how you did the yellow data table for the Mandelbrot set in much details as possible and stepwise..thanks

32) **Rutgerius** [November 17, 2010](#)

Hi

I tried it.. but it aint working 😞

33) **Hui...** [November 18, 2010](#)

@Schizophrenia, Rutgerius

.  
For a start thanx for taking the interest in this post.

.  
1. Download the Mandelbrot Spreadsheet from: <http://cid-b663e096d6c08c74.skydrive.live.com/self.aspx/Public/excel-mandelbrot.xls>

Don't click on the icon and open it in the web browser.  
It is an .xls file and will work in all versions of Excel.

.  
2. Goto the Calculations Page and select I3  
3. Press Ctrl Shift Right, Ctrl Shift Down, Delete  
This will select and delete the range I3:DE103  
4. Go back to H2  
5. Press Ctrl Shift Right, Ctrl Shift Down,  
This will select the range H2:DE103  
6. With your mouse got the Data Tab, What If Button and select Data Table  
7. In the Data Table dialog enter  
Row input cell: E5  
Column input cell: E6

.  
Voila

34) **schizophrenia** [November 18, 2010](#)

thank you much..it works!:)..it was of a great help for my project at university..

35) **James** [November 21, 2010](#)

@hui

any idea for my earlier posted problem?

thanks.

36) **Hui...** [November 21, 2010](#)

@James

Do you have an example you can email or post for me to see what your trying to do?

37) **James** November 22, 2010

@hui

couldn't find your email, trying google docs

[https://docs.google.com/leaf?](https://docs.google.com/leaf?id=0B00vs4RO2HKmN2IOOTRkNGEtMWYxNy00ODIzLWJhMjEtYmMyNTUwZDZjYjZi&hl=en&authkey=CI-XIFQ)

[id=0B00vs4RO2HKmN2IOOTRkNGEtMWYxNy00ODIzLWJhMjEtYmMyNTUwZDZjYjZi&hl=en&authkey=CI-XIFQ](https://docs.google.com/leaf?id=0B00vs4RO2HKmN2IOOTRkNGEtMWYxNy00ODIzLWJhMjEtYmMyNTUwZDZjYjZi&hl=en&authkey=CI-XIFQ)

the top middle portion show 1 iteration with 4 periods, the right data table is 1000 iterations of it

then, as you can see the bottom 2-way data table is referencing the data table on the right, but the different prices and supplies are not being used.

supposing that works, next i want to be able to change the prices from period to period for each iteration, (i.e. 60-45-55-70) [all possible permutations of price-period combinations]

Thanks!

38) **Hui...** November 23, 2010

Why not just use the first Table and run for 20 -50,000 iterations

Change

F3: =CHOOSE(RANDBETWEEN(1,6),45,50,55,60,65,70)

C20: =CHOOSE(RANDBETWEEN(1,6),1500,2000,2500,3000,3500,4000)

Add 2 columns to the table

to show Price and Fleet size

and feed results into a pivot tabl

as per: [http://rapidshare.com/files/432543642/data\\_table\\_referencing\\_another\\_data\\_table\\_Hui\\_ver.xls](http://rapidshare.com/files/432543642/data_table_referencing_another_data_table_Hui_ver.xls)

39) **James** November 23, 2010

thanks! that's an interesting approach, never used pivot tables before,

if i'm understanding correctly from the file, this means the number of 45's vs 50's vs 55's prices may differ, so I can't compare across supplies for averages computed upon the same sample sizes

same goes for the number of iterations that use 1500, or 2000's — they will differ.

anyway to have a fixed amount of all of them? ( i guess you could have 6 \* 6 \* 1000 iterations...)

40) **Hui...** November 23, 2010

That's why you do a large number of iterations

You can also do a count in the pivot table to see how many iterations fall into each category

41) **James** November 23, 2010

say i need exactly 1000 45's and 1000 50's and 1000 55's though?

is the way to private msg on this board without revealing email?

42) **Hui...** November 23, 2010

My email is at the bottom of

<http://chandoo.org/wp/about-hui/>

43) **Rob** January 7, 2011

Great post, I would just comment that the formula you are using to calculate percentage change in the one way table should be =1.68\*(1+E2)

44) **Dionne** February 2, 2011

Hi Hui

I have a question about using a data table to do scenario analysis on a model I have built. The model has an INPUT tab/ worksheet where I have placed my data table. However all the inputs pull onto a second tab (Profit and Loss) to calculate the output value which I want to use in my scenario data table. The data table is not producing the correct values. So my question is: for a data table to work, do all inputs AND calculations need to be on the same tab/worksheet?

45) **Hui...** February 3, 2011

@Dionne

Yes, All inputs/ouputs have to be on the same sheet as the Data Table

But this can easily be done with an input/output area, which will be linked to other parts of your model as appropriate

Calculations can go across any number of sheets

46) **Abhishek Sinha** February 3, 2011

Hi Chandoo,

Congratulations for the great work!  
I have a couple of questions regarding excel.

1) How can I generate auto correlated numbers in excel – Suppose I have fixed the correlation to be 0.7 (  $\text{Corr}(X,Y) = 0.7$  ) then how can I generate random X,Y for it? Is there any way to fix Intra class correlation and generate X,Y for it?

2) How a Monte Carlo simulation can be done to test Krippendorff's Alpha ( statistical parameter) against Intra class Correlation?

It would be really thankful for your reply!

Thanks!

47) **Natalia** [February 14, 2011](#)

Thank you sooooo much Hui!

A life changing post for me!

Happy Valentines too 🍷

48) **Carlos Santana** [April 7, 2011](#)

Thank Hui, your contribution is excellent, and use to calculate the value of the premiums for helth insurance.

49) **Hui...** [April 7, 2011](#)

@ Natalia & Carlos  
Thanx for your kind words  
Hui...

50) **Kathleen** [April 13, 2011](#)

Hui,  
Thank you so much for this valuable information! I have a question regarding the Monte Carlo Simulation (Simple.) You state, "The formula =NORMINV(RAND(),0.92,0.02), will generate a Random Exchange Rate with a distribution based on a mean on 0.92 A\$/U\$ and a spread of approximately 6 cents each way ie: there will be a 99.7% probability of the exchange rate being between 0.86 and 0.98 A\$/U\$." My question is: how did you determine the 0.02? I realize that 3 standard deviations will give us the range between 0.86 and 0.98, but how did you determine the 0.02 in the first place? Why not 0.01 or 0.03 or some other number?  
Thanks!

51) **Hui...** [April 13, 2011](#)

@Kathleen  
The Norminv function accepts 3 Parameters  
=NORMINV(probability,mean,standard\_dev)  
.  
The 0.92 and 0.02 are the Mean and Standard Deviation that the distribution I used had.  
.  
In this case the 2 numbers are made up for Demonstration ourposes only.  
Had I used a SD of 0.02 or 0.2 or 0.3 the Ranges Distribution would change, but it will still have a 99.7% probability of being within the Mean +/- 3 SD's.  
.

In reality you will take a number of measurements of your data and then work out what the actual distribution (Mean and Standard Deviation) of the data is.

52) **Sam** [May 4, 2011](#)

Hi Hui

Very good work. I am just not too sure one one particular point. Why is it that the Exchange rate you generated using "=NORMINV(probability,mean,standard\_dev)" be different to what you have in the "Ex Rate" column? Shouldn't they be the same?

Thanks

Sam

53) **Nitin** [May 13, 2011](#)

Hi Chandoo,

I downloaded both xls andxlsx versions of the file "gold-mine-monte-carlo-analysis" and attempted to open them twice. On both occasions, MS Excel simply hung up and I had restart it. Is there something wrong with my machine? I think it's unlikely there can be something wrong with your two files...pls advise. Cheers!

54) **Hui...** [May 14, 2011](#)

@Nitin  
Both files are still Ok  
.  
Click on the link and then select either  
1. The Download Link which will open the Download as Dialog  
or

2. Click on the large Spreadsheet Icon in the middle of the screen which will open the files in the browser, then File, Save a copy

55) **Srini** May 18, 2011

good information is presented. Thanks

56) **Srini** May 18, 2011

Chandoo, I need a help from you. Could you send the procedure of how to copy the values automatically into other cells using a macros? After completing the data table functions, I need to copy the STDEV of the generated numbers. I want to select the min STDEV. Kindly help me out of this.

57) **Nitin** May 18, 2011

Hi Hui,

Thanks for responding. As mentioned earlier, I have complete faith in Chandoo.org. However I regret to state that in spite of following the process you mentioned, I continue to face the same problem – both files simply take too long to load and in the meantime, MS Excel hangs – this in spite of a machine with C2D processor and 2GB RAM. Apologies for bothering you time and again, but could you suggest some other course of action? Thanks!

58) **Dotcomsx** May 19, 2011

All good ,Top stuff

Keep the good work

59) **Ambiguous Error** May 19, 2011

Wonderful work Hui & thanks for sharing 🙏 )

I find the Madlebrot set fascinating, although my PC didn't like the chart.

To get around this I applied xl 07 Graded Colour Scale Conditional formatting to the, once yellow, area. Zooming out this gives a very similar effect & less resource heavy.

Off to see if I can apply different distributions to the Monte Carlo exercise.

+ 1e6 Internets

60) **Ghazanfar J** May 21, 2011

=kick("ass","everybody's")

61) **kim** June 8, 2011

anyone know why i am getting the same output for every cell in the table?

62) **Hui...** June 9, 2011

@Kim

You have probably put the Data Table link in the Row Input Cell instead of the Column Input Cell or vise versa

63) **Elkhan** August 15, 2011

Hui,

first of all, thanks a lot for this post. it is great and what I have been looking for to understand how data tables work.

I have a question about 1 way (or 2 way) data tables using percentage variation of inputs. you recommend using formula for input cell (e.g. gold grade) as =INPUT\*1+Temp.Input.Cell. So, using this logic, -50% as in your spreadsheet, gives -15.5 M \$ profit which corresponds to 1.18 (i.e. 1.68-0.5). However, for some people, to me at least, -50% more logically means half of the original value, i.e. 1.68-50%=0.84. In this case the formula for the input cell should be =INPUT\*(1+Temp.Input.Cell).

thanks again for the great help

64) **Hui...** August 15, 2011

@Elkhan

I'm glad that you liked the post.

I nearly use Data tables as much as Sumproduct, it is such a powerful function.

Great pickup on the formula

You are totally correct that the formula should be

=INPUT\*(1+Temp.Input.Cell)

I will severely scold the proof reader...

65) **anup** September 18, 2011

Hui

thank you very much for this wonderful post.

Regards

Anup

66) **Ulrik** September 22, 2011

Excellent article Hui – thanks for unearthing such a beautiful and potent gem from the Excel vault!

67) **Andy Holaday** November 5, 2011

In the first 1-Way Table (<http://chandoo.org/wp/2010/05/06/data-tables-monte-carlo-simulations-in-excel-a-comprehensive-guide/#1way-tables>) I tried using NormInv to vary the Gold Price using formula =NORMINV(RAND(),1.68,0.1)  
 . This produces profit results that are completely inconsistent with the input values.

The problem is easy to see if the input value is rounded to produce a few discrete values: =ROUND(NORMINV(RAND()  
 ,1.68,0.1),1). Here is a partial sample output from the table using rounded inputs:

5.45  
 1.70 2.10  
 1.80 10.48  
 1.80 6.29  
 1.70 2.10  
 1.80 6.29  
 1.80 10.48  
 ...

How is it that the same input value can produce different outputs? I'm guessing that somehow the call to volatile Rand()  
 causes the Table to evaluate a different value than what is shown. If you look at the output values, they are discrete as well  
 (as expected), but it seems they are mismatched with the inputs.

As a test, I tried a different randomizing function for Gold Price =INT(RAND()\*3)+168. The same problem occurs: the same  
 input can yield different output in different trials.

I guess the moral of the story is not to use Rand() in the input variable formula. Has anyone else noticed this behavior?

68) **Hui...** November 6, 2011

@Andy  
 Thank you for pointing this out

.  
 There are two things that could be going on here.

#### 1. Excel Version

In Excel versions up to XP Norminv returns errors from time to time  
 Refer: <http://support.microsoft.com/kb/827358>

#### 2. Rand()

Your suggestion as to the Volatile Rand is correct  
 The Data Table recalculates after every iteration of each cell in the Input Row/Column.  
 So when the second row calculates, it forces the input cell in the first row to recalculate.  
 So in the example the Input Column is recalculated 9 times after the first iteration scrambling the input grades.  
 The Profit figures in that example are still correct as they haven't been recalculated, its just the input column that is  
 incorrect.

#### Workaround

Luckily there is an easy work around for this:  
 When setting up the data table at another column that will link to the Input Cell (C10)  
 in this example

Gold	Grade	Profit	Grade
5.5	1.68		
1.70	\$6.3	1.70	
1.80	\$2.1	1.60	
1.70	\$2.1	1.60	
1.70	\$10.5	1.80	
1.50	\$6.3	1.70	
1.70	-\$2.1	1.50	
1.60	\$2.1	1.60	
1.80	\$6.3	1.70	
1.60	\$10.5	1.80	
1.60	-\$2.1	1.50	

.  
 You can see above that the Profit is now consistent with the Grade Column, but not the input grade column.

69) **Andy Holaday** November 7, 2011

@Hui  
 Great explanation, and the work-around is so simple I couldn't see it. BTW, this is a great article! I've never seen the Excel  
 Data Table function explained so well anywhere else.

70) **Hui...** November 7, 2011

@Andy 😊

71) **Yun** November 8, 2011

Thank you so much for the information 😊

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