TIE2140 Engineering Economy Tutorial 6 (Lab 2)

Engineering-Financial Making Process using EXCEL

Step-by-Step Solutions Guide

Contributed by previous Engineering Economy Tutors

1. Learning Objectives

In this lab-based tutorial, you will learn how to:

1. Develop a basic deterministic financial after-tax cash flow model using Excel
2. Perform One-Way Range Sensitivity Analysis using Sensit (Tornado and Spider Diagrams)
3. Perform Break-Even Analysis using Rainbow Diagrams (and Goal Seek)
4. Perform Probabilistic Risk Analysis using Monte Carlo Simulation using @Risk.
5. Interpret Risk Profile and determine risk measures.

2. Problem Description

ISEM Company has recently successfully developed a new product. The market demand of this product is estimated to be 15,000 units per year at a sale price of $10 per unit. The product life is expected to be 10 years. The product can be manufactured using two alternative methods using different machines as follows:

Alternative A: Advanced manufacturing technology

This involves adopting a recently developed advanced manufacturing technology and requires expensive automatic machine tools with intelligent sensors system. Relevant data for this alternative are given below:

- Initial cost: $230,000.
- Useful life: 10 years.
- Salvage value: $10,000

- Manpower requirements and costs:
  - Production output: 8 units per hour
  - Number of operators needed: 1
  - Skill level: High
  - Manpower cost: $12 per hour per operator

- Annual maintenance and other costs:
  - Maintenance manpower: $25,000
  - Moldings & Tooling: $5,000
  - Spare parts: $5,000

- Direct material costs: $3 per unit.

Alternative B: Conventional manufacturing technology

This involves using an existing manufacturing technology which requires cheaper conventional machine tools operated low-skill workers. Relevant data for this alternative are given below:

- Initial cost: $90,000.
- Useful life: 5 years.
- Salvage value: $1,000

- Manpower requirement and costs:
  - Production output: 6 units per hours
  - Number of operators: 3
  - Skill level: Low
  - Manpower cost: $8 per hour per operator

- Annual maintenance and other costs:
  - Maintenance manpower: $10,000
  - Moldings & Tooling: $3,000
  - Spare parts: $2,000

- Direct material costs: $3 per unit.

Your Mission

ISEM management is not sure which of the two alternatives to select, and you have been engaged as a consultant to advice the company.

ISEM's CEO has instructed you to use a before-tax *MARR* 12% and a study period of 10 years in the analysis. In addition, you may use the repeatability assumption where needed. Income tax do not need to be considered in this analysis as the company has been granted special tax exemption by the Economic Development Board for this investment project.

3. Hand-on Exercises and Solutions

3.1 Base Model Development & Analysis

a. Using Excel, perform BTCF analysis to determine the Before-Tax AW (and / or PW) for the proposed alternatives based on the base estimates and a study period of 10 years. You may use the Excel template provided.
b. Is Alternative A or Alternative B economically feasible based on the base estimates?

3.1.1 Base Model for Alternative A

First, open the ***ie2140-19-tut-06-lab2-templates*** and go to the **Base Model A** sheet. The relevant variable and their corresponding base values for Alternative A are already inputted in the Excel sheet. Then, let's conduct the Before-Tax Cash Flow Analysis.

Let's compute the **Variable manpower cost per piece** = Manpower cost × No. of operators required / Output per hour (C28 = C20*C19/C21).

You should be able to get the answer:

Computed	
Variable manpower cost per piece	$1.5000

C28 = C20*C19/C21

Then let's move to **Before-Tax Cash Flows Analysis**:

There are some useful formulas which can help you to fill up the table:

- Annual Revenue = Annual production volume × Unit selling price
  [Example of computing Annual Revenue by using Excel]

Before-Tax Cash Flows Analysis	
	Cash Flow A
Initial Investment	-$230,000.00
Annual Revenue	=C5*C6
Annual Direct Manpower cost	-$22,500.00
Annual Direct Material cost	-$45,000.00
Annual Overheads	-$35,000.00
Salvage value	$10,000.00

Here are the input instructions:

C33 = -C13
C34 = C5*C6
C35 = -C5*C28
C36 = -C5*C23
C37 = -SUM(C15:C17)
C38 = C25

- Annual direct manpower cost = Annual production volume × Variable manpower cost per piece
- Annual Direct Material cost = Annual production volume × Direct material cost per unit
- Annual Overheads = Annual Maintenance Manpower + Annual Moldings & Tooling + Annual Spare parts

After you have computed all the required data, you should be able to get the results as follows (Please check your answer before we move to the next session):

Before-Tax Cash Flows Analysis	
	Cash Flow A
Initial Investment	-$230,000.00
Annual Revenue	$150,000.00
Annual Direct Manpower cost	-$22,500.00
Annual Direct Material cost	-$45,000.00
Annual Overheads	-$35,000.00
Salvage value	$10,000.00

Here are the input instructions:

C33 = -C13
C34 = C5*C6
C35 = -C5*C28
C36 = -C5*C23
C37 = -SUM(C15:C17)
C38 = C25

After checking your answer, and make sure it is correct. Now, let's move to compute AW and PW for Alternative A with a before-tax *MARR* 12%.

Here is the formula you can refer to:

AW (12%) = − Initial Investment [A/P, 12%, N]

+ (Annual revenue – Annual direct manpower cost

– Annual Direct Material cost – Annual Overheads)

+ Salvage value [A/F, 12%, N]

For AW of Alternative A:

SUM =SUM(C34:C37) - PMT(C7, C24, C33, C38, 0)

	A	B	C	D	E
31		**Before-Tax Cash Flows Analysis**			
32			**Cash Flow A**		
33		Initial Investment	-$230,000.00		C33 = -C13
34		Annual Revenue	$150,000.00		C34 = C5*C6
35		Annual Direct Manpower cost	-$22,500.00		C35 = -C5*C28
36		Annual Direct Material cost	-$45,000.00		C36 = -C5*C23
37		Annual Overheads	-$35,000.00		C37 = -SUM(C15:C17)
38		Salvage value	$10,000.00		C38 = C25
39					
40		**AW of A**	**=SUM(C34:C37) - PMT(C7, C24, C33, C38, 0)**		
41		PW of A	$41,605.33		C41 = -PV(C7, C8, C40, 0, 0)
42		**Project is**	Feasible		

For PW of Alternative A:

SUM = -PV(C7, C8, C40, 0, 0)

	A	B	C	D	E
31		**Before-Tax Cash Flows Analysis**			
32			**Cash Flow A**		
33		Initial Investment	-$230,000.00		C33 = -C13
34		Annual Revenue	$150,000.00		C34 = C5*C6
35		Annual Direct Manpower cost	-$22,500.00		C35 = -C5*C28
36		Annual Direct Material cost	-$45,000.00		C36 = -C5*C23
37		Annual Overheads	-$35,000.00		C37 = -SUM(C15:C17)
38		Salvage value	$10,000.00		C38 = C25
39					
40		**AW of A**	**$7,363.48**		C40 = SUM(C34:C37) - PMT(C7, C24, C33, C38, 0)
41		PW of A	= -PV(C7, C8, C40, 0, 0)		
42		**Project is**	Feasible		

After you have computed *AW* and *PW* of Alternative A, you should be able to get the results as follows (Please check your answer before we move to the next session):

AW of A	**$7,363.48**	C40 = SUM(C34:C37) - PMT(C7, C24, C33, C38, 0)
PW of A	$41,605.33	C41 = -PV(C7, C8, C40, 0, 0)
Project is	Feasible	Here are the input instructions:

And please be noted that, since AW (or PW) of Alternative A > 0, so we can conclusion that the project is **Feasible.**

3.1.2 Base Model for Alternative B

Secondly, please go to the **Base Model B** sheet. The relevant variable and their corresponding base values for Alternative B are already inputted in the Excel sheet. Before we start our Before-Tax Cash Flow Analysis, there is an **Assumption of "Repeatability"** should be noted. Our study period is 10 years, but the useful life of Alternative B is 5 years, so the **Assumption of "Repeatability"** is needed here.

Let's start to conduct the Before-Tax Cash Flow Analysis for **Alternative B**.

Similarly, let's compute the **Variable manpower cost per piece** = Manpower cost × No. of operators required / Output per hour (C28 = C20*C19/C21)

You should be able to get the answer as follows:

Computed	
Variable manpower cost per piec	$4.0000

C28 = C20*C19/C21

Then let's move to **Before-Tax Cash Flows Analysis**:

There are some useful formulas that can help you to fill up the table:

- Annual Revenue = Annual production volume × Unit selling price
  [Example of computing Annual Revenue by using Excel]

Before-Tax Cash Flows Analysis	
	Cash Flow B
Initial Investment	-$90,000.00
Annual Revenue	=C5*C6
Annual Direct Manpower cost	-$60,000.00
Annual Direct Material cost	-$45,000.00
Annual Overheads	-$15,000.00
Salvage value	$1,000.00

Here are the input instructions:

C33 = -C13
C34 = C5*C6
C35 = -C5*C28
C36 = -C5*C23
C37 = -SUM(C15:C17)
C38 = C25

- Annual direct manpower cost = Annual production volume × Variable manpower cost per piece
- Annual Direct Material cost = Annual production volume × Direct material cost per unit
- Annual Overheads = Annual Maintenance Manpower + Annual Moldings & Tooling + Annual Spare parts

After you have computed all the required data, you should be able to get the results as follows (Please check your answer before we move to the next session):

Before-Tax Cash Flows Analysis	
	Cash Flow B
Initial Investment	-$90,000.00
Annual Revenue	$150,000.00
Annual Direct Manpower cost	-$60,000.00
Annual Direct Material cost	-$45,000.00
Annual Overheads	-$15,000.00
Salvage value	$1,000.00

Here are the input instructions:

C33 = -C13
C34 = C5*C6
C35 = -C5*C28
C36 = -C5*C23
C37 = -SUM(C15:C17)
C38 = C25

After checking your answer, make sure it is correct. Now, let's move to compute AW and PW for Alternative B with a before-tax *MARR* 12%.

Here is the formula you can refer to:

AW (12%) = - Initial Investment [*A*/*P*, 12%, *N*]

+ (Annual revenue – Annual direct manpower cost

– Annual Direct Material cost – Annual Overheads)

+ Salvage value [*A*/*F*, 12%, *N*]

For AW of Alternative B:

SUM | =SUM(C34:C37) - PMT(C7, C24, C33, C38, 0)

	B	C	D	E
31	**Before-Tax Cash Flows Analysis**			
32		**Cash Flow B**		
33	Initial Investment	-$90,000.00		C33 = -C13
34	Annual Revenue	$150,000.00		C34 = C5*C6
35	Annual Direct Manpower cost	-$60,000.00		C35 = -C5*C28
36	Annual Direct Material cost	-$45,000.00		C36 = -C5*C23
37	Annual Overheads	-$15,000.00		C37 = -SUM(C15:C17)
38	Salvage value	$1,000.00		C38 = C25
39				
40	**AW of B**	**=SUM(C34:C37) - PMT(C7, C24, C33, C38, 0)**		
41	PW of B	$29,327.67		C41 = -PV(C7, C8, C40, 0, 0)
42	**Feasibility**	Feasible		

For PW of Alternative B:

SUM | = -PV(C7, C8, C40, 0, 0)

	A	B	C	D	E
32			**Cash Flow B**		
33		Initial Investment	-$90,000.00		C33 = -C13
34		Annual Revenue	$150,000.00		C34 = C5*C6
35		Annual Direct Manpower cost	-$60,000.00		C35 = -C5*C28
36		Annual Direct Material cost	-$45,000.00		C36 = -C5*C23
37		Annual Overheads	-$15,000.00		C37 = -SUM(C15:C17)
38		Salvage value	$1,000.00		C38 = C25
39					
40		**AW of B**	**$5,190.53**		C40 = SUM(C34:C37) - PMT(C7, C24, C33, C38, 0)
41		PW of B	= -PV(C7, C8, C40, 0, 0)		
42		**Feasibility**	Feasible		

After you have computed *AW* and *PW* of Alternative B, you should be able to get the results as follows (Please check your answer before we move to the next session):

AW of B	**$5,190.53**	C40 = SUM(C34:C37) - PMT(C7, C24, C33, C38, 0)
PW of B	$29,327.67	C41 = -PV(C7, C8, C40, 0, 0)
Feasibility	Feasible	Here are the input instructions:

And please be noted that, since AW (or PW) of Alternative B > 0, so we can conclude that the project is **feasible** as well.

Now, we can answer your lab worksheet questions Q1.1 – Q1.3.

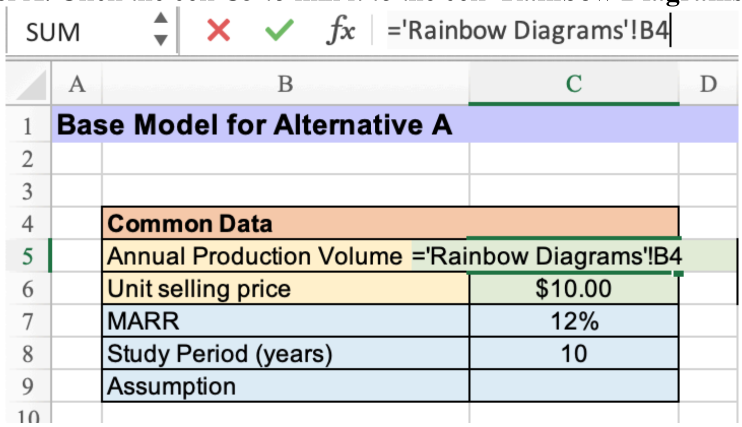
3.2 Break-Even Analysis on Annual Production Volume

Uncertainty in Annual Production Volume has been identified by the company as a major concern.

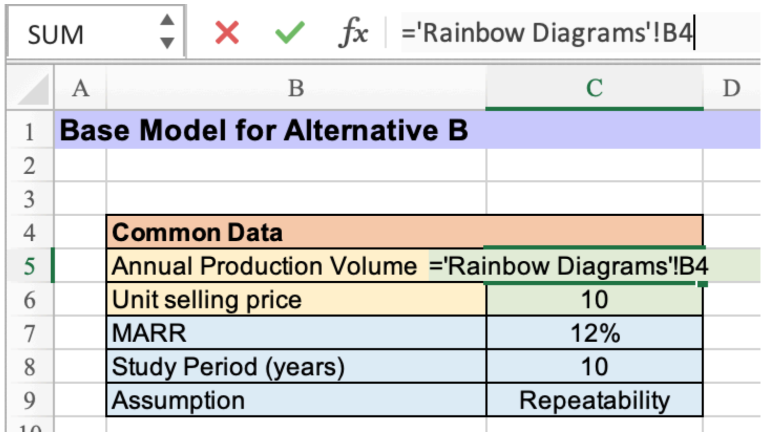
Let's compute the AW of the two alternatives when the Annual production volume is varied from 13,000 to 17,00 in steps of 500 by using the Excel **Date Table** function.

Please follow the steps closely for plotting the rainbow diagram using Tabel().

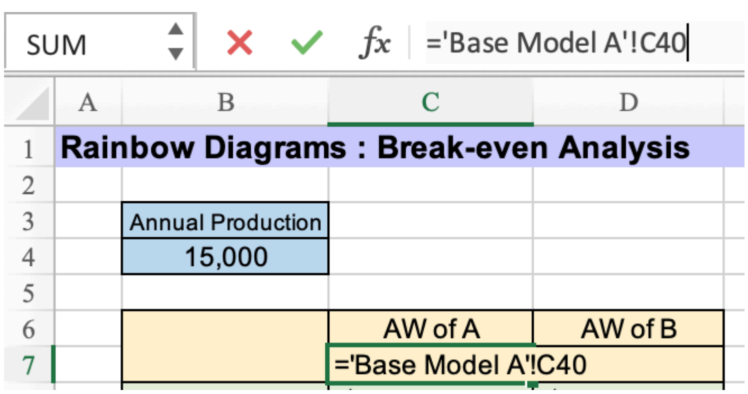
1. Go to **Base Model A**. Click the cell C5 to link it to the cell **'Rainbow Diagrams'!B4**



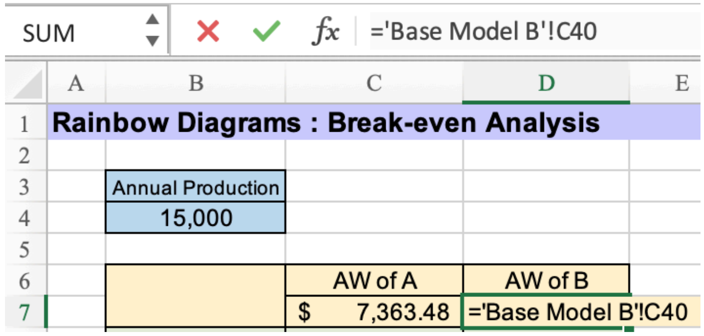
2. Then, go to **Base Model B**. Click the cell C5 to link it to the cell **'Rainbow Diagrams'!B4.**



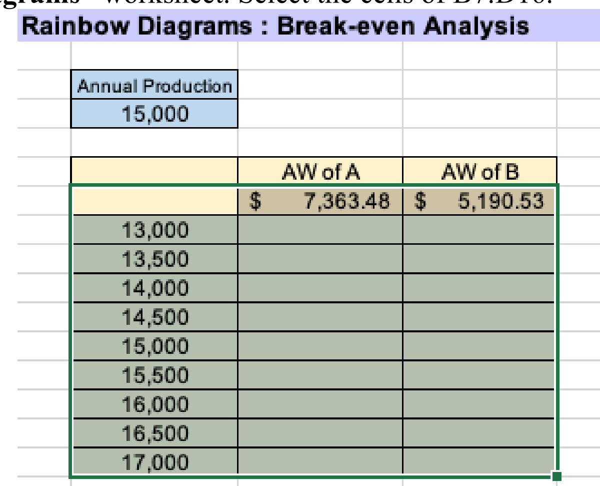
3. Go the **"Rainbow Diagrams"** worksheet. Click the cell C7 to link it to the cell **'Base Model A'!C40**



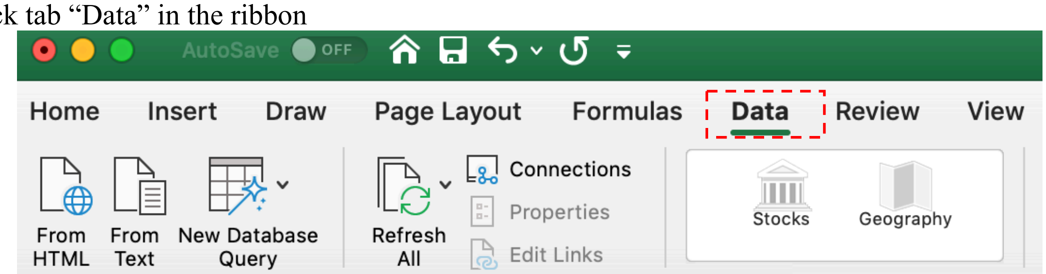
4. Then, Go to the **"Rainbow Diagrams"** worksheet. Click cell D7 to link it to the cell **'Base Model B'!C40**



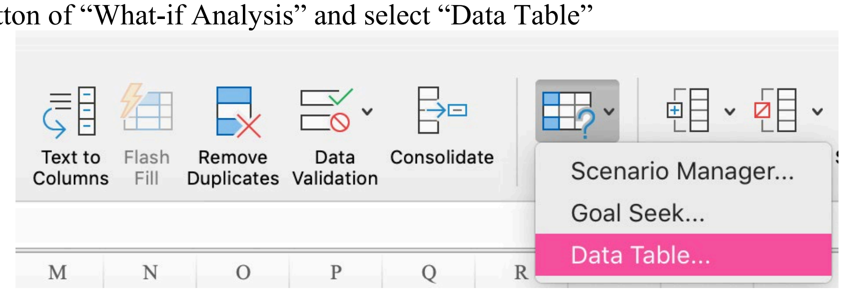
5. Go the **“Rainbow Diagrams”** worksheet. Select the cells of B7:D16.



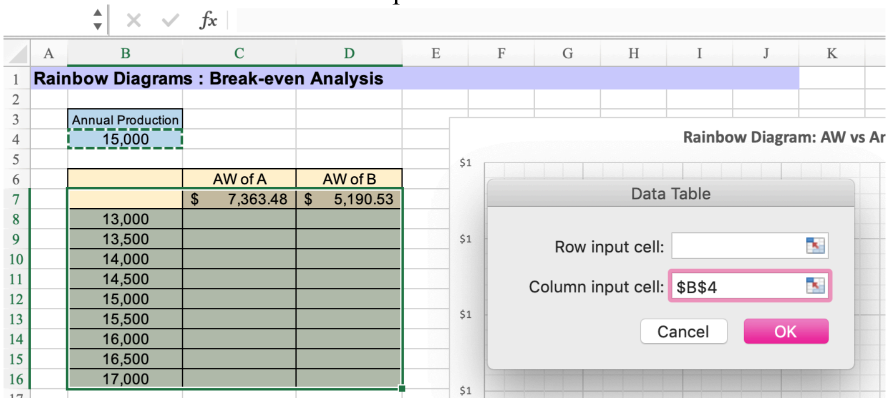
6. Click tab “Data” in the ribbon



7. Click the button of “What-if Analysis” and select “Data Table”



8. Go to "Column input cell" and select cell B4

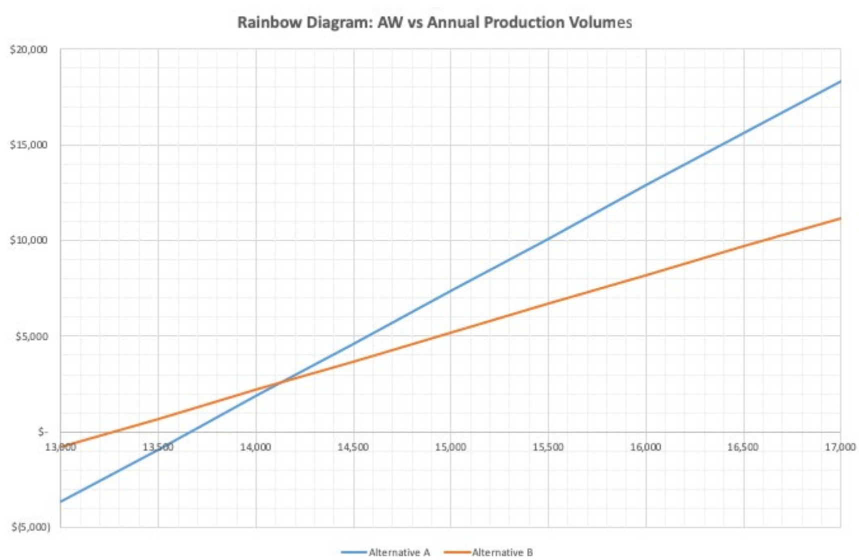


9. Then Click "Ok", and we will get the table updates and the Rainbow Diagram for various **Annual Production Volume.**

Rainbow Diagrams : Break-even Analysis

Annual Production
15,000

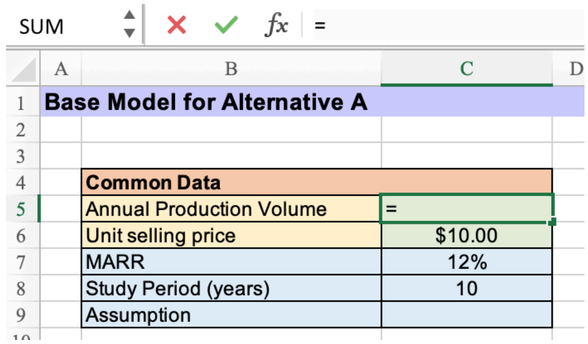
	AW of A	AW of B
	$ 7,363.48	$ 5,190.53
13,000	$ (3,636.52)	$ (809.47)
13,500	$ (886.52)	$ 690.53
14,000	$ 1,863.48	$ 2,190.53
14,500	$ 4,613.48	$ 3,690.53
15,000	$ 7,363.48	$ 5,190.53
15,500	$ 10,113.48	$ 6,690.53
16,000	$ 12,863.48	$ 8,190.53
16,500	$ 15,613.48	$ 9,690.53
17,000	$ 18,363.48	$ 11,190.53



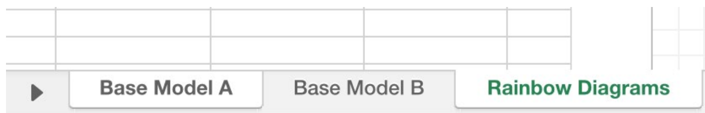
Explanations: By following Step 1 until Step 9, the values of the annual production volume varying from 13,000 to 17,000 in steps of 500 are inputted to cell B4 in the "Rainbow Diagrams" worksheet, which are picked up by Base models A and B to computed AW for different scenarios. Then outputs are fed into the table.

[There are the step-by-step guideline of linking the cells from different worksheets, we use Step 1 as example]

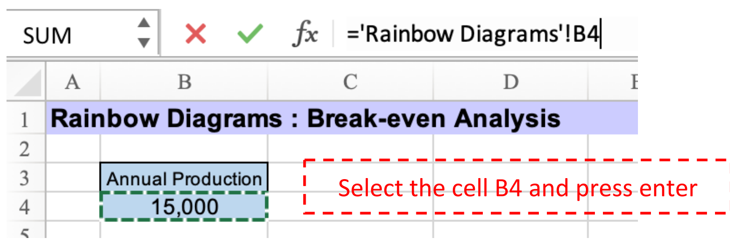
a. Go to **Base Model A**, and click the cell C5 and type "="

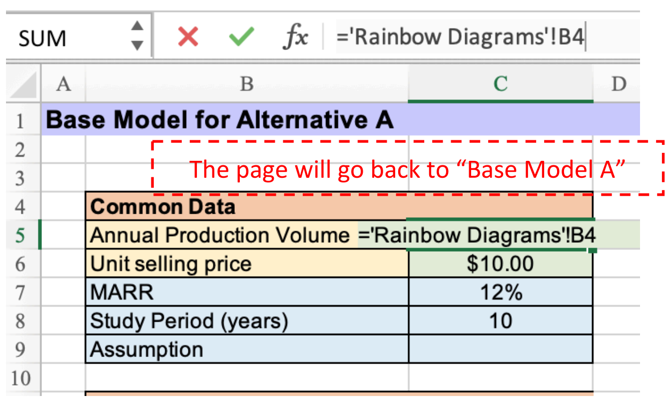


b. Click the tab of "Rainbow Diagrams" and the worksheet will change to "Rainbow Diagrams"



c. Select the cell B4 and press "Enter" key to return (The page will go back to "Base Model A" automatically)





Now, we can answer your lab worksheet questions Q2.1 – Q 2.3.

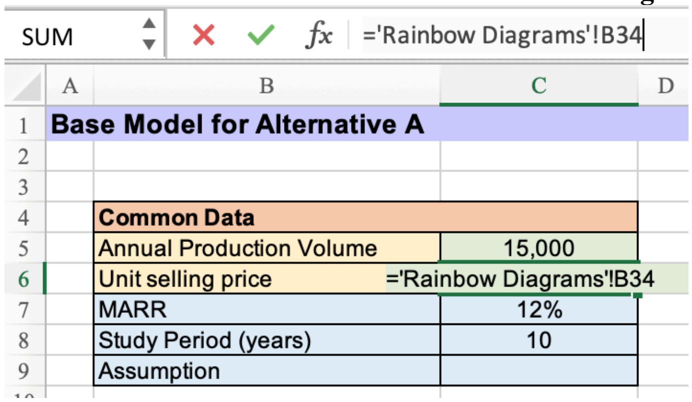
3.3 Break-Even Analysis on Unit selling price

Unit selling price of the product has also been identified by the company as a major concern.

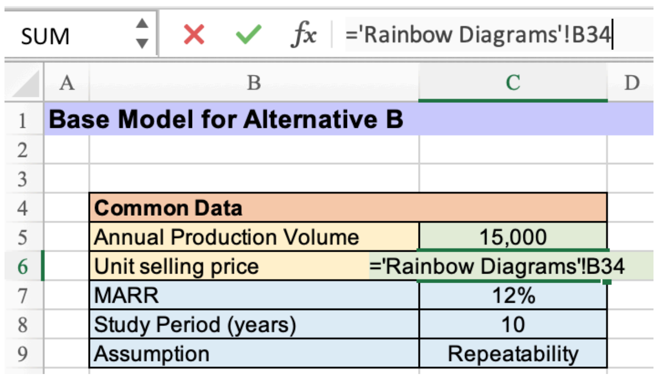
Let's compute the AW of the two alternatives when the unit selling price is varied from \$9.00 to \$11.00 in step of \$0.10 by using Excel **Date Table** function.

Please follow the steps closely for plotting the rainbow diagram using Tabel().

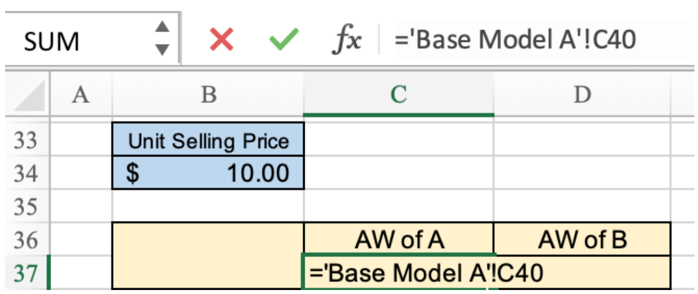
1. Go to **Base Model A**. Click the cell C6 to link it to the cell **'Rainbow Diagrams'!B34**



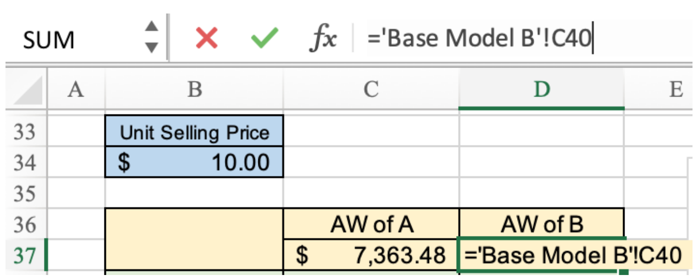
2. Then, go to **Base Model B**. Click the cell C6 to link it to the cell **'Rainbow Diagrams'!B34.**



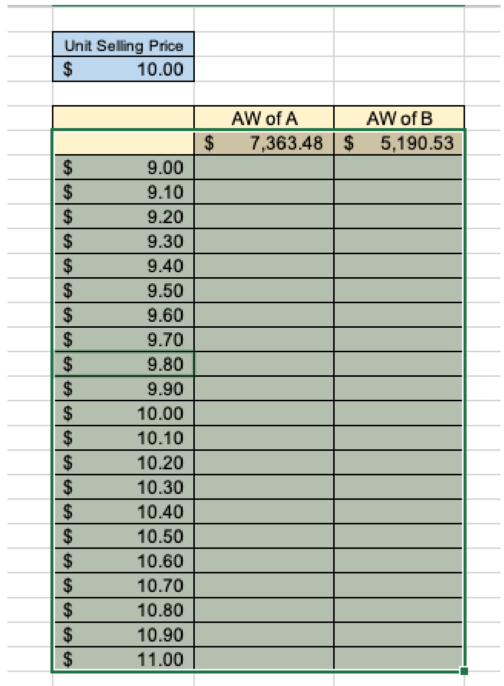
3. Go the **"Rainbow Diagrams"** worksheet. Click the cell C37 to link it to the cell **'Base Model A'!C40**



4. Then, Go the **"Rainbow Diagrams"** worksheet. Click the cell D37 to link it to the cell **'Base Model B'!C40**

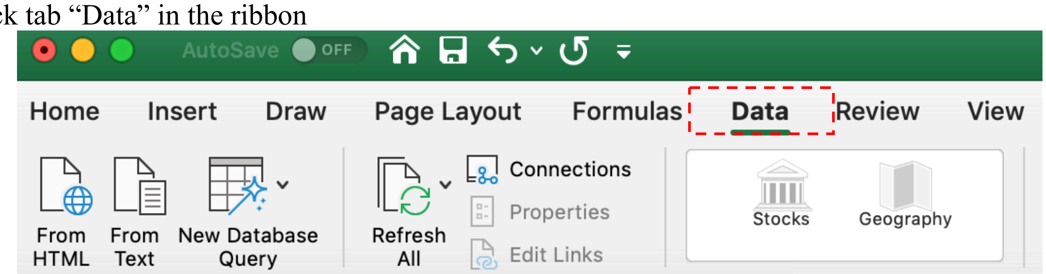


5. Go the **"Rainbow Diagrams"** worksheet. Select the cells of B37:D58.

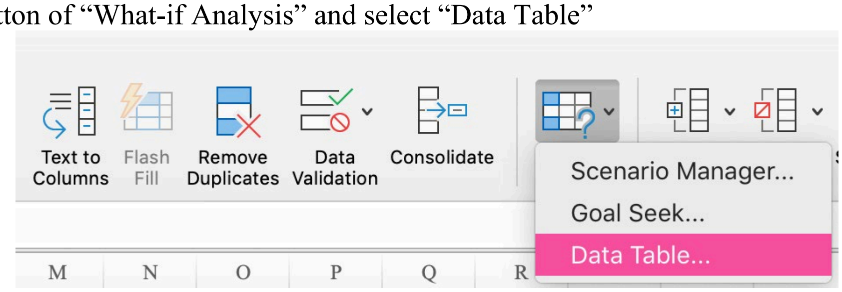


Unit Selling Price		
$ 10.00		
	AW of A	AW of B
	$ 7,363.48	$ 5,190.53
$ 9.00		
$ 9.10		
$ 9.20		
$ 9.30		
$ 9.40		
$ 9.50		
$ 9.60		
$ 9.70		
$ 9.80		
$ 9.90		
$ 10.00		
$ 10.10		
$ 10.20		
$ 10.30		
$ 10.40		
$ 10.50		
$ 10.60		
$ 10.70		
$ 10.80		
$ 10.90		
$ 11.00		

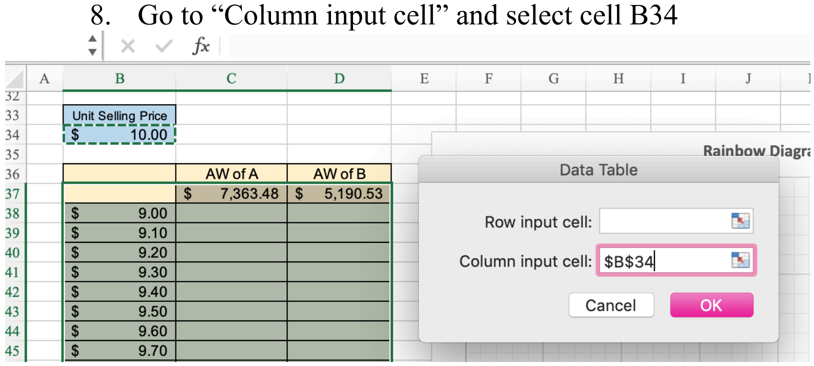
6. Click tab "Data" in the ribbon



7. Click the button of "What-if Analysis" and select "Data Table"



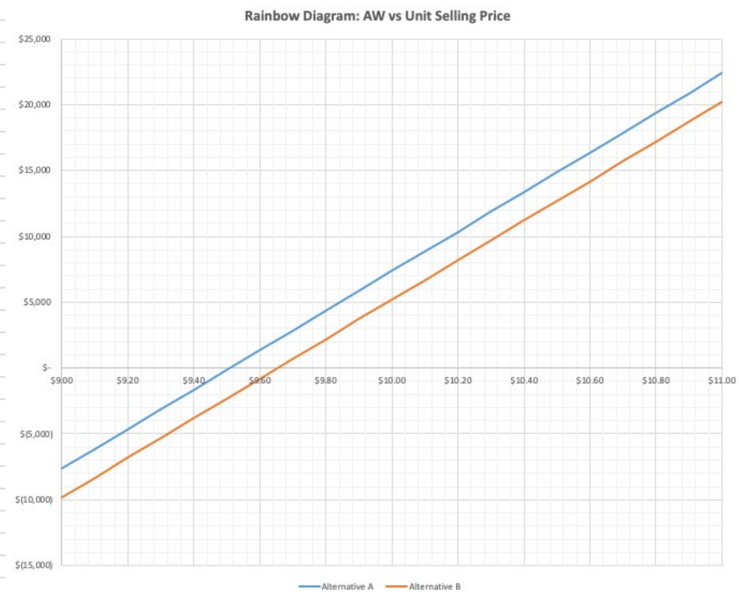
8. Go to "Column input cell" and select cell B34



9. Then Click "Ok", and we will get the table updates and the Rainbow Diagram for various **Annual Production Volume.**

Unit Selling Price
$ 10.00

	AW of A	AW of B
	$ 7,363.48	$ 5,190.53
$ 9.00	$ (7,636.52)	$ (9,809.47)
$ 9.10	$ (6,136.52)	$ (8,309.47)
$ 9.20	$ (4,636.52)	$ (6,809.47)
$ 9.30	$ (3,136.52)	$ (5,309.47)
$ 9.40	$ (1,636.52)	$ (3,809.47)
$ 9.50	$ (136.52)	$ (2,309.47)
$ 9.60	$ 1,363.48	$ (809.47)
$ 9.70	$ 2,863.48	$ 690.53
$ 9.80	$ 4,363.48	$ 2,190.53
$ 9.90	$ 5,863.48	$ 3,690.53
$ 10.00	$ 7,363.48	$ 5,190.53
$ 10.10	$ 8,863.48	$ 6,690.53
$ 10.20	$ 10,363.48	$ 8,190.53
$ 10.30	$ 11,863.48	$ 9,690.53
$ 10.40	$ 13,363.48	$ 11,190.53
$ 10.50	$ 14,863.48	$ 12,690.53
$ 10.60	$ 16,363.48	$ 14,190.53
$ 10.70	$ 17,863.48	$ 15,690.53
$ 10.80	$ 19,363.48	$ 17,190.53
$ 10.90	$ 20,863.48	$ 18,690.53
$ 11.00	$ 22,363.48	$ 20,190.53



Explanations: By following Step 1 until Step 9, the values of the unit selling price varying from $9.00 to $11.00 in steps of $0.10 are inputted to the cell B34 in "Rainbow Diagrams" worksheet, which are picked up by Base models A and B to computed AW for different scenarios. Then outputs are fed into the table.

Now, we can answer your lab worksheet questions Q 3.1 – Q 3.3.

3.4 One-Way Range Sensitivity Analysis

ISEM management is not very comfortable with the results based on the base case data as the company does not have much experience in advanced manufacturing. In addition, there are still many uncertainties in the data to be considered.

You proposed that one-way range sensitivity analyses be performed on the base model to better understand the key uncertainties and hence raise the company's confidence in adopting the best alternative.

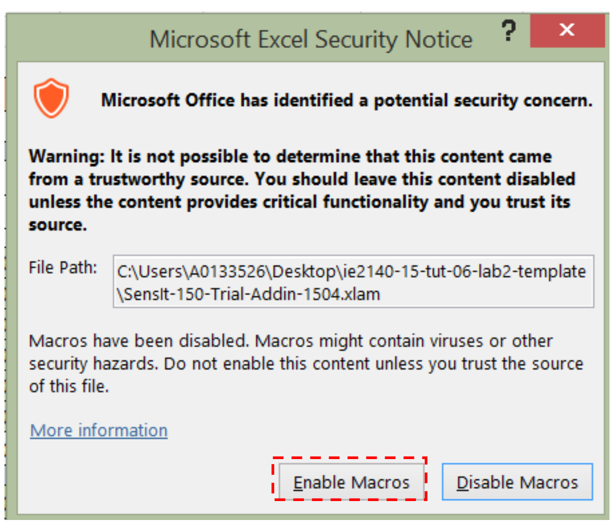
Expert's estimates of the possible range of values for each of the uncertain variables are given in the table below:

		Alternative A Advanced Manufacturing			Alternative B Conventional Manufacturing		
	Uncertain Variable	Low	Base	High	Low	Base	High
1	Annual production quantity	13,000	15,000	17,000	13,000	15,000	17,000
2	Unit selling price	\$9	\$10	\$11	\$9	\$10	\$11
3	Annual maintenance Cost	\$24,000	\$25,000	\$26,000	\$9,000	\$10,000	\$11,000
4	Annual moldings & tooling cost	\$4,500	\$5,000	\$5,500	\$2,500	\$3,000	\$3,500
5	Annual Spare parts cost	\$4,500	\$5,000	\$5,500	\$1,500	\$2,000	\$2,500
6	Manpower cost/worker/hour	\$9.00	\$12.00	\$15.00	\$7.00	\$8.00	\$9.00
7	Output per hours (pieces)	7.5	8	8.5	5.5	6	6.5
8	Variable material cost per unit	\$2.80	\$3.00	\$3.20	\$2.80	\$3.00	\$3.20
9	Salvage value	\$6,000	\$10,000	\$14,000	\$0	\$1,000	\$2,000

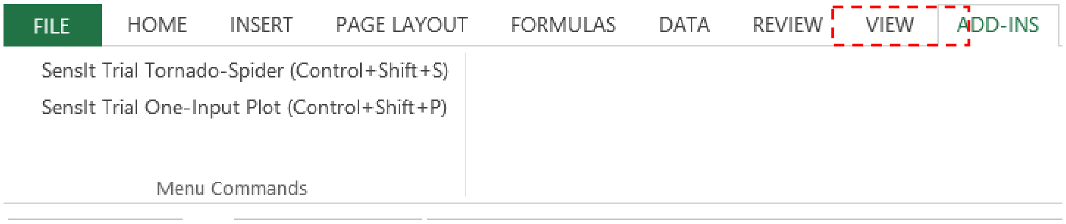
Now let's:

a. Perform one-way range sensitivity analysis by generating Tornado and Spider Diagrams using the Sensit software. Interpret the results.
b. Identify the sensitive variables.
c. Identify the insensitive variables.

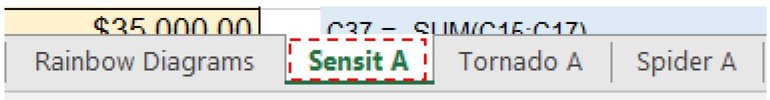
In this part, instead of having just one base value, each variable now has its low value and high value. To perform one-way range sensitivity analysis, we need to add in macros. We go back to the folder of the templates, double click the *Sensit-XXX-Trial-Addin-XXXX*, and add the macro into Excel.



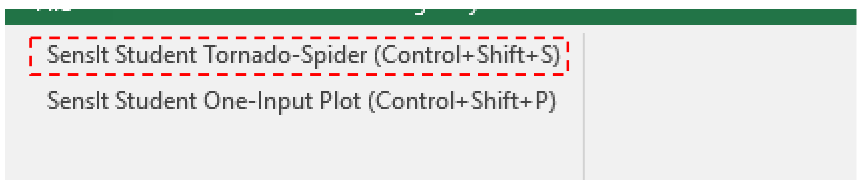
Then we could find **ADD-INS** in the menu bar.

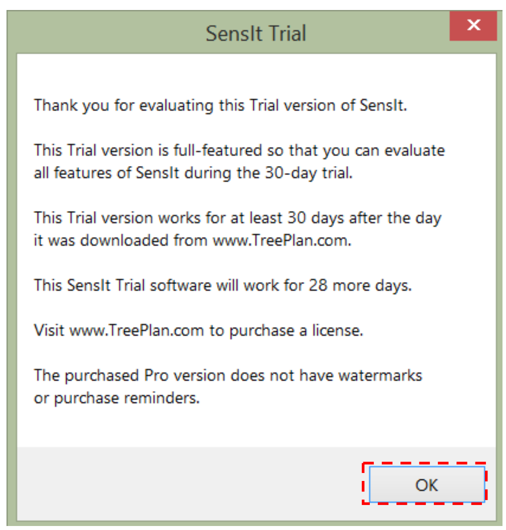


To conduct the sensitivity analysis, we go to the Sensitivity Model A (**Sensit A**). Here we can find the correct answers of Q4.1.



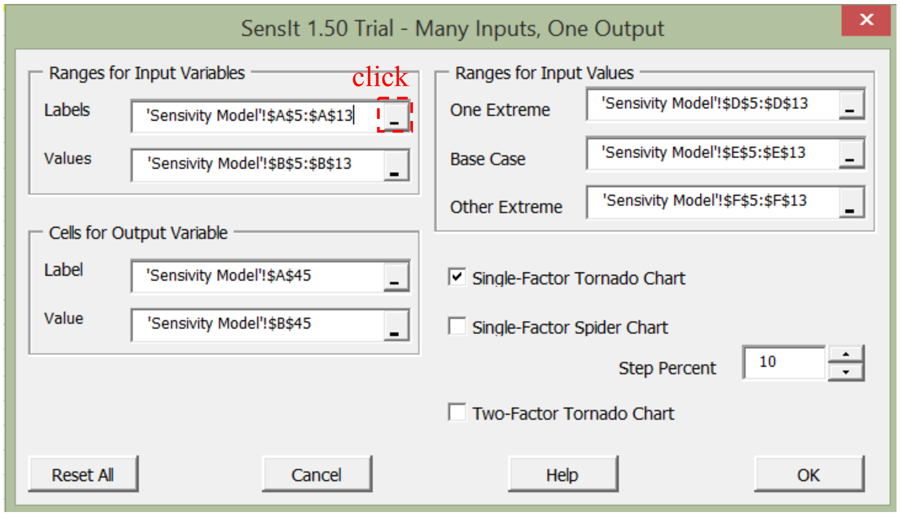
First, we click the *SensIt Student Tornado-Spider* option, and click OK.

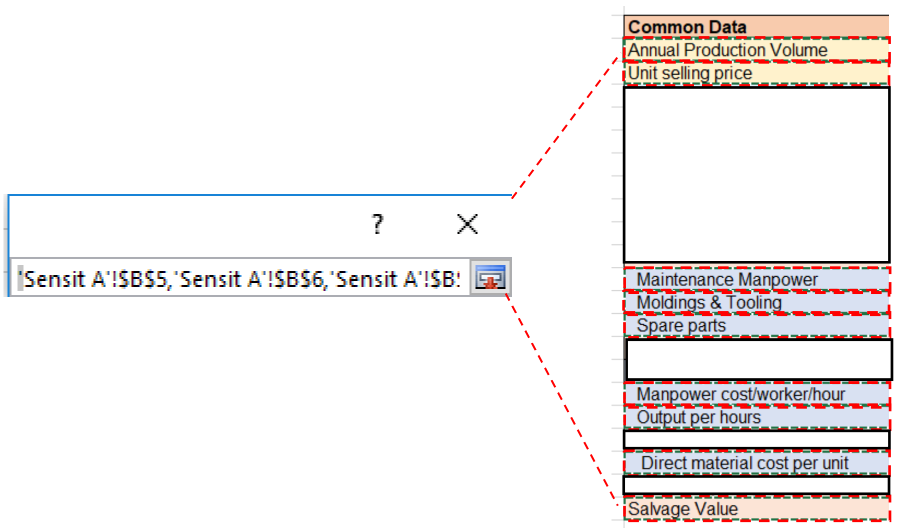




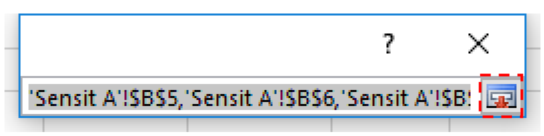
Then, to input the variables, we click the drop-down list, and select all the names of uncertain variables, which are B5, B6, B15, B16, B17, B20, B21, B23, B25.

[Note: **"Labels"** refers to the name of the uncertain variables, please input the cell which contains the name of the uncertain variables, while **"Values"** refers to the values of the uncertain variables, please input the cell which contains the values / formula of the uncertain variables]





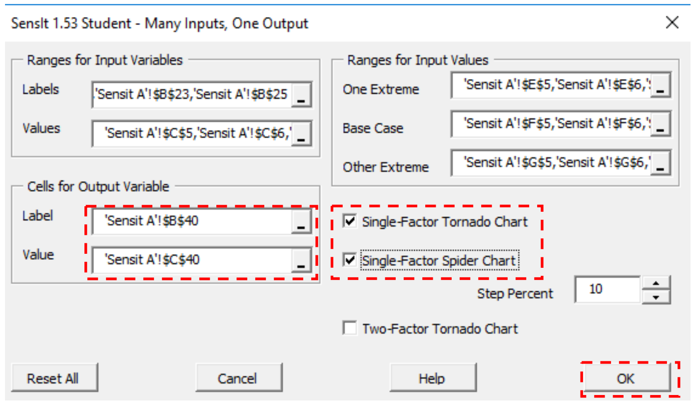
Then, click the right side and back to the main menu.



click to go back

By the same procedure, we input the value of the input variables, \$C\$5, \$C\$6, \$C\$15, \$C\$16, \$C\$17, \$C\$20, \$C\$21, \$C\$23, \$C\$25. In the right side, One Extreme is the low value, so we select \$E\$5, \$E\$6, \$E\$15, \$E\$16, \$E\$17, \$E\$20, \$E\$21, \$E\$23, \$E\$25. The Base Case is the middle column, \$F\$5, \$F\$6, \$F\$15, \$F\$16, \$F\$17, \$F\$20, \$F\$21, \$F\$23, \$F\$25, and Other Extreme is all the high values, \$G\$5, \$G\$6, \$G\$15, \$G\$16, \$G\$17, \$G\$20, \$G\$21, \$G\$23, \$G\$25. As for the Cells for Output Variable, it is the AW of A, \$B\$40, whose value is \$C\$40.

After select all the related variables, we click both the Tornado Chart and Spider Chart, then click on OK.

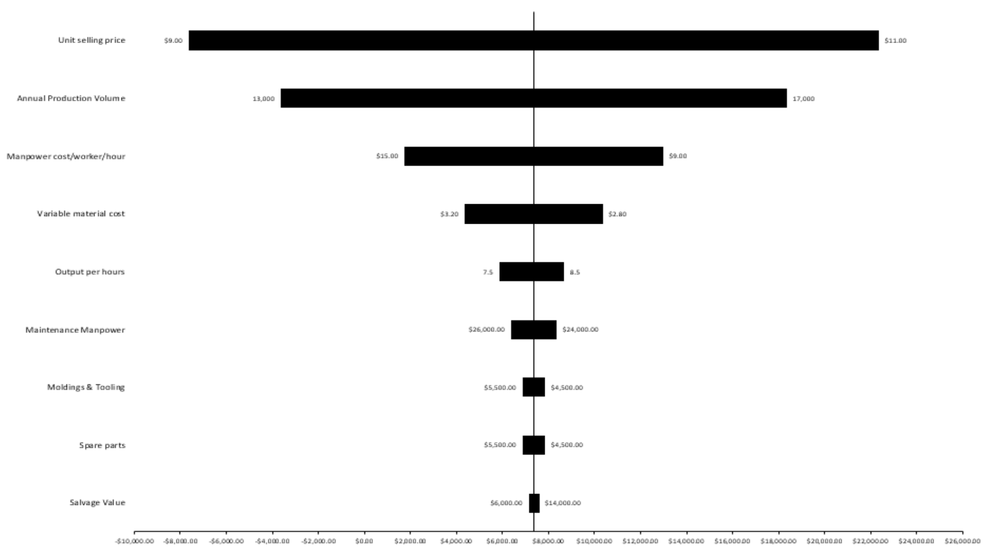


After running the macros, we obtain the Tornado Chart and Spider Chart.

In the **Tornado A** worksheet, it gives a summary table of all the relevant information.

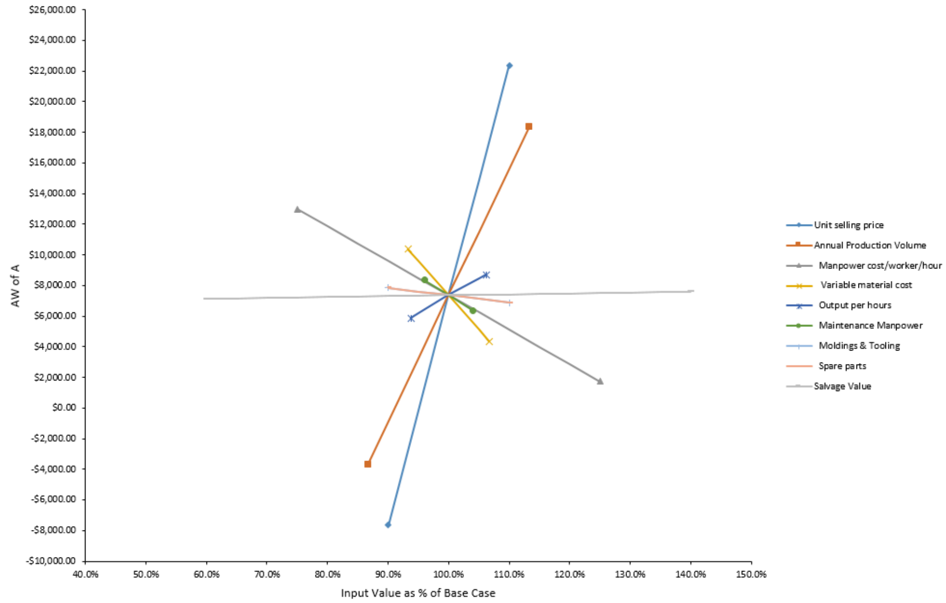
				AW of A				
	Corresponding Input Value			Output Value				Percent
Input Variable	Low Output	Base Case	High Output	Low	Base	High	Swing	Swing^2
Unit selling price	$9.00	$10.00	$11.00	-$7,636.52	$7,363.48	$22,363.48	$30,000.00	57.7%
Annual Production Volume	13,000	15,000	17,000	-$3,636.52	$7,363.48	$18,363.48	$22,000.00	31.0%
Manpower cost/worker/hour	$15.00	$12.00	$9.00	$1,738.48	$7,363.48	$12,988.48	$11,250.00	8.1%
Variable material cost	$3.20	$3.00	$2.80	$4,363.48	$7,363.48	$10,363.48	$6,000.00	2.3%
Output per hours	7.5	8	8.5	$5,863.48	$7,363.48	$8,687.01	$2,823.53	0.5%
Maintenance Manpower	$26,000.00	$25,000.00	$24,000.00	$6,363.48	$7,363.48	$8,363.48	$2,000.00	0.3%
Moldings & Tooling	$5,500.00	$5,000.00	$4,500.00	$6,863.48	$7,363.48	$7,863.48	$1,000.00	0.1%
Spare parts	$5,500.00	$5,000.00	$4,500.00	$6,863.48	$7,363.48	$7,863.48	$1,000.00	0.1%
Salvage Value	$6,000.00	$10,000.00	$14,000.00	$7,135.55	$7,363.48	$7,591.42	$455.87	0.0%

For each of the variables, we have the low, base and high values. Excel calculates the corresponding values of AW, and then generate the Tornado Chart. It is shown that the **Unit Selling Price** is the most sensitive, we define the first five variables as the sensitive variables. The **Salvage value** is the least sensitive.



The Spider AW of A output file contains a summary table and the spider diagram. All variables were sorted in descending order of sensitivity. As shown in the table and figure, the **Unit Selling Price** is the most sensitive. We define the first five variables as sensitive variables. The **Salvage value** is the least sensitive.

								AW of A		
	Corresponding Input Value			Input Value as % of Base				Output Value		
Input Variable	Low Output	Base Case	High Output	Low %	Base %	High %	Low	Base	High	Swing
Unit selling price	$9.00	$10.00	$11.00	90.0%	100.0%	110.0%	-$7,636.52	$7,363.48	$22,363.48	$30,000.00
Annual Production Volume	13,000	15,000	17,000	86.7%	100.0%	113.3%	-$3,636.52	$7,363.48	$18,363.48	$22,000.00
Manpower cost/worker/hour	$15.00	$12.00	$9.00	125.0%	100.0%	75.0%	$1,738.48	$7,363.48	$12,988.48	$11,250.00
Variable material cost	$3.20	$3.00	$2.80	106.7%	100.0%	93.3%	$4,363.48	$7,363.48	$10,363.48	$6,000.00
Output per hours	7.5	8	8.5	93.8%	100.0%	106.3%	$5,863.48	$7,363.48	$8,687.01	$2,823.53
Maintenance Manpower	$26,000.00	$25,000.00	$24,000.00	104.0%	100.0%	96.0%	$6,363.48	$7,363.48	$8,363.48	$2,000.00
Moldings & Tooling	$5,500.00	$5,000.00	$4,500.00	110.0%	100.0%	90.0%	$6,863.48	$7,363.48	$7,863.48	$1,000.00
Spare parts	$5,500.00	$5,000.00	$4,500.00	110.0%	100.0%	90.0%	$6,863.48	$7,363.48	$7,863.48	$1,000.00
Salvage Value	$6,000.00	$10,000.00	$14,000.00	60.0%	100.0%	140.0%	$7,135.55	$7,363.48	$7,591.42	$455.87



<u>Similarly, we can also get the Tornado Chart and Spider Chart of Model B.</u>

<u>Now, we can answer your lab worksheet questions Q 4.1 – Q 4.2.</u>

3.5 Risk Analysis using Monte Carlo Simulation

To better understand and assess the risk associated with each alternative, you recommended that the probabilistic behavior of the sensitive variables identified in the previous section be fully studied and Monte Caro Simulation is performed on these variables to determine the risk profiles for the two alternatives.

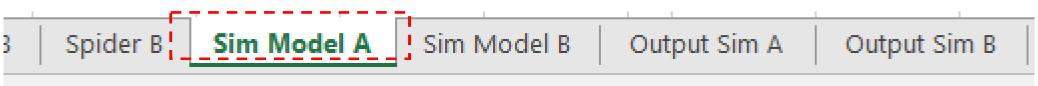
Expert's assessments of the probability distributions of the sensitive variables are given in the table below:

	Alternative A	Distribution	Parameters
1	Annual volume	Uniform Integer	min=13,000; max=17,000
2	Unit selling price	Truncated Normal	mean=10; sd=0.5; min=9; max=11
3	Annual Maintenance cost	Uniform	min=24,000; max=26,000
4	Manpower cost/worker/hour	Truncated Normal	mean=12; sd=1.5; min=9; max=15
5	Output per hours (pieces)	Triangular	min=7.50; mode=8.00; max=8.50
6	Variable material cost per unit	Triangular	min=2.80; mode=3.00; max=3.20

	Alternative B	Distribution	Parameters
1	Annual volume	Uniform Integer	min=13,000; max=17,000
2	Unit selling price	Truncated Normal	mean=10; sd=0.5; min=9; max=11
3	Annual Maintenance cost	Uniform	min=9,000; max=11,000
4	Manpower cost/worker/hour	Truncated Normal	mean=8; sd=0.5; min=7; max=9
5	Output per hours (pieces)	Triangular	min=5.50; mode=6.00; max=6.50
6	Variable material cost per unit	Triangular	min=2.80; mode=3.00; max=3.20

We can answer the worksheet questions Q5.1 - Q 5.5 after conducting the two Risk Analysis and getting the results.

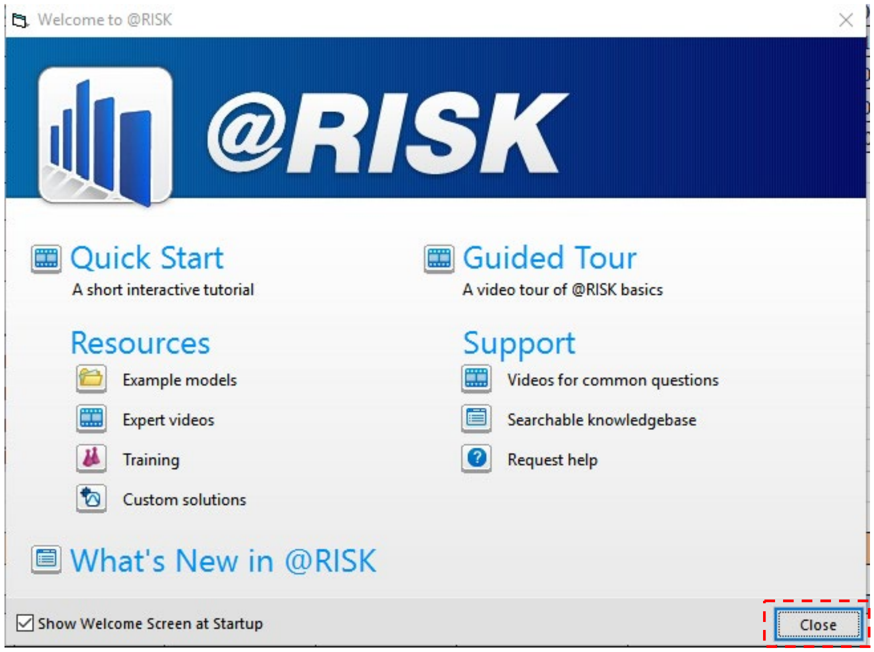
In this question, first we move to the Sim Model A.



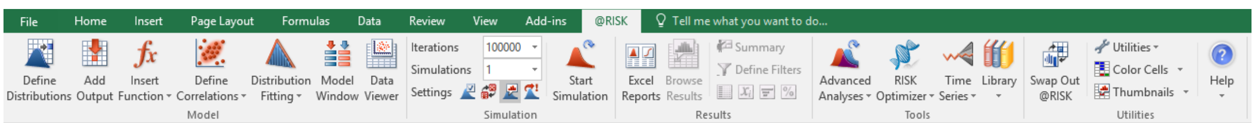
The distribution of variables are already given in the Excel sheet.

```
C5 = RiskIntUniform(J5, K5)
C6 = RiskNormal(J6, K6, RiskTruncate(L6, M6))
C15 = RiskUniform(J15, K15)
C20 =RiskNormal(j20, k20, RiskTruncate(L20, M20))
C21 = RiskTriang(J21, K21, L21)
C23 = RiskTriang(J23, K23, L23)
```

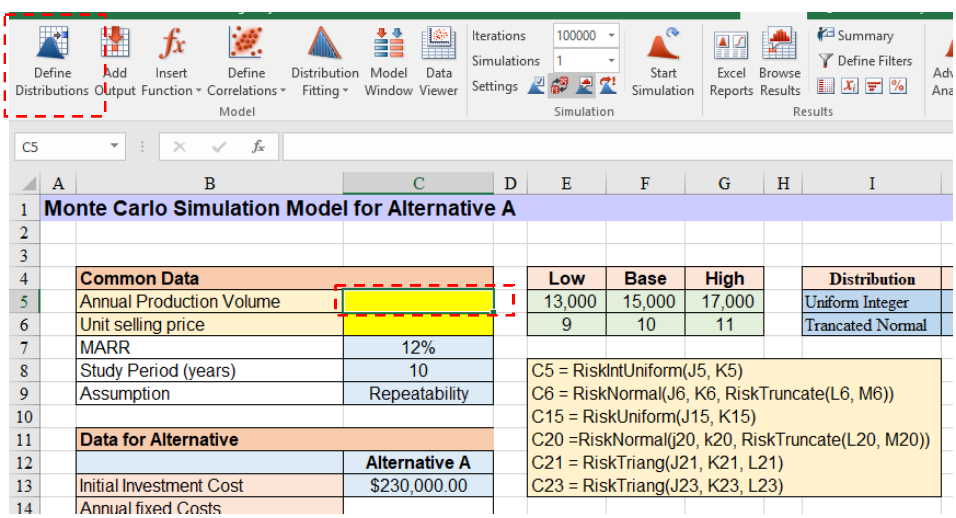
We will use @Risk to do the probabilistic analysis. Search "@Risk" in your computer. After you find it, simply double click its icon, @RISK 7.5 . Click "Close" when you see the following dialog.



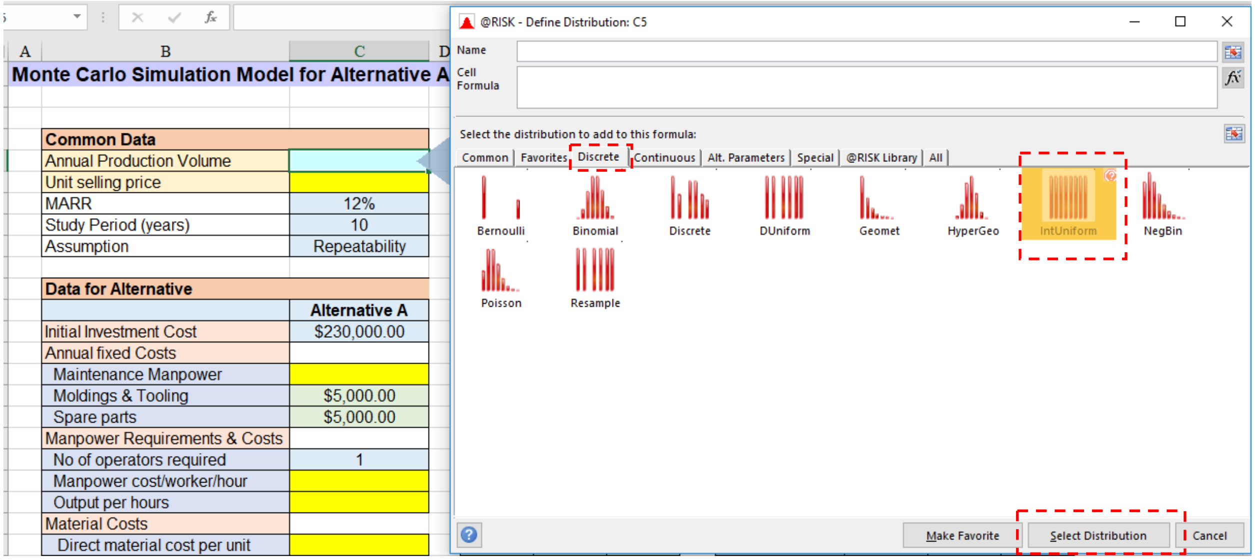
After @Risk having been successfully loaded, you will see @Risk in the menu bar.



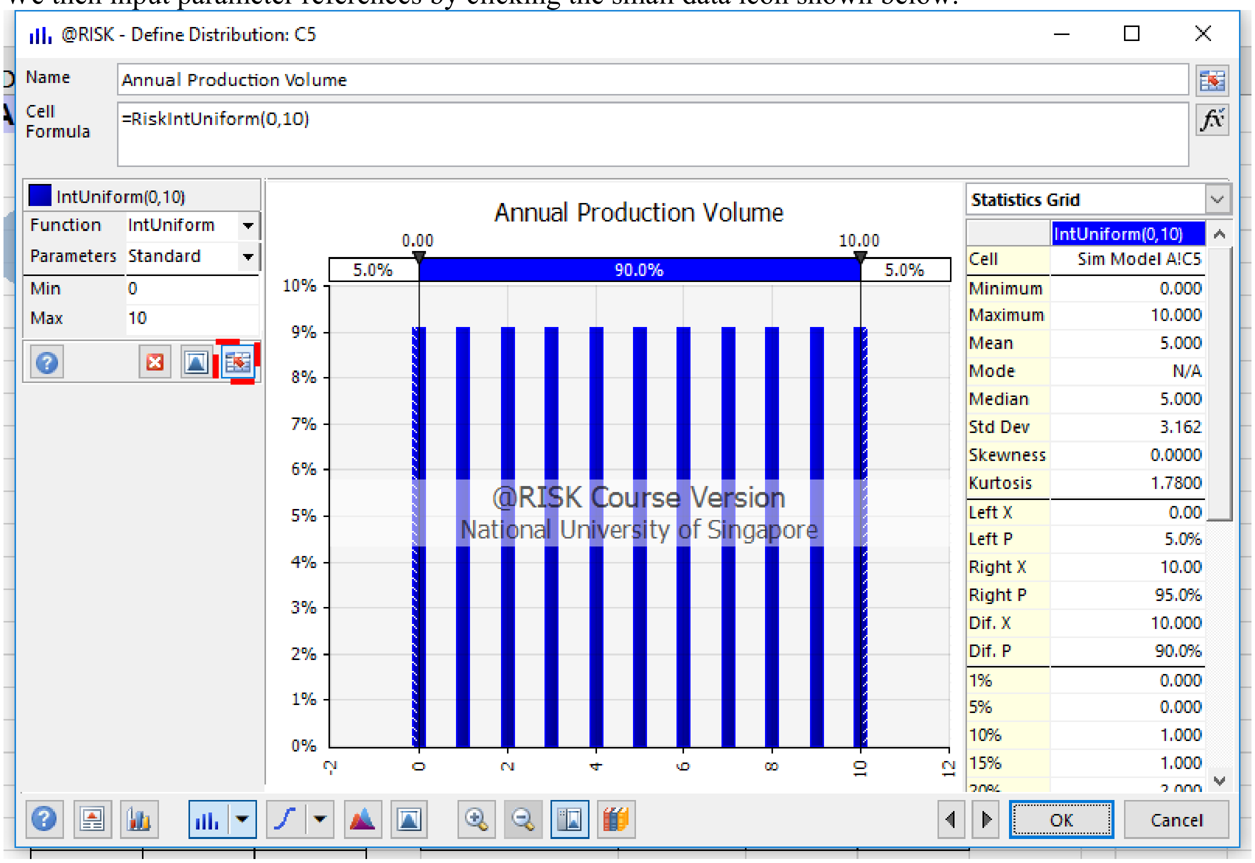
In the probabilistic analysis, each uncertain variable has a distribution. So we need to use Excel to generate random numbers for each variable according to its distribution. To define a uniform integer distribution for the number of pieces produced per year, we first click cell B5. Then click "Define Distributions" .



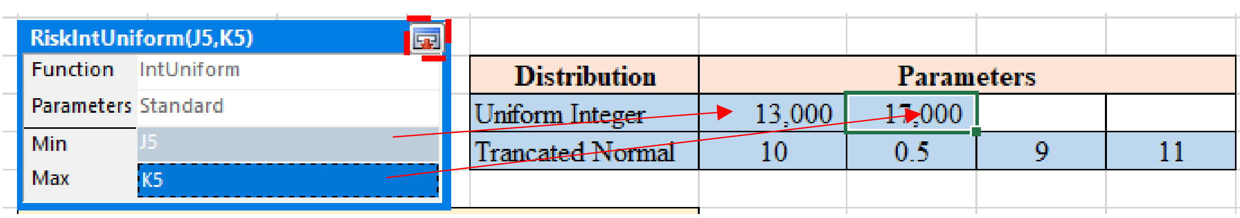
The uniform integer function can be found in the "Discrete" group of functions. Click "IntUniform" and click "Select Distribution".

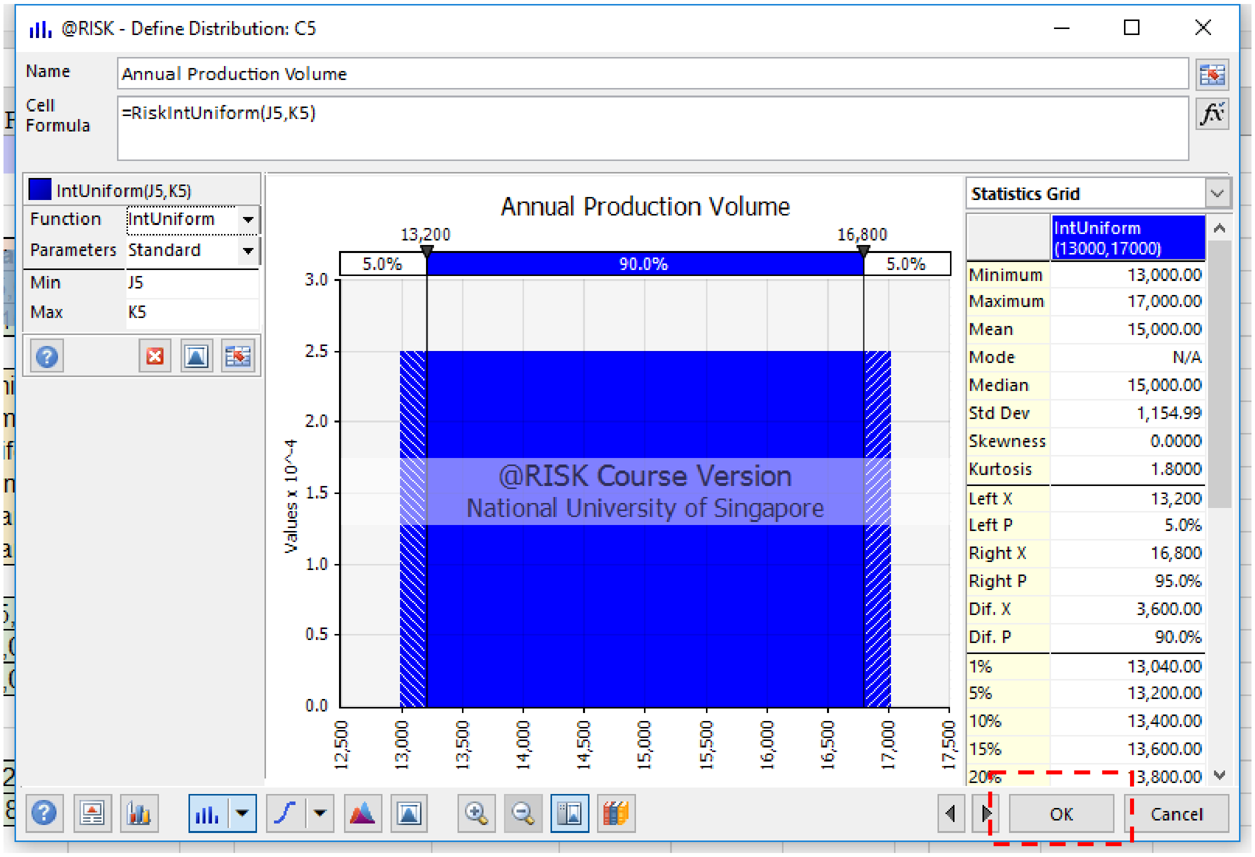


We then input parameter references by clicking the small data icon shown below.

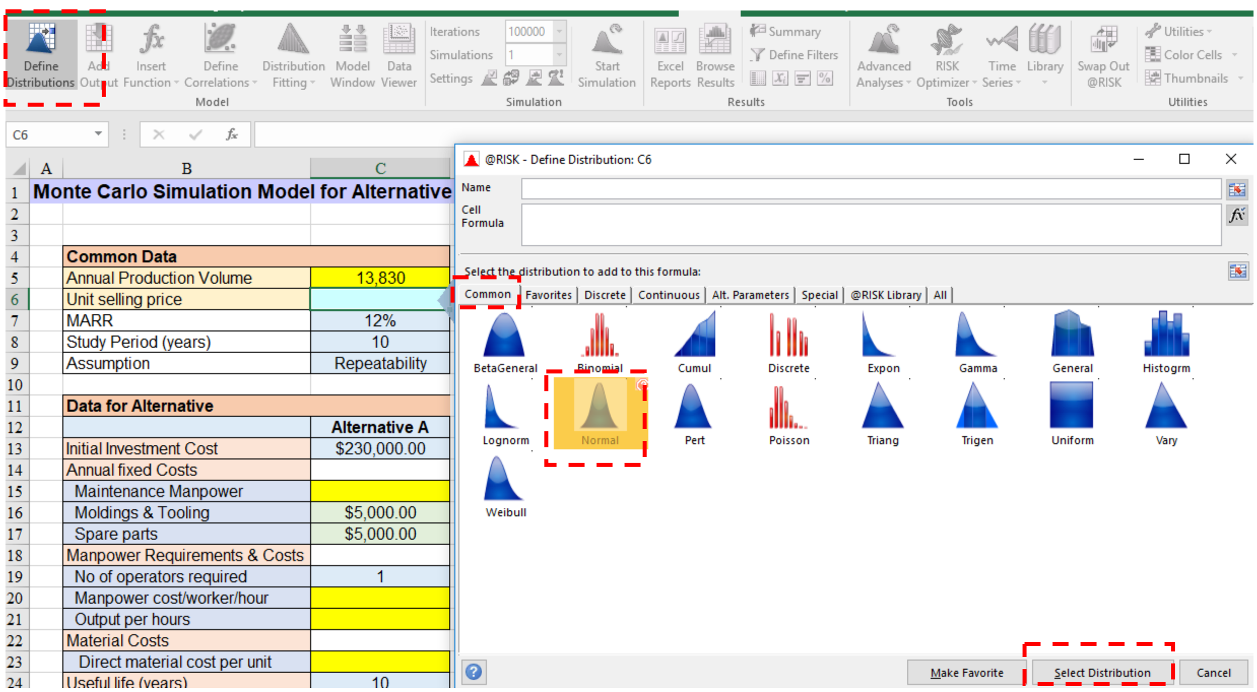


Min and Max should contain cell K5 and J5, respectively. Then click the icon in the upper right corner to go back and then click “Ok”.

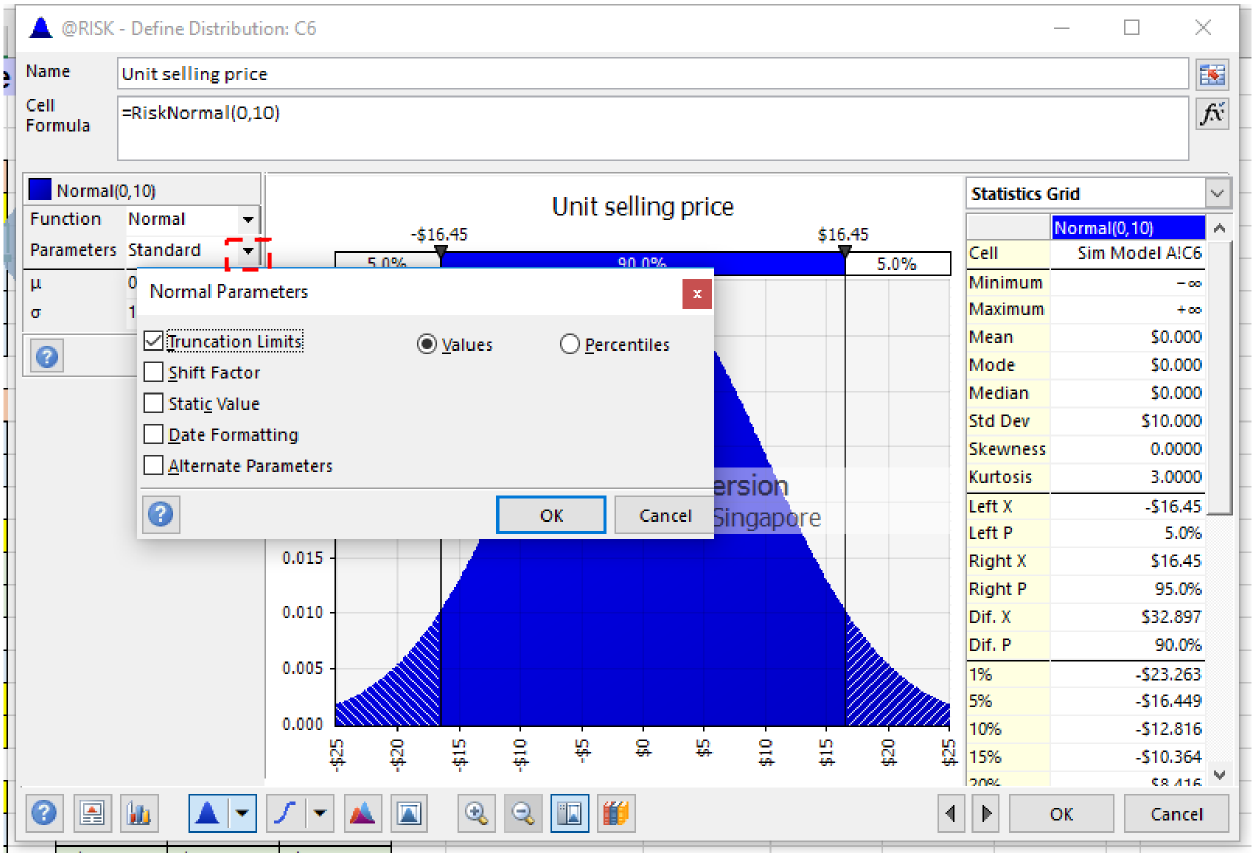




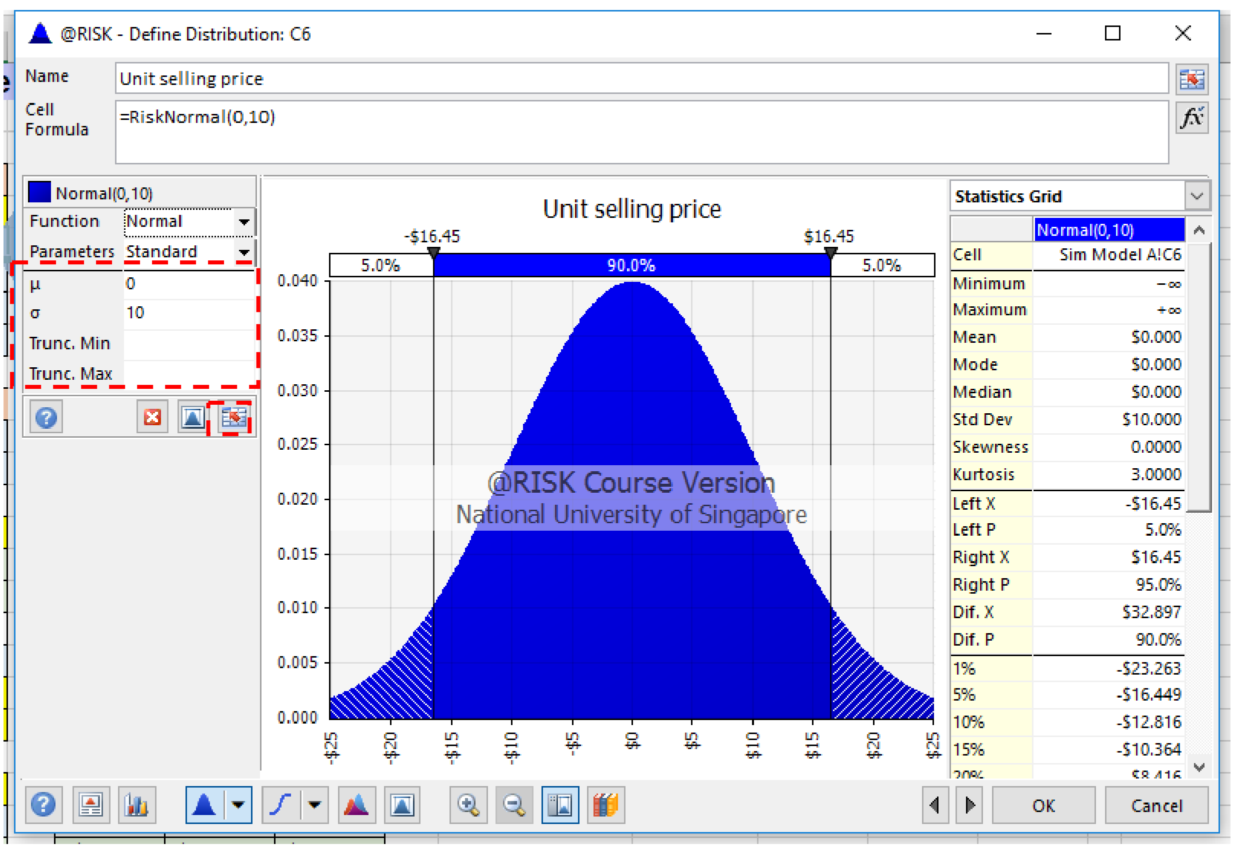
Most of distributions can be input in a similar way while the truncated normal distribution requires more effort. To define a **truncated normal** distribution for the selling price, we first find a normal distribution and then specify limits. Click C6. Go to Define Distributions. Find normal distribution under “Common” or “Continuous” and then click “Select Distribution”.



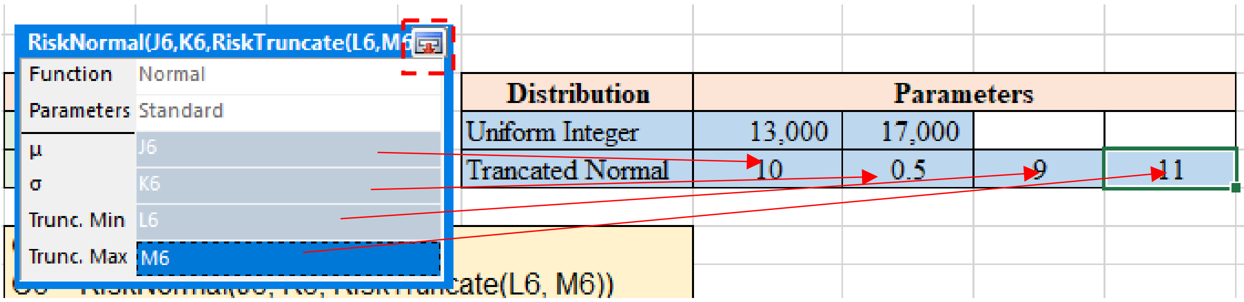
Click the small arrow next to “Parameter” and select “Truncation Limits” and “Values”. Click OK.

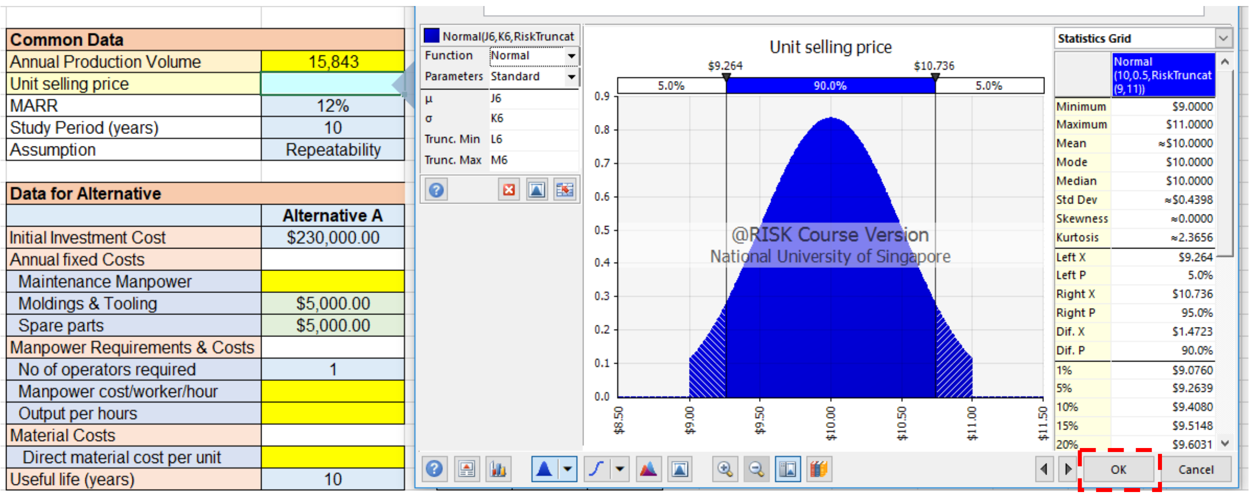


Besides mu and sigma, you will see there are two more entries (Trunc. Min and Trunc.Max) to specify. Again, click the icon at the bottom right corner.



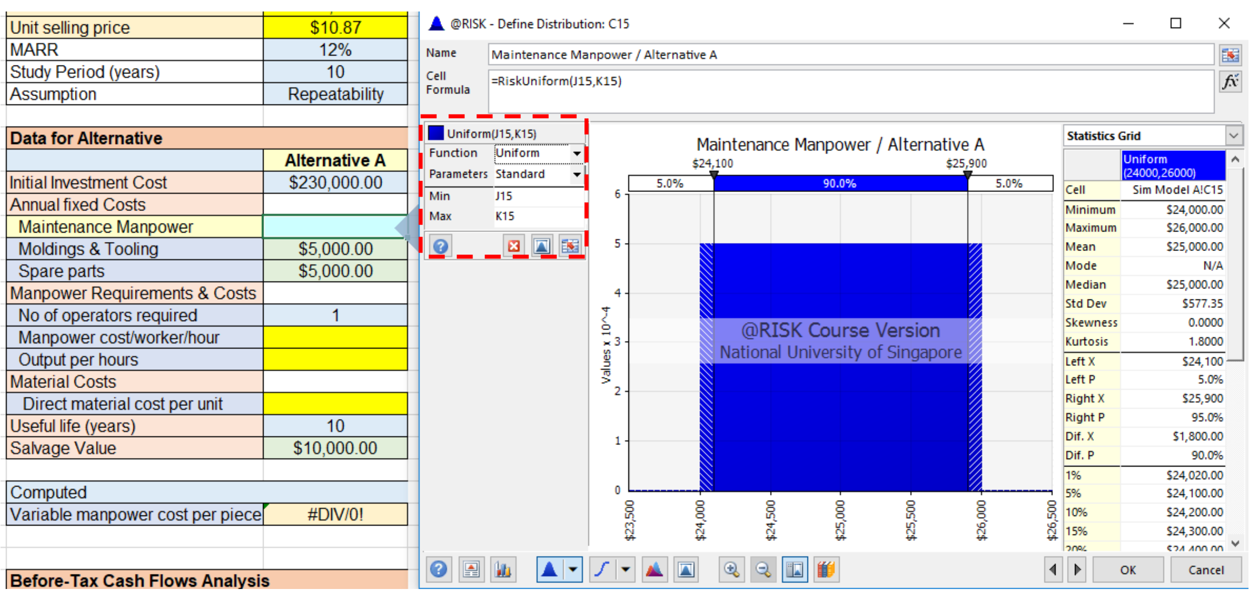
Mu, Sigma, Trunc.Min, Trunc.Max should correspond to cells M6, J6, K6, and L6, respectively. Then click the icon in the upper right corner to go back and then click "OK".



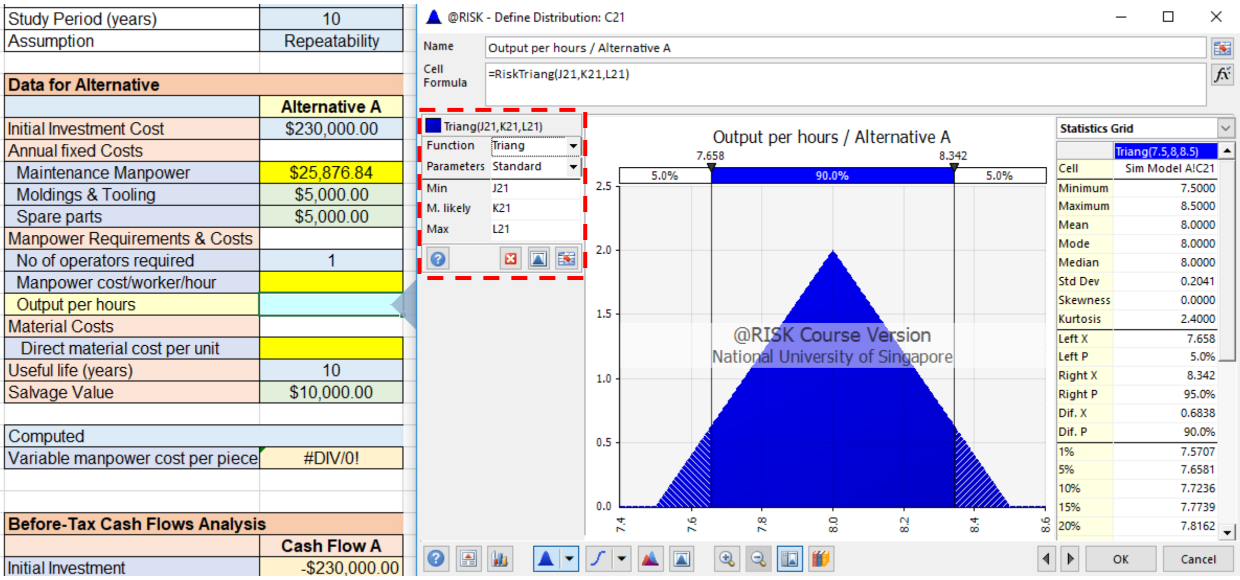


Distributions for Manpower cost/worker/hour can be defined similarly as Unit selling price.

The uniform distribution for the Maintenance Manpower is defined below.



The Trangular distribution for Output per hours is defined as below.



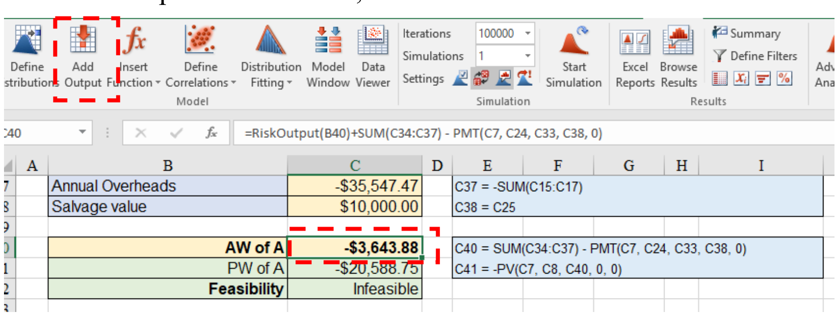
Distributions for Direct material cost per unit can be defined similarly as Output per hours.

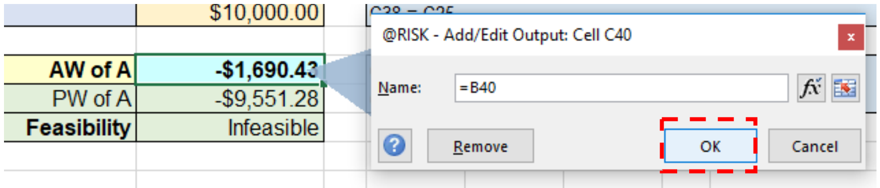
Note that we have provided the formula for all variables so that you can check whether your input is correct or not.

Common Data		Low	Base	High	Distribution
Annual Production Volume	16,760	13,000	15,000	17,000	Uniform Integer
Unit selling price	$10.13	9	10	11	Trancated Normal
MARR	12%				
Study Period (years)	10				
Assumption	Repeatability				
Data for Alternative					
	Alternative A				
Initial Investment Cost	$230,000.00				
Annual fixed Costs					
Maintenance Manpower	$24,547.21	$24,000	$25,000	$26,000	Uniform
Moldings & Tooling	$5,000.00	$4,500	$5,000	$5,500	
Spare parts	$5,000.00	$4,500	$5,000	$5,500	
Manpower Requirements & Costs					
No of operators required	1				
Manpower cost/worker/hour	$11.46	$9.00	$12.00	$15.00	Trancated Normal
Output per hours	8.25	7.5	8	8.5	Trangular
Material Costs					
Direct material cost per unit	$ 3.00	$2.80	$3.00	$3.20	Trangular

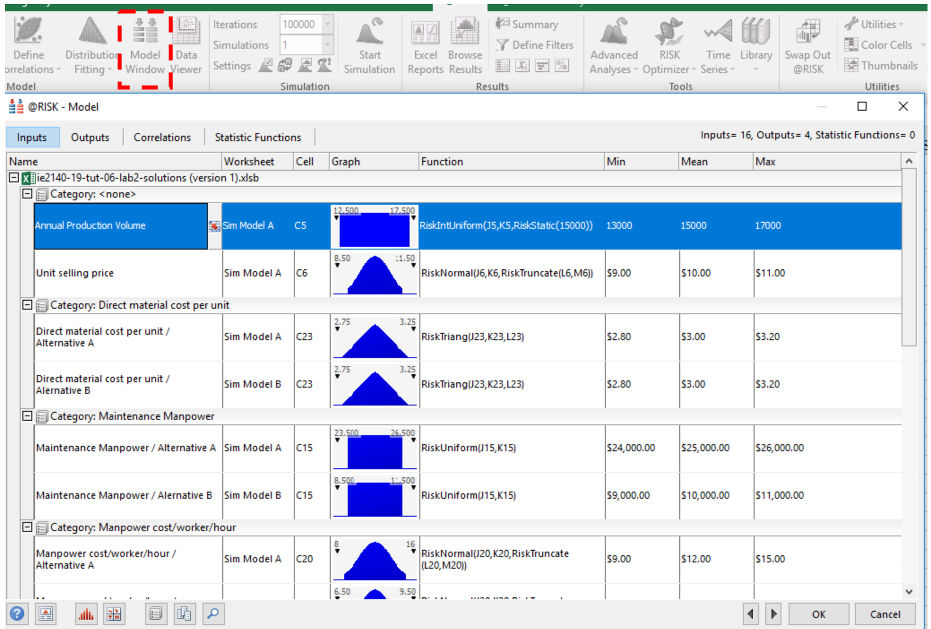
C5 = RiskIntUniform(J5, K5)
C6 = RiskNormal(J6, K6, RiskTruncate(L6, M6))
C15 = RiskUniform(J15, K15)
C20 =RiskNormal(j20, k20, RiskTruncate(L20, M20))
C21 = RiskTriang(J21, K21, L21)
C23 = RiskTriang(J23, K23, L23)

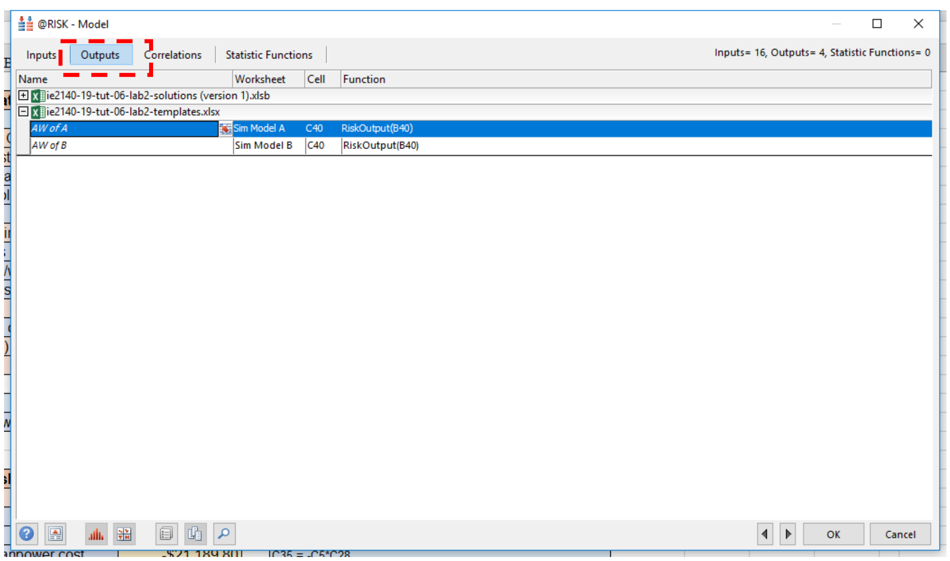
As we would like to see the risk profile for the project's AW of A, we next add AW of A as the output. Click cell C40, click "Add Output" in the menu, and click "OK".



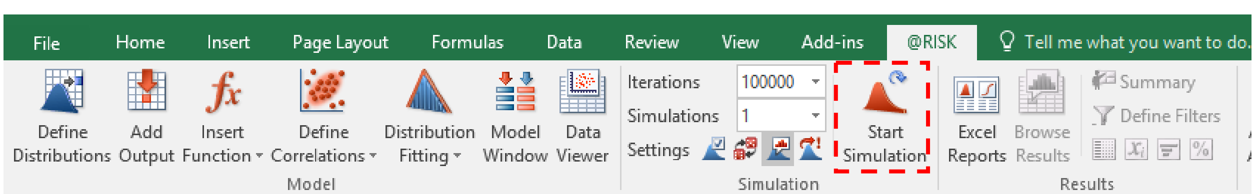


Before running the simulation, it is highly suggested to check model inputs and outputs carefully. You can do this by clicking "Model Window". As can be seen, there are six inputs corresponding to six random variables of Sim Model A and one outputs of interest of Sim Model A.



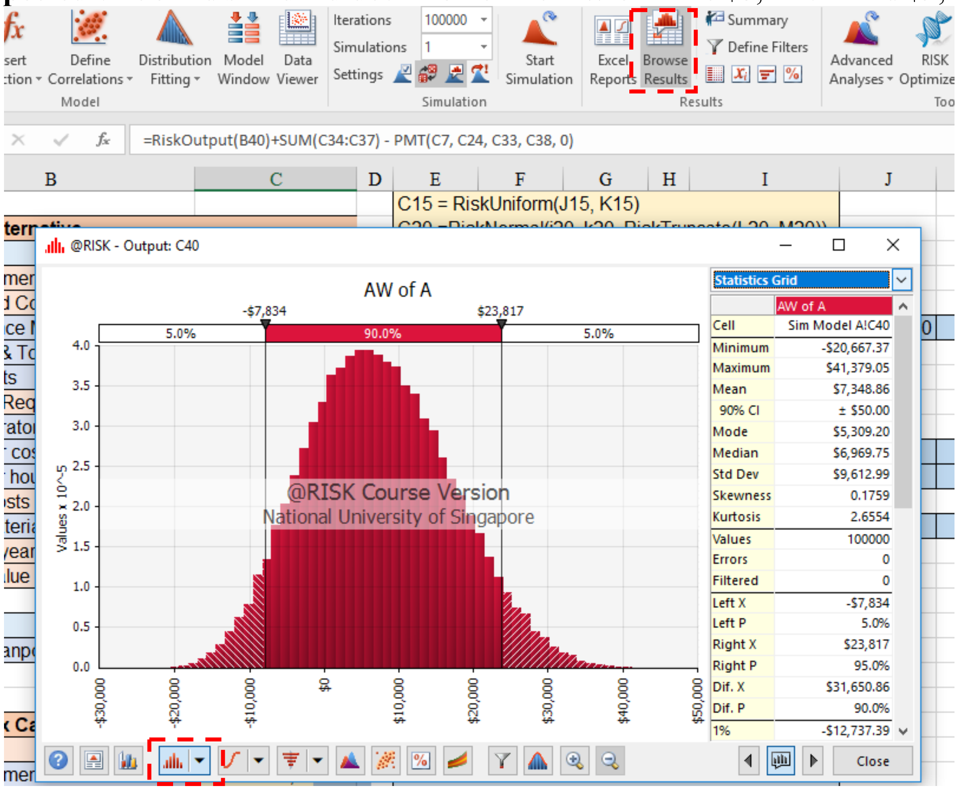


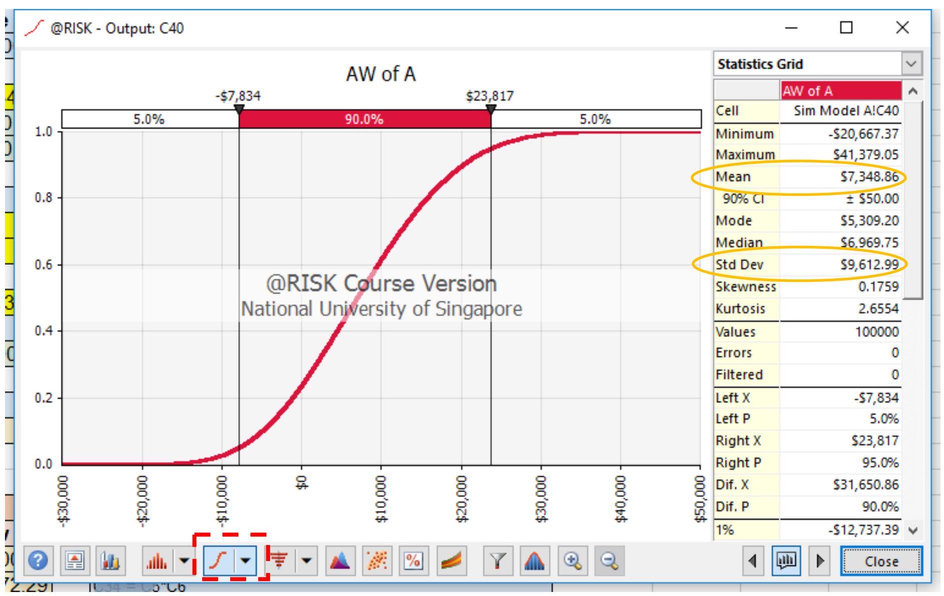
Then click "Start Simulation" to run the simulation.



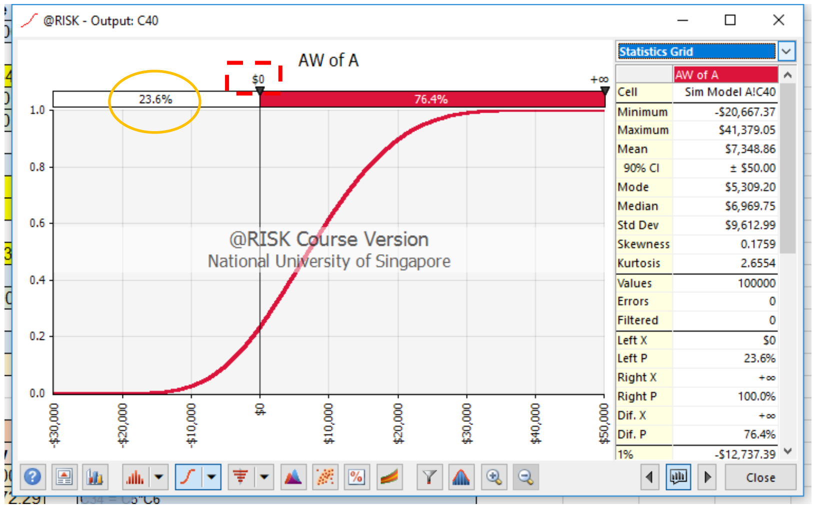
Simulation results will be shown in a separate window and you can always view the results by clicking "Browse Results" in the menu.

The **expected value** and **standard deviation** of the AW of A are $7,348.86 and $9,612.99.



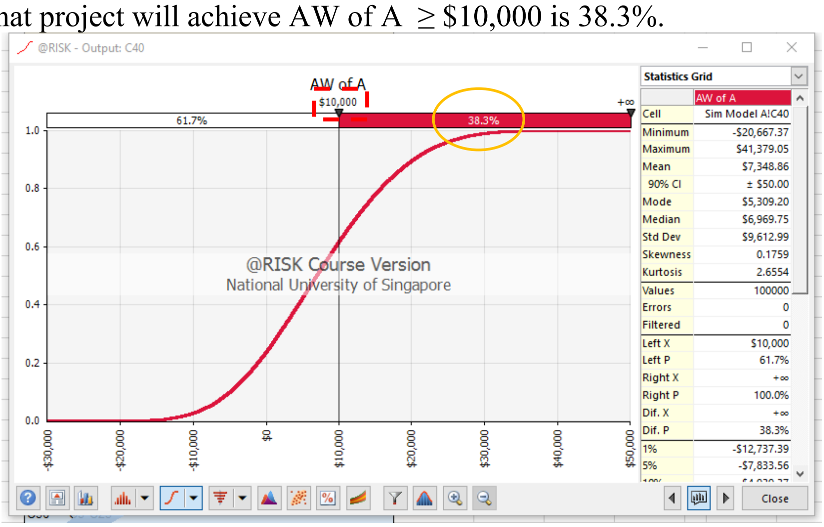


Downside Risk: The probability that the project will be economically infeasible based on AW of A is about 23.6%.

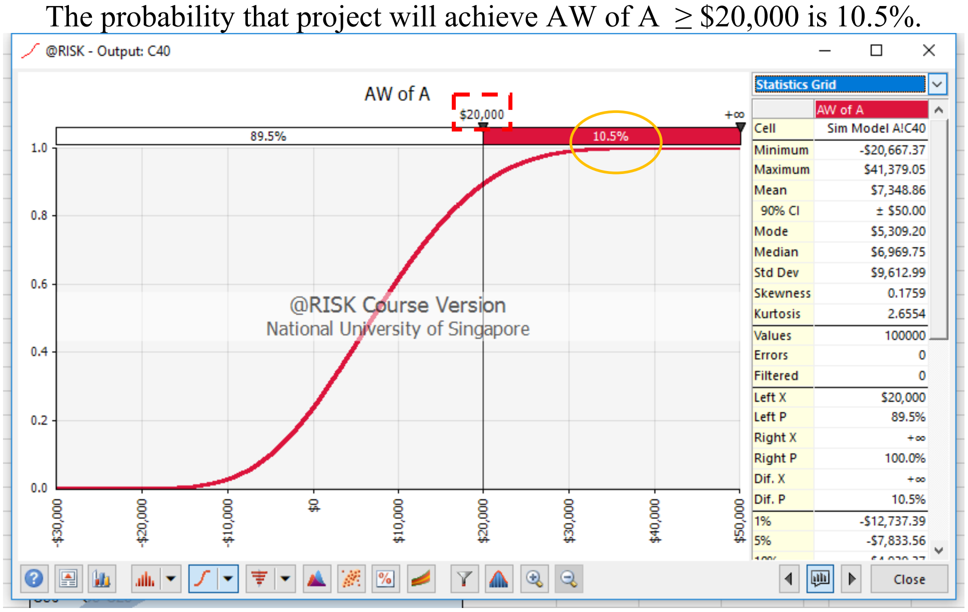


Upside Potentials:

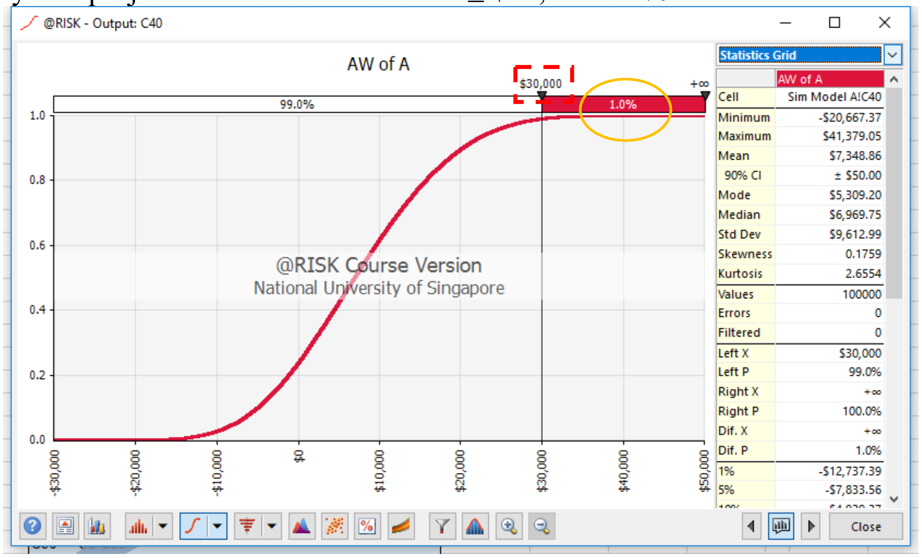
The probability that project will achieve AW of A $\geq$ \$10,000 is 38.3%.



The probability that project will achieve AW of A $\geq$ \$20,000 is 10.5%.

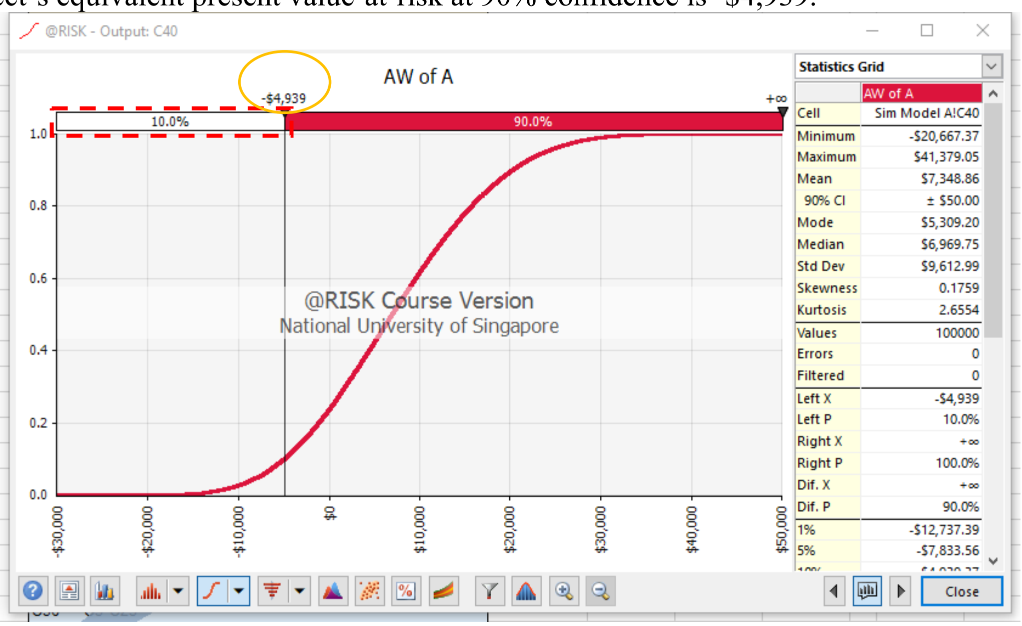


The probability that project will achieve AW of A $\geq$ \$30,000 is 1%.

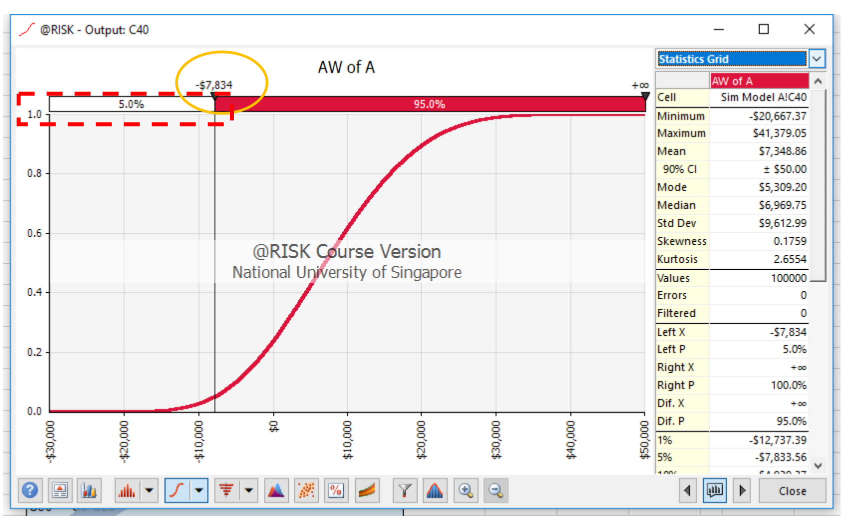


Project Value-at-Risk:

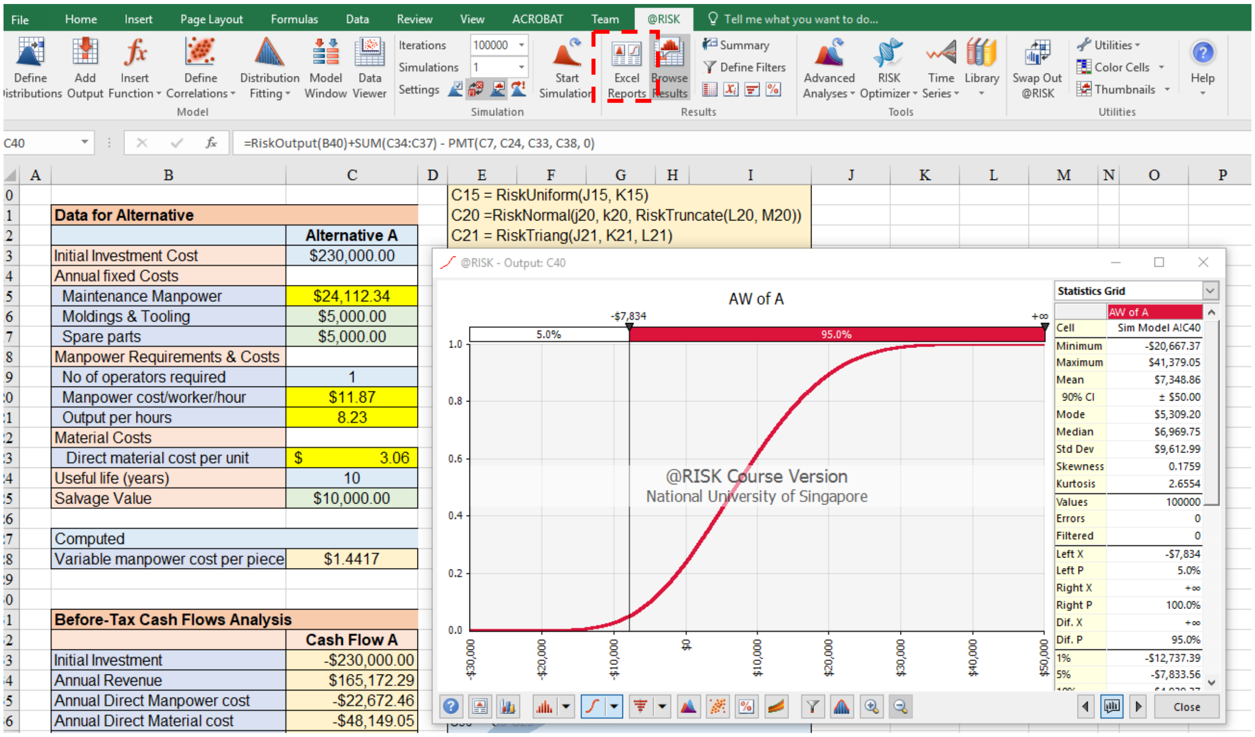
The project's equivalent present value-at-risk at 90% confidence is -\$4,939.



The project's equivalent present value-at-risk at 95% confidence is -\$7,834.

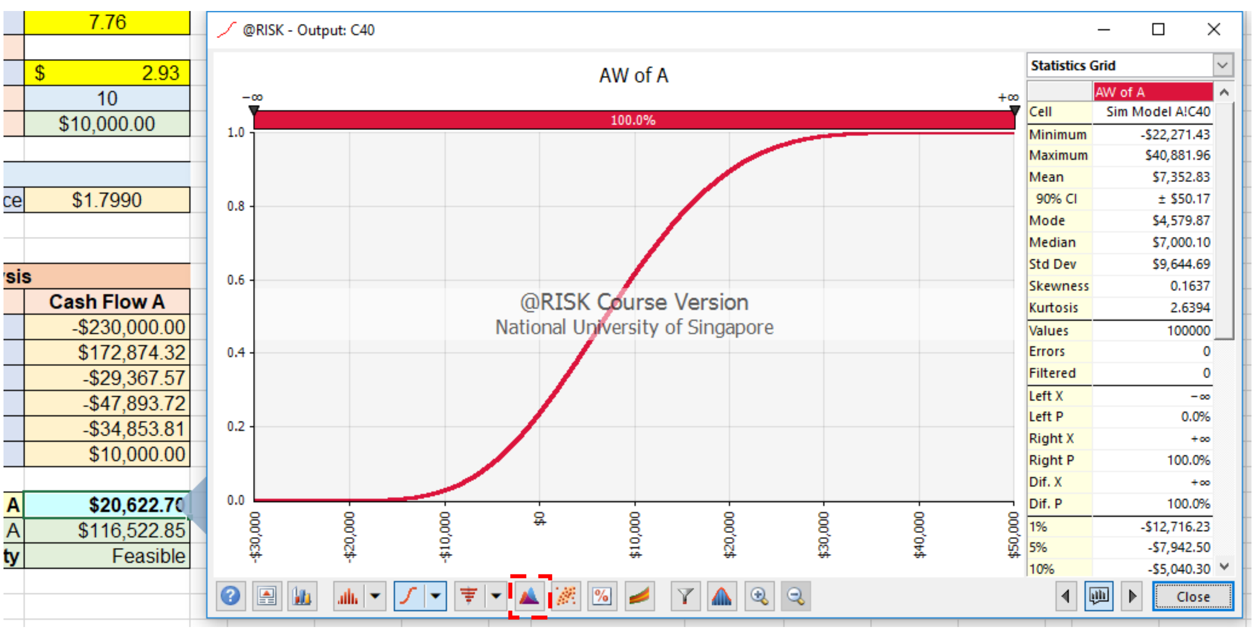


To generate excel report, you can click “Excel Reports” in the menu bar or the icon at bottom left of the result window.

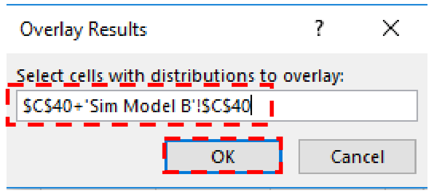


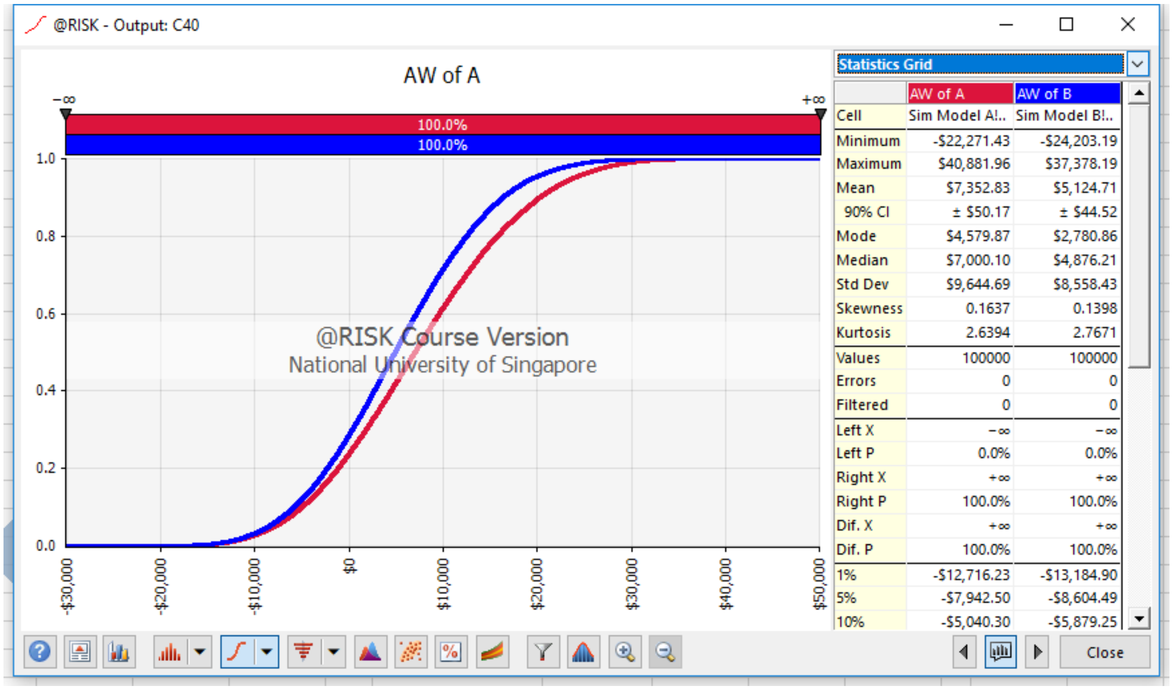
Similarly, we can conduct the Risk Analysis of Model B.

After we get the Risk Analysis of Model A and Model B, we can analyze if there is any first order stochastic dominance. Firstly, we should combine the two results into one. Click the button “Add Overlay to Graph” on the Risk Analysis of Model A.



Then choose the output of AW of B and click “OK”. We will get the two results in one graph.





Now, we can answer your lab worksheet question Q 5.1 – Q 5.5.

[Hint: if the CDF of Alternative B is always above the CDF of Alternative A, we can conclude that there is the first order dominance.

To find out more about stochastic dominance including second order dominance, take IE4243 Decision Modeling and Risk Analysis (Summer) by Prof. Poh.

3.6 Conclusion

Now, the lab is ending. Please do not forget to answer the lab worksheet question Q6.