



11.434 Advanced Real Estate Finance Engineering Economy Module

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About this class

- Based on ESD.70 – Excel modeling
- Explain some tools used on Tuesday
- Learn enough Excel to:
 - Become dangerous
 - Appreciate the power of Excel
 - Gain confidence in own Excel modeling prowess
 - Prepare for ESD.71

This class is :

- Informal:
 - Please ask questions at any time - **A question not asked is a waste of your tuition money!**
 - Compare notes/help each other
- Theoretically easy going:
 - I'll cover a few relevant theories – you do NOT have to learn theory to benefit from this class
 - Just learn how to use them in Excel

Course Outline

Three main topics:

1. NPV and Sensitivity Analysis through Data Tables
2. Monte Carlo simulations
3. Analyzing the system in the context of flexibility

Class Materials

- Excel spreadsheets on the web:
 - Session# – 1.xls : setup before the class
 - Session# – 2.xls : reflects all the work done in class
 - Do the exercises with me → the only way to learn
 - Refer to the Session# –2.xls to validate your work
- Files posted on the Web

Class Philosophy

- Decision-making with an eye towards the future can be approached from two strategic directions:
 - **Deterministic** – improving forecast (and making the best decision based on the probabilities of the expected outcomes)
 - **Dynamic** – admitting that the forecast is likely to be wrong (trading-off suboptimal near-term decisions for the flexibility to delay longer-term commitment until the uncertainties resolve or the forecasts improve)
- Exercises built around analyzing the case of “Big vs. Small”

Human (in-)ability to forecast

Heavier-than-air flying machine are impossible.

Lord Kelvin – British Mathematician, Physicist, and President of the British Royal Society, c. 1895

Everything that can be invented has been invented.

Charles H. Duell – Commissioner of the U.S. Patent Office, 1899

Reagan doesn't have the presidential look.

United Artists Executive – dismissing Ronald Reagan for the starring role in the movie of THE BEST MAN, 1964

... weather ... oil supply ... stock market ...

Modeling with dynamic mentality

- We cannot ignore the intrinsic uncertainty of the future → Dynamic mentality in decision-making to the rescue
- Excel is a decent tool for decision analysis.
- We teach how to unleash the power of Excel to model in a dynamic setting

Why Excel?

- Seems too simple ...
- Why not something more exotic, like MatLab, SAS, C++, etc?
- Excel is a LOT more POWERFUL than you think
- Excel is ubiquitous
- Excel forces you to build your models at a granular level – great for learning the nuts and bolts
- Knowledge of Excel is assumed in ESD.71 and in many real-world modeling situations
- Excel models are relatively easy to explain, understand and debug

Session one – Big vs. Small

- Objectives:
 - Good spreadsheet setup habits to facilitate sensitivity analysis
 - One-way/Two-way Data Tables

Proper spreadsheet setup

- Programming/modeling → debugging
- Sensitivity analysis requires input changes

Good habits that will make your life easier:

- Enter inputs in a separate area or a sheet
- Set up the calculations by formulas linked to entries => **NEVER HARD CODE INPUTS**

Set up NPV base case

Open “Excel 07 session 1 1.xls”

*(we have saved you the joy of manually
entering the data)*

Big vs. Small setup

- Building a computer plant
- Deterministic demand projections for years 1, 2 and 3 are 300,000, 600,000, and 900,000 respectively
- No sales in year 4 or thereafter
- Plan A – a big plant; Plan B – one small plant each year;
- Plants take 1 year to construct
- Big plant capacity of 900,000 with capital cost of \$900 million
- Each small plant capacity of 300,000 with capital cost of \$300 million
- No salvage value for Plan A; \$300 million salvage value for Plan B
- Discount rate for Plan A is 9%, Plan B 9%
- The company will sell each computer for \$2,000
- Variable cost for Plan A is \$1,280 due to economies of scale; Variable cost for Plan B is \$1,500

Worksheet for Plan A

Year	0	1	2	3
Number of plants		1	1	1
Capacity		900	900	900
Demand		300	600	900
Production		300	600	900
Unit Price (Thousand dollar)		2	2	2
Revenue (Million dollar)		600	1200	1800
Unit Variable Cost (Thousand dollar)		1.28	1.28	1.28
Variable Cost (Million dollar)		384	768	1152
Investment (Million dollar)	900	0	0	0
Salvage (Million dollar)				0
Net value (Million dollar)	-900	216	432	648
Discount Factor @ 9.0%	1	0.917431	0.84168	0.772183
Present Value (Million dollar)	-900.0	198.2	363.6	500.4
NPV (Million dollar)	162.1			

$$=1/((1+Entries!\$C\$3)^E2)$$

Worksheet for Plan B

Year	0	1	2	3
Number of plants		1	2	3
Capacity		300	600	900
Demand		300	600	900
Production		300	600	900
Unit Price (Thousand dollar)		2	2	2
Revenue (Million dollar)		600	1200	1800
Unit Variable Cost (Thousand dollar)		1.5	1.5	1.5
Variable Cost (Million dollar)		450	900	1350
Investment (Million dollar)	300	300	300	
Salvage (Million dollar)				300
Net value (Million dollar)	-300	-150	0	750
Discount Factor @ 9.0%	1	0.917431	0.84168	0.772183
Present Value (Million dollar)	-300.0	-137.6	0.0	579.1
NPV (Million dollar)	141.5			

Sensitivity Analysis

- With the “Big vs. Small” analysis, a manager may want to know:
 - What is the impact of changes in discount rate for Plan B while keeping the discount rate for Plan A constant ?
 - What is the impact of simultaneous changes of two variable costs?

Tools for Sensitivity Analysis

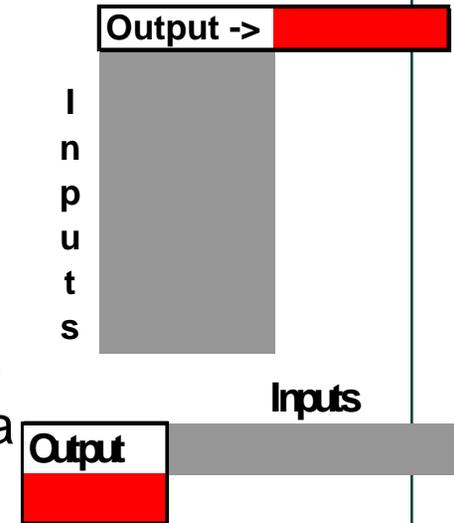
- Data Tables (1- and 2-way)

Data Tables

- Use data tables to see how different input values affect the output
- Data tables provide a shortcut for calculating, viewing and comparing multiple versions in one calculation (what-if scenarios or simulations)
- Two types of *Data Tables*:
 - one-way data tables: evaluate how changes in one input variable effect the output
 - two-way data tables (a matrix): evaluate how changes in two input variables effect the output

One-way Data Tables

- Step 1: Create a list of relevant input variable values (discount rates) either down a column (column-oriented) or across a row (row-oriented).
- Step 2: Enter the output formula for NPV “='Plan A'!C16-'Plan B'!C16” in Cell D40:
 - If the data table is column-oriented, type the output formula in the row above the first value and one cell to the right of the column of values.
 - If the data table is row-oriented, type the formula in the column to the left of the first value and one cell below the row of values.
- Cells that hold output formulas in Data Table contain references to cells in the model.



One-way Data Table (Cont)

- Step 3: Select the range of cells that contains the formulas and values (no labels!), select “Table” under “Data” menu:
 - If the data table is column-oriented, type the cell reference for the input cell in the “Column input cell” box.
- The “***input cell***” is **cell reference** to the input variable in your model whose value Excel will vary as it iterates through the Data Table. Here it is the Discount rate for Plan B.
- Finally, click “OK”.

More Excel tricks

- Reference “*input cell*” MUST BE on the same sheet as the data table
 - Solution: establish a reference cell on the Data Table sheet referencing the input variable (worked for older Excel versions)
 - Insert Data Table on the Entries sheet
- Once you create a Data Table, you can then copy/paste it onto another sheet, as done in sheets “One-way Data Table” and “Two-way Data Table”

One-way Data Table Example

- Varying discount rate for Plan B from 9.6% to 7.6%
- Incremental step 0.1%
- Keep discount rate for Plan A constant at 9%
- Calculate the delta of $(NPV_A - NPV_B)$ for each discount rate for Plan B



Give it a try....

Check with your neighbors...

Check the solution sheet...

Ask questions ...



Modifying Data Tables

- You can change the input values down the left-hand column of the Data Table. The Data Table recalculates automatically.
- You can NOT change the matrix size. If you want to extend the range of input values or change the number of output variable columns, you'll need to erase and rebuild the DataTable
- You can explore Data Table with output calculation beyond those in your model

Two-way Data Tables

- Same idea as one-way, only now we explore output dependency on 2 inputs
- Expect a 2-D matrix

Two-way Data Tables

- Step 1: Create one column and one row varying input values for each of the inputs
- Step 2: Enter the output formula in the upper-left corner of the data table matrix.
- Step 3: Select the range of cells that contains the formula and input values
- Step 4: <Data>→<Table>. In the **Row input cell** and **Column input cell** boxes, enter corresponding output formula input references.

Two-way Data Table Example

- Varying variable cost for Plan A from \$1200 to \$1450
- Varying variable cost for Plan B from \$1400 to \$1600
- Incremental step \$100
- Find out the corresponding delta of $(NPV_A - NPV_B)$ for each pair of variable costs for Plan A and B

Summary

- Excel is a powerful Decision Analysis modeling tool
- We've just scratched the surface
- Good habits will make your life easier
(separate input variables, no hard coding)
- Data tables allow sensitivity analysis

Next...

With the deterministic base case NPV sheet finished, we proceed onto the Monte Carlo simulation.

Critical part of the class!

Open “Excel 07 Session2 1.xls”

Session two – Simulations

- Objectives:
 - Generate random numbers
 - Set up simulations by Data Table
 - Generate statistics from simulations
 - Draw histogram and cumulative distribution function (CDF), or Value At Risk and Gain (VARG) curve

Questions for “Big vs. small”

From the base case spreadsheet, we've calculated NPV's. However, we assumed deterministic demand forecasts for years 1, 2 and 3. It is an over-simplifying assumption since actual demand will vary.

We need to evaluate the range of NPV outcomes, their Min, Max, distributions and the expected NPV values!

Excel's RAND() f'n

- Returns uniformly distributed random number greater than or equal to 0 and less than 1
- To generate a random real number between a and b, use: $=\text{RAND()}*(b-a)+a$
- Formula in cell C3: “ $=\text{Entries!C9}*((1-\text{Entries!C25})+2*\text{Entries!C25}*\text{RAND()}))$ ”
Returns a uniformly distributed random demand for year 1 around 300, but may differ by plus or minus 50%.
[or just: “ $=\text{Entries!C9}*(\text{RAND()}+(1-\text{Entries!C25}))$ ”]

The Same logic for cell C4 and C5

Random number generator

Follow the instructions, step by step

1. Go to sheet “Rand”
2. Type “=Entries!C9*((1-Entries!C25)+2*Entries!C25*RAND())” in cell C3
3. Type “=Entries!C10*((1-Entries!C25)+2*Entries!C25*RAND())” in cell D3
4. Type “=Entries!C11*((1-Entries!C25)+2*Entries!C25*RAND())” in cell E3
5. Press “F9” several times to see what happens

We have built a random demand generator for the 3 years that assumes independent demand (0 correlation) from year to year



Check the solution sheet.

Please ask questions now...

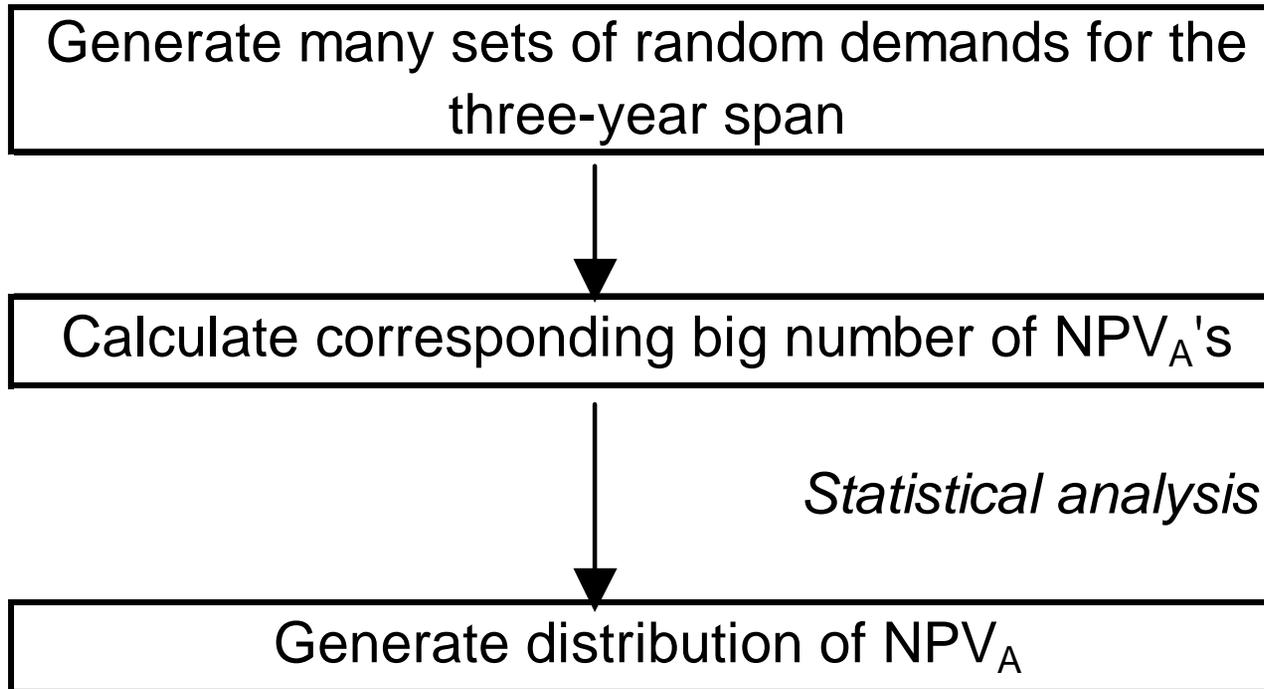
How Monte Carlo Simulation works

Calculate two NPV_A 's corresponding to the two random demand simulations

Demand in Year 1	Demand in Year 2	Demand in Year 3	NPV_A
345	678	1001	
189	579	690	

How about generating many sets of random demands, and get the corresponding NPV_A 's

Monte Carlo Simulation (Cont)



Set up simulation by Data Table

Follow these instructions, step by step:

1. Link demand in sheet for Plan A to the random demand generated, specifically, Plan A!E5 = Rand!C3; Plan A!G5 = Rand!D3; Plan A!I5 = Rand!E5
2. In “Simulation” sheet, type “=‘Plan A’!C16” in cell B8 (“=‘Plan A’!C16” is the output of result for NPV_A)
3. Select “A8:B2008”, click “Table” under “Data” menu, in “column input cell” put “A7”, leave “row input cell” blank

Explanation

- For the one-way Data Table, there is no need to set up the input values in a list, since each row of the Data Table calls `RAND()` and generates an NPV_A projection
- We have 2000 rows in the Data Table, so we have simulated 2000 times
- Click “F9” to try another simulation run

Excel crashing note

If your Excel crashes during simulation runs, input some numbers (0's or whatever) into the dummy input column to the left of the data series. Do not leave the area of input values blank in the data table.

You can hide the dummy values by setting their font value to “white” color.



Check the solution sheet.

Please ask questions now...

Calculating descriptive statistics

- Useful to know mean, maximum, and minimum values for the simulated results

Follow step by step:

1. In “Simulation” sheet in cell D1 type in “=AVERAGE(B\$9:B\$2008)”, Cell D2 type in “=MAX(B\$9:B\$2008)”, cell D3 type in “=MIN(B\$9:B\$2008)”

Deterministic vs. dynamic results

- From the base case spreadsheet, we learn NPV_A is \$162.1 million
- What is your result for the expected NPV_A and NPV_B when considering demand uncertainty?



Check the solution sheet.

Please ask questions now...

Value at Risk and Gain (VARG)

- The VARG curve is another name for cumulative distribution function (CDF)
- It aims at making a representation to managers that
 - “There is a probability X that we will lose (or gain) more than Y dollars for this project.”
- Value At Risk is a common language on Wall Street. It stresses downside risk, though we should also look at CDF for upside potential of a project. Hence the name Value At Risk AND GAIN!
- Use your cursor on the graph for a few examples

Cumulative Distribution Function

Follow the instructions, step by step:

1. In sheet “Simulation”, type “Bound” in G6, “Count” in H6, and “CDF” in I6
2. Enter “0, 1, 2, ..., 20” in cells F7 to F27
3. Set Cell G7 “ $=\$D\$3+(\$D\$2-\$D\$3)/20*F7$ ”, and drag the formula down to G27
4. Set Cell H7
“ $=\text{COUNTIF}(\$B\$9:\$B\$2008, "<=" \&G7)$ ”, and drag the formula down to H27
5. Set Cell I7 “ $=H7/2000$ ”, and drag down to cell I27

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6. Click “Chart” under “Insert” menu (or click)
 7. “Standard types” select “XY(Scatter)”, “Chart sub-type” select anything with lines, click “Next”
 8. “Data range” select “=Simulation!\$G\$7:\$L\$27”, click <Next>
 9. Go to <Series> tab and define the two series in which we are interested (bound vs. CDF).
 10. Click <Next>or <Finish>, exploring tertiary settings.
 11. In the chart, double click Value (Y) axis to adjust min/max unit range, grid lines, number formatting.
 12. Hit “F9” and watch the CDF move !

Explanation

- We set up 20 data buckets and count how many data points fall into each interval
- “=countif()” function counts the number of cells within a range that meet the criteria.
- The file also shows how you can:
 - add mean NPV_A and mean NPV_B as vertical lines.
 - add histograms for two NPV distributions.



Check the solution sheet.

Please ask questions now...

Summary

- Random number generation is fairly straightforward (though not always stable) in Excel
- At least two ways to run Monte Carlo simulation:
 - direct RAND() calls
 - Using Data Table
- Descriptive statistics from simulations
 - Mean, Max, Min, VARG curve

Next...

The class has so far concentrated on ways to model uncertainty.

Modeling is passive. As human being, we have the capacity to manage uncertainties proactively. This capacity is called flexibility and contingency planning.

Next we'll finally explore ways to introduce flexibility in our model.

Questions for “Big vs. small”

The past two sessions have covered ways to model uncertainty. It seems like the big plant is better... Does it feel right?

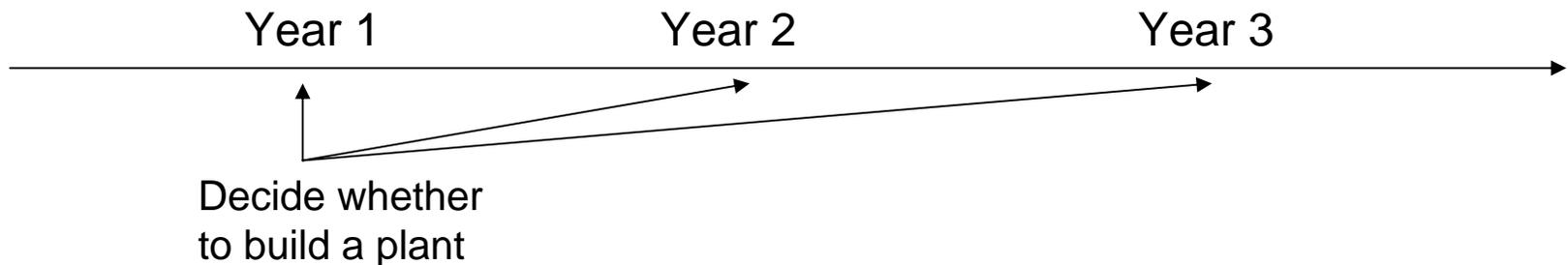
Note: we had assumed a commitment to building one small plant each year regardless of what demand reality turns out to be down the road. So much for flexibility and common sense. Lets correct that oversight!

Session three - Flexibility

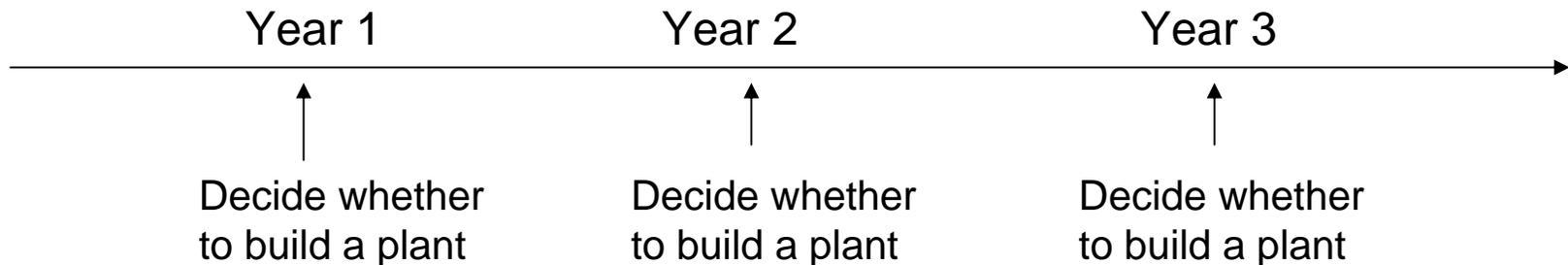
- Objectives
 - Build flexibility into the model
 - See how that impacts our decision-making
 - Perform simple breakeven analysis

Key limitation of NPV analysis

- It assumes that future decisions are made today, for example for constructing small plants



- But the decisions are actually made each year



Key limitation of NPV analysis

- There is a LOT of value in delaying decisions until:
 - More information becomes available
 - Forecast uncertainty decreases with time and collection of additional data
- Ability to delay decisions in future is a source of flexibility
- Flexibility is the magic bullet against uncertainty!

Modeling contingency decisions

- Recall the spreadsheet we built for Session two
- Press “F9” and check which plan is better?
- Think about the following decision rule:
 - After the first plant is built in year 1, we build an additional small plant only if we observe a bigger demand than capacity
- How do we model that?
- Open “Excel 07 Session3 1.xls”

Modeling contingency decisions

- In “Plan B RAND with Flexibility” sheet:
 - in Cell G3 type: “=IF(E5>E4,E3+1,E3)”
 - In Cell I3 type: “=IF(G5>G4,G3+1,G3)”
- Press “F9”
- Now which plan is better?
- How easily can the traditional analysis be misleading, despite properly simulating the uncertainties!
- How different is this kind of analysis from sensitivity analysis?



Check the solution sheet.

Please ask questions now...

Question for “Big vs. small”

Since Plan B with flexibility is better than Plan A, the manager is tempted to go with small plant. Just then the Chief Operations Officer reports the variable cost for the big plant can be further cut (the variable cost for a small plant remains the same).

What is the breakeven variable cost point for Plan A where the two plans are equivalent?

Breakeven analysis

- A breakeven level for a parameter – a target value where some particularly interesting event occurs
- In a deterministic case, a breakeven point can be determined by “Goal Seek”
- In a simulation, we can not use Data Tables (sim on sim). However, we still can do trial-and-error search

Use the Spinner

1. On “Entries” sheet, type “=Simulation!D4-Simulation!D1” in Cell H3
2. Hit F9 and find “mean NPV_B – mean NPV_A”.
3. Use spinner to lower Variable cost for big plant
4. Somewhere around Variable cost for big plant = 1.25, mean NPV_A – mean NPV_B approaches 0
5. Note: what we are really trying to do is run a “simulation on simulation” to find the Plan-A’s variable cost where average NPVs for the two plans are equal.
 - Excel does not support recursive simulations ;-(
 - Spinner gives an approximate answer, but requires manual input.



Check the solution sheet.

Please ask questions now...

Summary

- Incorporated flexibility into the models
- Breakeven analysis
- Excel is a powerful modeling tool. It will accompany you throughout your career.
- We hope this short class increased your awareness of Excel's functionality
- **Uncertainty/risk management is cool and very profitable !**

Excel self-study references

- MS Support center <http://support.microsoft.com/?scid=ph;en-us;2512>
- “Advanced Excel for Scientific Data Analysis” by Robert De Levie
- “Advanced modeling in finance using Excel and VBA” by Mary Jackson, Mike Staunton
- www.amazon.com

Big picture of Excel

- Basics

- Names
- References
- Formula
- Functions

Database integration

Date and time f'ns

Engineering f'ns

Financial f'ns

Information f'ns

Logical f'ns

Lookup and reference f'ns

Math and trigonometry f'ns

Text f'ns

- Charts

- Statistical analysis

- Optimization (Solver)

- Macros

- Visual Basic – now sky is the limit !

Using Excel Help

- Ways to search
 - Contents
 - Answer wizard
 - Index
 - Online at <http://support.microsoft.com>
 - Google your questions
- Explore links to related topics