

An Introduction to Frontier Analyst® 4

By Asia Hussain & Matthew Jones, Banxia Software Ltd
Version 4.0, March 2010, for Frontier Analyst version 4

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Frontier Analyst® is developed and published by Banxia Software Ltd. Full information, this workbook, and a working demonstration of the software are all available free of charge at www.banxia.com or on request by calling Banxia on +44 (0)1539 815660.

1 OVERVIEW

Frontier Analyst® Workbook 1

By Asia Hussain & Matthew Jones, Banxia® Software Ltd

Version 4.0, Published March 2010.

This is a step-by-step tutorial to introduce you to Banxia's Frontier Analyst.

By spending an hour or so working through the core parts of this tutorial you will get to grips with the basics of data entry, project structuring, and analysis. You will also start to see more ways in which Frontier Analyst can help you to explore efficiency. Managers are continuously under pressure to improve the performance of the organisation and make the best use of resources. Frontier Analyst can help you determine the relative efficiency of your organisational units, be they people, departments, vehicles, wards or anything else that you manage.

Frontier Analyst allows you to:

- perform comparative efficiency studies
- visualise important information
- allocate resources more efficiently
- obtain information for planning strategy
- identify under-achievers
- identify star performers
- dig deeper than the "bottom line".

Frontier Analyst® is developed and published by Banxia® Software Ltd. Full information, this workbook and a working demonstration of the software are all available free of charge at www.banxia.com.

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1.1 Feedback please

We welcome your comments and feedback on this tutorial, on how useful you found it and how it might be improved, so please pass on your comments to us.



Please email your comments to info@banxia.com. Thank you.

1.2 The software

Frontier Analyst® is a Windows® based efficiency analysis tool, which uses a technique called data envelopment analysis (DEA) to examine the relative performance of organisational units, which carry out similar functions. It is, therefore, suited for use in organisations which operate through a system of outlets (such as retail outlets, banks, franchises and so on) and for use with public sector or "not for profit" organisations, such as hospitals, schools, and other "unit based" public sector organisations. The DEA technique evolved in the public sector where measures other than purely financial measures, were needed to assess performance.

As part of the analysis the inputs (resources) and outputs (products) associated with the business process are identified. These variables are classified as controllable and uncontrollable variables. A ratio of output over input is calculated across all of the variables, which results in an efficiency score for each of the units being analysed. The comparison is peer based and so the potential improvements identified for inefficient units should be realistic and (largely) achievable.

1.3 The tutorial

As you go through this tutorial you will be asked to perform various tasks and an explanation will be given of what you have done and why. By the end of the tutorial you should be able to run your own DEA analysis. Having completed the tutorial the best thing to do is to start to put what you have learnt into action and work with a situation that is real to you - in doing this you should start to see some of the benefits of using Frontier Analyst.

This tutorial is based on Frontier Analyst version 4. There may be some differences in the operation of other versions.

To help you to work your way through the tutorial the following system for displaying information has been used:



Core exercises are shown in activity boxes using this style (with dark border)



Optional exercises are shown in activity boxes using this style (with light border)

Important points to note are shown in notes boxes using this style (with double border)

Background information is shown with a shadow behind the text. You may not want to read all of the background information but reading it will give you a better understanding of Frontier Analyst and DEA.

1.4 Getting started

Before starting the tutorial you should be familiar with the Microsoft Windows® environment and have a version of Frontier Analyst® installed, either the demonstration or full version.

If you have a CD-ROM: Insert the Frontier Analyst or Banxia Demonstration CD-ROM into the drive. On most systems, the installer will be detected and automatically started. If your system does not do this, run the CDStart.exe program on the CD-ROM. The welcome screen will be displayed and the installation process started.

If you are downloading from the internet: Save the demonstration file (called FA4demo.exe or similar) to a suitable location. Then start the installer in the usual way (perhaps by double-clicking on it). The welcome screen will be displayed and the installation process started.

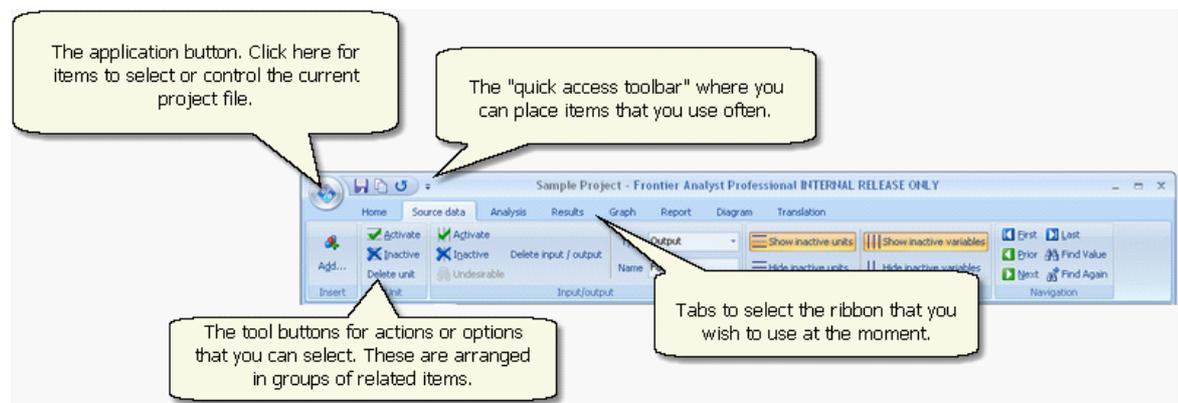
At the end of the installation, you may have to restart your computer to ensure that the components are properly configured.

Once you have the software installed, use the Start menu to start the application.

1.5 Ribbon toolbar

Frontier Analyst® facilities are available through a modern toolbar system called a "ribbon", as used in Office 2007. The main ribbon provides access to the most common facilities. Individual windows have specialised ribbons that are activated when they are in use.

The following tips may help with the operation of the new "ribbon" interface.



Use the Ribbon to find and use features

The Ribbon is the area at the top of the window which provides access to all of the features in the program. The Ribbon is organized into several tabs (such as Insert, Page Layout, and Review) which group related features together.

Tip: To temporarily hide the Ribbon, double-click the selected tab or press Ctrl+F1 on the keyboard.

Contextual Tabs show features related to the selected object

Whenever you change the active window the specialized tools for working with that object will automatically be selected in the Ribbon.

Click the Application Button to do something with your project

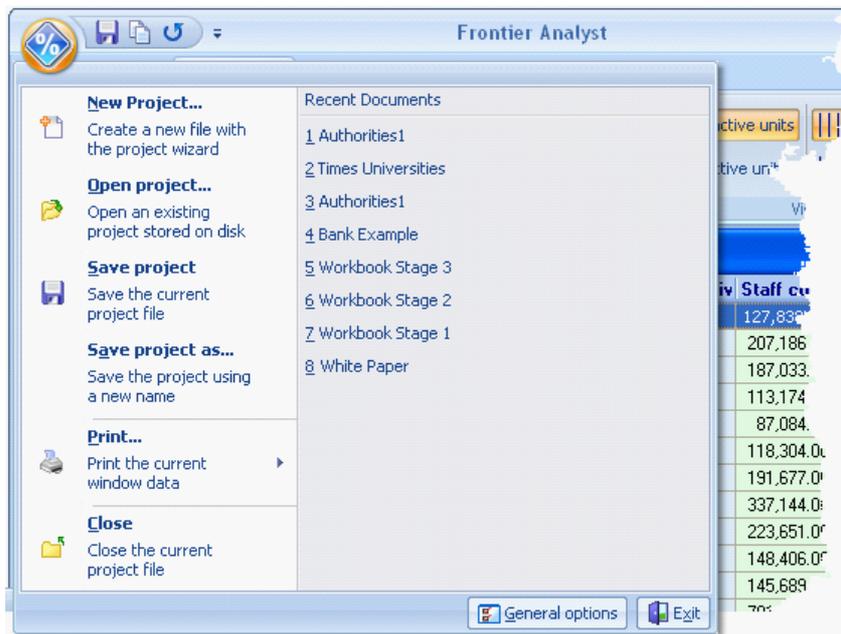
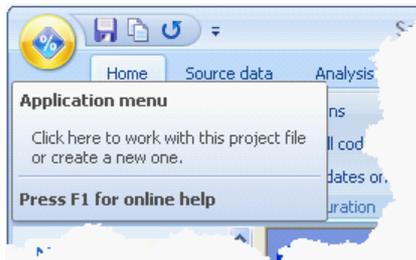
The round Application Button contains all of the features that are used to open or start a new project, to print or close your project. From the bottom of the Application Menu you can open the Options dialog box to change the way the program works.

Put your favourite features on the Quick Access Toolbar

The Quick Access Toolbar is the customizable place to put features you always want to have one click away. To add a feature anywhere in the Ribbon to the Quick Access Toolbar, right-click the control and click "Add to Quick Access Toolbar."

1.6 Application menu

The application button is the round button at the top left of the ribbon. When you click on it, the application menu appears to allow you to select a project file, or to operate on the current project file.



1.7 Requirements

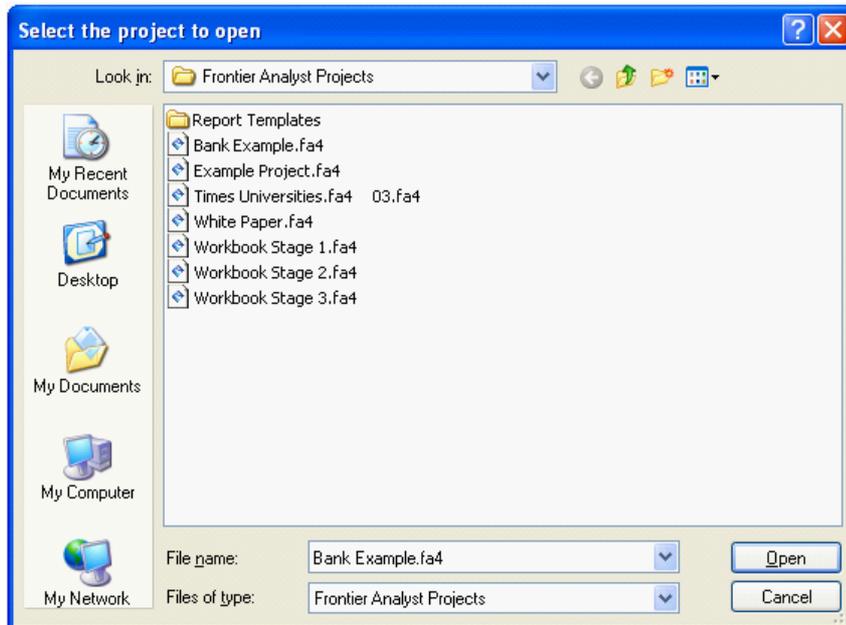
Frontier Analyst runs under Microsoft Windows 2000, XP and Vista . It requires 15Mb of hard disk space (plus additional space for your data files), a mouse and a CD-ROM drive **or** internet connection for installation. It is advisable to use SVGA (800x600) screen or better. Software sold under licence (available for inspection prior to purchase on our web site).

2 STAGE 1 - BASIC DATA ENTRY

This section shows you the basic user interface, and how to get data into the software so that you can analyse it.

2.1 The opening screen

When you have loaded the program and you run it for the first time, you will be faced with a window, overlaid by an 'Open Project' dialog. This shows existing projects available on your system. To open an existing project simply click on the project you want to open then click 'OK'. The data will then be loaded into the Data Viewer window in Frontier Analyst. To begin this tutorial we will open the "Workbook Stage 1" example.



Action: (opening Workbook Stage 1 example)

1. In the Open Project dialog, click on the "Workbook Stage 1" project and then click OK. This will load the data into Frontier Analyst and the Data Viewer window will open.

If the project name does not appear in the Open Project dialog, check the "My Documents" locations as this is where it is installed as standard. If you cannot find it, re-install Frontier Analyst with the sample projects enabled.

The workbook data is based on the performance information on British Universities. You should now be faced with a page which looks similar to this.

| Unit Name | Activ | Teaching As | Research | Entry Stand | Staff-studen | Library and I | Facilities S | Firsts and | Graduate I |
|----------------------------------|--------|-------------|----------|-------------|--------------|---------------|--------------|------------|------------|
| Cambridge | 100.00 | 100.00 | 100.00 | 100.00 | 82.00 | 88.00 | 69.00 | 100.00 | 100.00 |
| Oxford | 94.00 | 96.00 | 99.00 | 75.00 | 99.00 | 66.00 | 93.00 | 99.00 | 99.00 |
| Imperial College of Science, Tec | 96.00 | 85.00 | 92.00 | 93.00 | 86.00 | 100.00 | 74.00 | 94.00 | 94.00 |
| London School of Economics and P | 92.00 | 96.00 | 92.00 | 80.00 | 100.00 | 82.00 | 75.00 | 86.00 | 86.00 |
| Uri College London | 92.00 | 84.00 | 81.00 | 100.00 | 83.00 | 73.00 | 77.00 | 88.00 | 88.00 |
| Warwick | 99.00 | 85.00 | 81.00 | 62.00 | 75.00 | 72.00 | 78.00 | 99.00 | 99.00 |
| Edinburgh | 88.00 | 79.00 | 88.00 | 60.00 | 77.00 | 81.00 | 88.00 | 89.00 | 89.00 |
| Bristol | 84.00 | 72.00 | 87.00 | 70.00 | 92.00 | 86.00 | 99.00 | 99.00 | 99.00 |
| York | 99.00 | 79.00 | 81.00 | 59.00 | 70.00 | 80.00 | 74.00 | 86.00 | 86.00 |
| St Andrews | 91.00 | 72.00 | 83.00 | 59.00 | 70.00 | 75.00 | 92.00 | 98.00 | 98.00 |
| Nottingham | 84.00 | 69.00 | 88.00 | 66.00 | 72.00 | 73.00 | 82.00 | 99.00 | 99.00 |
| Sheffield | 90.00 | 70.00 | 80.00 | 64.00 | 65.00 | 77.00 | 73.00 | 87.00 | 87.00 |
| Durham | 86.00 | 72.00 | 88.00 | 56.00 | 69.00 | 71.00 | 74.00 | 92.00 | 92.00 |
| Birmingham | 84.00 | 69.00 | 82.00 | 62.00 | 67.00 | 76.00 | 76.00 | 98.00 | 98.00 |
| Bath | 73.00 | 78.00 | 79.00 | 56.00 | 82.00 | 84.00 | 79.00 | 94.00 | 94.00 |
| Lancaster | 85.00 | 79.00 | 73.00 | 50.00 | 72.00 | 80.00 | 75.00 | 90.00 | 90.00 |
| Victoria Manchester | 80.00 | 74.00 | 80.00 | 63.00 | 78.00 | 70.00 | 71.00 | 91.00 | 91.00 |
| King's College London | 80.00 | 69.00 | 77.00 | 82.00 | 78.00 | 67.00 | 70.00 | 87.00 | 87.00 |
| Newcastle-upon-Tyne | 81.00 | 64.00 | 74.00 | 76.00 | 77.00 | 74.00 | 72.00 | 92.00 | 92.00 |
| Glasgow | 87.00 | 58.00 | 85.00 | 56.00 | 69.00 | 72.00 | 81.00 | 89.00 | 89.00 |

Unit names appear in the left hand column (Cambridge, Oxford etc.) and variable names appear in the first row (across the top of the grid). The variables represent inputs and outputs for the process being analysed. The variables Staff-Student ratios, Library and Computer, and Facilities and Spending are inputs in the analysis i.e. these are resources which are used to produce the outputs. In this example, the outputs being measured are: Teaching Assessments (to represent the external grade given to the university), Research, Entry Standards, First and 2:1's, and Graduate Destination. The measured values of the variables for each unit appear in the body of the database grid.

Successful application of DEA requires a number of units (Decision Making Units or DMU's) which are performing a similar process. In the Workbook Stage 1 example, these Units are simply different Universities within the UK (Cambridge, Durham, Sheffield etc.). Also necessary are variables which take the form of inputs and outputs. The determination of which inputs and outputs to use in an efficiency study is particularly important as they define the basis on which the efficiency of the units is to be assessed. Only those inputs and outputs which are most relevant to the function of the units should therefore be included in the analysis.

An input is any resource used by a unit to produce its outputs. This can include resources which are not a product but are an attribute of the environment in which the units operate. An output is any product or service produced by a unit or a measure of how effectively a unit has achieved its goals.

There are three main ways in which to enter data into Frontier Analyst:

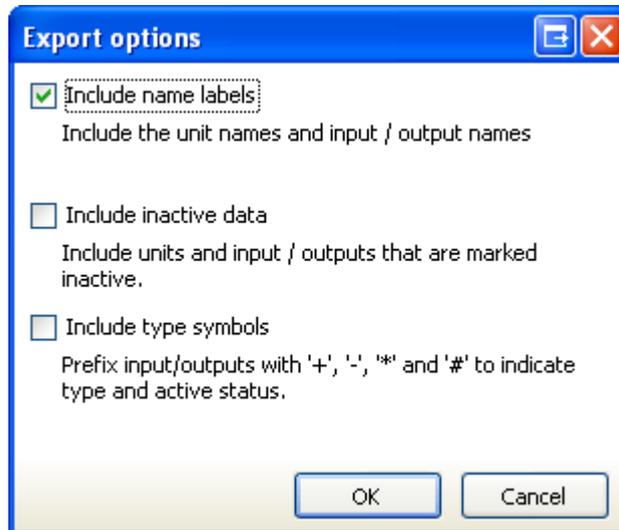
1. Paste data from clipboard (e.g. Excel)
2. Import from disk file
3. Direct (manual) data entry into the data viewer.

You can also import direct from Excel or SPSS, but we will not cover those options here. To get some practice of the main options available in Frontier Analyst, export the Workbook Stage 1 data to a text file and save it to your computer. This will allow you to work through the core activities which follow.



Action: (exporting the data as a text file)

1. Make sure that the Data viewer is active by clicking on a data item.
2. Go to the Home tab, Export as text item. The export options dialog should now be displayed.



3. The Include name labels options is selected as default. (We do not need any of the other options at this time because we have not edited the data in any way). Click OK.
4. Choose where on your computer you want to save the exported data file. We suggest that you use the file name "DEA sample.txt" and save the file to a suitable location.
5. Close the Workbook Stage 1 project using the Application menu, Close item.

2.2 Pasting data from the clipboard

To carry out the next activity, open the exported data ("DEA sample.txt") using the Windows Notepad application. This will allow you to copy the data to the clipboard.

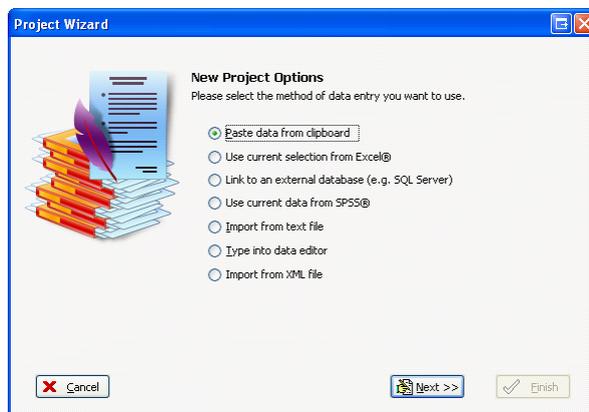
Select the data you want to copy into Frontier Analyst, and by using the Edit menu, Copy item to copy the data to the clipboard (alternatively Ctrl+C may be used).

| University | 32 | 6 | 52 | 40 | 65 | 64 | 55 | 66 | 72 | 49 | 68 | | |
|-----------------------------|----|----|----|----|----|----|----|----|----|----|----|--|--|
| Sou | 11 | 39 | 55 | 66 | 72 | 49 | 68 | | | | | | |
| Mid | 18 | 42 | 31 | 64 | 65 | 61 | 88 | | | | | | |
| Hud | 18 | 42 | 54 | 66 | 69 | 60 | 81 | | | | | | |
| Lee | 57 | 9 | 51 | 45 | 61 | 63 | 56 | 87 | | | | | |
| Cen | 68 | 9 | 47 | 40 | 63 | 59 | 60 | 67 | | | | | |
| Her | 14 | 44 | 45 | 66 | 65 | 56 | 91 | | | | | | |
| Nor | 16 | 29 | 34 | 65 | 69 | 53 | 75 | | | | | | |
| Sta | 61 | 13 | 46 | 39 | 59 | 63 | 49 | 78 | | | | | |
| Lon | 60 | 12 | 42 | 36 | 68 | 64 | 47 | 83 | | | | | |
| Wol | 8 | 41 | 36 | 58 | 72 | 55 | 78 | | | | | | |
| Der | 45 | 38 | 61 | 63 | 55 | 77 | | | | | | | |
| Eas | 16 | 39 | 38 | 65 | 66 | 51 | 64 | | | | | | |
| Sun | 13 | 40 | 28 | 58 | 67 | 52 | 82 | | | | | | |
| Lut | 36 | 34 | 61 | 59 | 33 | 85 | | | | | | | |
| Lincolnshire and Humberside | 52 | 8 | 39 | 30 | 62 | 57 | 55 | 86 | | | | | |
| Bournemouth Uni | 32 | 6 | 52 | 40 | 65 | 64 | 55 | 86 | | | | | |



Action: (pasting data from the clipboard)

1. Create a new project. Click on the Application button () and select the New Project menu item.
2. In the Project Wizard select the Paste Data from Clipboard radio button, then click Next. If there is no suitable data on the clipboard then you will be told, and given the opportunity to retry. Repeat the copy operation in the source application, and try again.



The clipboard analysis stage is presented as a set of possible ways of interpreting the data on the clipboard. In general, you should not need to change the options presented (they are derived by examining the data) and should simply click Next. (If you find that the import does not work as you expect, you may consider changing the options).

3. After the Import Progress dialog shows that it has completed the import, click Finish. The data should now appear in the Data Viewer window in Frontier Analyst.

The data is now ready for analysis. From here you could move on to the Project Structuring stage where you will choose between input minimisation/output maximisation and between constant and variable returns to scale.

We are not going to work on this data at present as this exercise was to illustrate how the import options can be used in Frontier Analyst.

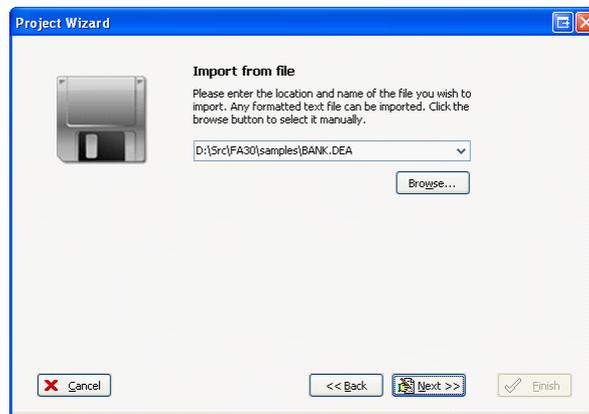
4. From the Application menu choose the Close item to close the project. You then have the option to save or not save the project. In this case there is no need to save the project. Click No to close the project.

2.3 Importing data from a disk file



Action: (importing data from a file)

1. Click on the [Application menu button](#) ⁴ and select the New Project menu item to create another project.
2. In the Project Wizard, click the "Import from file" radio button and click Next. You can now either enter a file name, ("DEA sample.txt") or click the Browse button to display a standard file selector to choose the file.



3. Select your source data, then click Next. (Some samples are provided in the same directory as the Frontier Analyst application.)
4. Again, the Project Wizard will show its interpretation of the imported data. Click Next to continue.
5. After the database storage has completed, click on Finish to complete the import. The data should now appear in the Data Viewer window in Frontier Analyst.
6. Again, we are going to try other things first, so we will close the project. Use the Application menu, Close option to close the project. There is no need to save the project and so when prompted click "No".

Note: Frontier Analyst will only read delimited text data from files when importing. Therefore, if your data is saved in Microsoft Excel, you will have to save it as a text (preferably tab delimited) file to be able to import its contents into Frontier Analyst (or use the direct transfer mode of version 3).

2.4 Direct data entry into the data editor

Now that you have experimented with the Pasting from clipboard and Import from disk file options, the remaining option is to type the data manually into the Data Editor. Frontier Analyst operates using a database, not a spreadsheet, so you need to be aware of the differences.



Action: (typing data into the Data Editor)

1. Click on the New button to open another project. If the current project has been changed, you will be prompted to save it.
2. Select the "Type into data editor" option and click Next.
3. You will be asked to enter the name for an input/output variable, and its type. Enter the first name from the table below (Teaching Assess), select the type (output), and click Next. When you click Next the data will be stored, and the edit box will be cleared, ready for the next variable name. For this example, type Research as the variable name and select Output for Input/Output type, then click Next. You can now enter the name and type of the next variable in the analysis.
4. Repeat Step 3 until you have entered all input/output variables required. Select Finish when you are completed. After entering the variables and finishing, the software moves on to the unit names.
5. The wizard now asks for the names of the units that you want to add to the project. Simply enter the name, then click Next. Click Finish when all the units have been added. The wizard has an option to auto-capitalise the names to save typing effort. When you have entered all the names, click Finish to close the wizard and return to the data viewer.
6. Manually enter the values for the variables in the Data Viewer window. You can omit this exercise if you wish as it is merely to give an indication of how you would manually enter the data values. Alternatively, try entering the values for one unit, then when you are confident that you know how it is done, move on to the next section.

| | Teaching Assess | Research | Entry Standards | Staff-student Ratios | Library and Comp | Facilities Spend | Firsts and 2:1s | Graduate Destination |
|-----------------------------------|-----------------|----------|-----------------|----------------------|------------------|------------------|-----------------|----------------------|
| | output | output | output | input | input | input | output | output |
| Cambridge | 100 | 100 | 100 | 82 | 88 | 69 | 100 | 100 |
| Oxford | 94 | 96 | 99 | 75 | 99 | 66 | 93 | 99 |
| Imperial College of Science, Tech | 96 | 85 | 92 | 93 | 86 | 100 | 74 | 94 |

| | | | | | | | | |
|----------------------------------|----|----|----|-----|-----|----|----|----|
| London School of Economics and P | 92 | 96 | 92 | 80 | 100 | 82 | 75 | 86 |
| Uni College London | 92 | 84 | 81 | 100 | 83 | 73 | 77 | 88 |
| Warwick | 99 | 85 | 81 | 62 | 75 | 72 | 78 | 99 |
| Edinburgh | 88 | 79 | 88 | 60 | 77 | 81 | 88 | 89 |
| Bristol | 84 | 72 | 87 | 70 | 70 | 92 | 86 | 99 |
| York | 99 | 79 | 81 | 59 | 70 | 80 | 74 | 86 |

When manually typing in the values of the variables in Frontier Analyst, the blank cells will appear with a pink background to indicate it is empty (or zero). When a value for the variable is entered, the colour of the background will change to either blue, yellow or green depending on the input or output type. This allows you to visually differentiate between the types of variable.

You can add new units or variables at any stage simply by clicking on the Add button in the top left hand corner of the Data Viewer window.

The input/output type selection can be one of the following:

| | |
|--------------------|--|
| Controlled input | A controlled input or output is one over which the management of the unit has control and, as a result, can alter the amount of resource used or product produced. (Controlled variables are also sometimes referred to as discretionary variables). |
| Uncontrolled input | An uncontrolled or uncontrollable variable is one over which the unit's management does not have control and hence cannot alter its level of use or production. An example of an uncontrolled input for a retail outlet would be the number of competitors it had in its area. Uncontrollable variables are also referred to as exogenously fixed and non-discretionary variables. |
| Output | Outputs are the products (goods, services or other outcome) which result from the processing and consumption of inputs (resources). An output may be physical goods or services or a measure of how effectively a unit has achieved its goals. |
| Text | Text fields are not analysed, but can be used to filter units, perhaps by region or other category. |
| Date | Date fields are not analysed, but can be used to filter units, perhaps by period. |

Now that you have experimented with the different options for data entry, the next step is to get the data in the correct format so that we can run the DEA analysis. Click on the Application menu Open Project item and select the Workbook Stage 1 project. Click OK to re-open the project file. If you are

prompted to restore the demonstration data click Yes.

2.5 Editing the data

To correct any errors you may have made in inputting your data, simply click on the cell you wish to change and type in the new value, then press Enter. Note that in the Workbook Stage 1 data, the value of Teaching Assessments for Cambridge is 100. We will assume for the exercise that this should in fact be 107.



Action: (editing variable values)

1. Move the pointer over the cell you want to edit (in this case the cell which contains the Teaching Assessments value for the unit Cambridge).
2. Left click once to select the cell, it will change to indicate that you have selected it.
3. Type in 107 then press Enter.

The data envelopment analysis cannot operate if there are zero values in the dataset. If you try to analyse and Frontier Analyst reports that you have zero values, you can use the option in Frontier Analyst which replaces all 0 values with a small number. This is done by clicking on the DEA Options button on the Analysis tab of the ribbon toolbar. This will open an Analysis Options window. Below the analysis options there is a check box for the option to Substitute zero values with. Check this box to use this option. Then specify the value with which you would like the zero values in the dataset to be replaced. The substitute value that you choose should be small relative to the other values in the dataset. For formal analysis, you should check and modify all the data yourself.

2.6 Activating and removing data

Having run a preliminary analysis, you may want to assess the impact of certain variables or units on your results. If one unit is performing exceptionally well, you may want to temporarily remove the unit from the analysis. By using the facilities in Frontier Analyst you can temporarily remove various variables and units from the analysis to assess their impact on the results. This allows you to experiment with your data and get a feel for the most important/influential variables and units.

The Source data tab on the ribbon toolbar contains options to remove (permanently) units and variables from the analysis. If you want to temporarily remove a unit or variable from the analysis, you can use the Inactive button to disable or the Active button to enable it. Inactive units and variables are shown on the data editor using greyed out text. You can still edit the data when in an inactive state, but the values will be ignored in the analysis.



Action: (making a variable inactive)

1. Move the pointer mouse over one of the cells in the column with the variable Teaching Assessments, left click once to select the cell.

In the Source data tab on the ribbon toolbar you will find an Input/output section, and to the left of this two buttons.



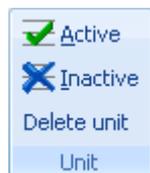
2. Click on Inactive. The values for this variable will now be greyed out text. You have temporarily removed this variable from the analysis.
3. Click on Active to reactivate the variable as we want to use it in the analysis.



Optional activity: (Experimenting with unit active/inactive option)

1. Place the pointer mouse over any of the cells in the row of the unit you want to make inactive (Durham for example). Left click once on the cell to select it.

In the Source data tab on the ribbon toolbar you will find another set of active/inactive options in the Unit section. These allow individual units to be made active or inactive.



2. Click on the Inactive button. You will notice that the values of the variables for Durham are now greyed out. You have now temporarily removed this unit from the analysis.
3. Re-activate the Unit by clicking on the Active button.

An alternative method of making units active and inactive is to use the column of check boxes next to the unit names. All of the boxes are ticked as default (i.e. all of the units are active). To de-activate a unit simply double click on the check box for the unit you want to remove from the analysis. This will remove the tick from the box, and the row for that Unit will be displayed in greyed out text. To re-activate the unit, double click on the unit's check box again and it will be re-activated.

| Active |
|-------------------------------------|
| <input checked="" type="checkbox"/> |

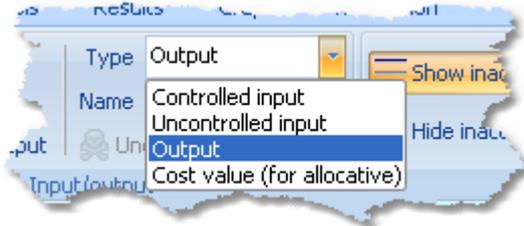
2.7 Variable types

The next step is to set the input/output variables in the dataset to their appropriate type. Teaching Assessments, Research, Entry Standards, First and 2:1's, and Graduate Destination are all outputs in the analysis, and Staff-student ratios, Library and Computer, and Facilities Spending should be set to controlled inputs.



Action: (setting variables to appropriate types)

1. Place the cursor over any cell in the Teaching Assessments column and left click once on the cell to select the column. The column name will appear in the Input/output section on the ribbon.
2. On the Source data tab go to the Input/output section and click on the Type drop down list to view the choices.



3. Select Output. You will notice that the background colour of the column is now blue.
4. Repeat this process for the variables: Research, Entry Standards, Firsts and 2:1's, and Graduate Destinations. The background colour of each of these columns should now be blue, indicating that these variables are outputs in the analysis. (If everything is a white background, see below).

Staff-student ratios, Library and Computer, Facilities and Spending should be set to Controlled Input.

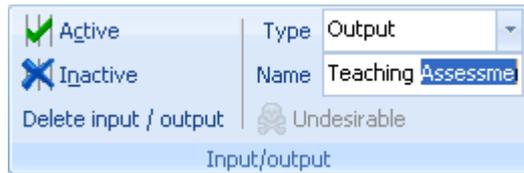
5. Place the cursor over any cell in the Staff/student ratios column.
6. Left click once on the cell to select it.
7. This time, in the input/output type option select Controlled Input.
8. Repeat this process for the Library and Computer, and Facilities Spending variables.

You should now find that the output columns have a light blue background and the input columns have a light green background giving visual differentiation between inputs and outputs. (If everything is a white background, then the colour background option has been turned off, or the contrast on your display is affecting the output which is particularly common on LCD displays.)

2.8 Changing unit and input/output names

Depending on how you enter the data, it may or not have meaningful names for the units and input and output variables. You can change them to suit your purposes by clicking in the column for that variable, and then editing the text in the edit box in the Source data tab of the ribbon. Variable and unit names should be unique.

For example, if you wanted to change the variable Teaching Assessments to just Teaching, click one of the cells in the Teaching Assessments column and then delete Assessments from the Input/output section Name edit box. **Press Enter to confirm the change.**



If you want to change the name of one of the units, this is done directly in the data viewer. Click on the cell with the name you wish to change, and then edit the unit name as required.

In general you will find that shorter unit and variable names are best as they occupy less space on graphs and displays. Abbreviations commonly used in your company or industry will retain understanding while conserving space.

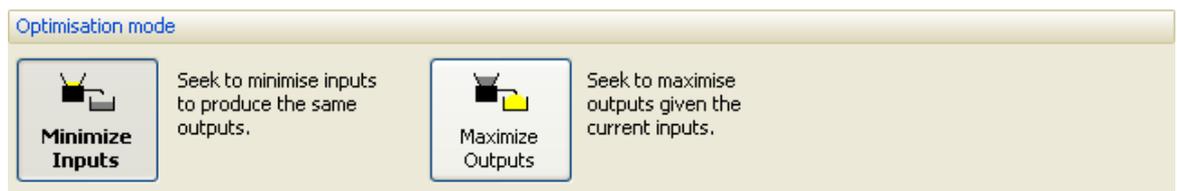
3 STAGE 2 - PROJECT STRUCTURING

Now that your data is ready and you are confident with using different methods of data input, the next step is to make decisions about the type of model that you want to use to analyse your data. Two decisions have to be made which we will look at in detail. The first is whether you want the analysis to minimise inputs or maximise outputs for the process which you are considering. The second is whether to assume constant or variable returns to scale. Frontier Analyst uses the most tried and tested models in DEA, which, in academic literature, have proven to be the most robust. The two models used are the BCC model for variable returns to scale and the CCR model for constant returns to scale. (BCC and CCR are the initials of the people who developed the formulae used.)

3.1 Input minimisation or output maximisation

In Frontier Analyst, the efficiency model can address one of two questions:

1. Given the level of outputs that a unit produces, by how much might the inputs be reduced while maintaining the current level of outputs? This is input minimisation.
2. Given the current level of inputs used by a unit, what level of outputs should it be possible to achieve? This is output maximisation.



Note: the use of input minimisation or output maximisation depend on the situation being analysed. In the case of the output maximisation model, an appreciation of whether it is actually possible to achieve the target outputs generated by the analysis is needed, e.g. if the output targets are considered to be unattainable because of external factors then this model is likely to be inappropriate. Alternatively, it may be that the inputs a unit uses are relatively inflexible in which case the output maximisation project might be best.

Under the assumption of constant returns to scale, the efficiency results obtained from both the input minimisation and output maximisation options are identical.

With the Workbook Stage 2 example we will assume that for the given expenditure on Library and

Computers, Facilities Spending and other input variables, we want to maximise the number of First and 2:1's as well maximising the Entry Standards and Teaching Assessment etc. Therefore we want output maximisation.



Action: (setting project type to output maximisation)

1. Left click once on the DEA options button (on the Analysis tab) to open the Analysis Options dialog.
2. The first set of options refer to the optimisation mode. Left click once on the "Maximize Outputs" button to select it. Do not close this window yet as we need it in the next section.

If when running your own analysis you want to experiment and change the optimisation project from minimising inputs to maximising outputs use the DEA button, as we have just done, open the Analysis Options dialog and change the optimisation mode as desired.

3.2 Returns to scale

Frontier Analyst allows you to assess the relative efficiency of units under a system of either constant or variable returns to scale. The efficiency results obtained from using the different scale assumptions are likely to be different.

| Scaling mode | |
|---|--|
|  <p>Constant returns</p> | <p>Outputs directly reflect input levels. (i.e. doubling input produces exactly double outputs.)</p> <p>CCR mode</p> |
|  <p>Varying returns</p> | <p>Outputs fall off as input levels rise. (i.e. doubling input produces less than double outputs.)</p> <p>BCC mode</p> |

Using the variable returns to scale option allows the analysis more room to find optimal solutions. The result of this is that no unit will receive a lower efficiency score using variable returns to scale, than it had with a constant returns to scale model. Any units which are operating with minimum input or maximum output levels, will also be found efficient, using variable returns to scale, and so the total number of 100% efficient units will probably be higher.

The choice of model, constant (CCR) or variable (BCC), depends on the process being analysed. The question to be asked is, if resources are increased by amount 'x', do outputs increase by the full amount 'x', or is there a proportionately higher or lower increase in outputs? If the answer is that any increase in input (resources) used yields a proportionate increase in outputs (results) then this indicates that a linear relationship between the inputs and outputs, so a constant returns to scale model should be used. If however, an increase in inputs does not yield the same increase in outputs, then the variable returns to scale model should be used, as a non-linear relationship between results and resources has been identified.

For the Workbook Stage 2 example we will use variable returns to scale, as a doubling of the inputs is not likely to produce a doubling of outputs.



Action: (setting project to variable returns to scale)

1. The second set of options in the Analysis Options dialog refers to the scaling mode. Left click once on the "Varying returns" button to select it.

You have now chosen your optimisation mode as maximising outputs, and your returns to scale mode as variable returns to scale. Other options available in the window are the zero replacement facility (discussed in Editing the data section). The Analysis Options window also has an Advanced>> button, which opens an extension to the current options, displaying the weighting options available in Frontier Analyst. Weights are discussed in the [Other Options section](#)^[35]. Close the Analysis Options window.

You are now ready to run the DEA model.

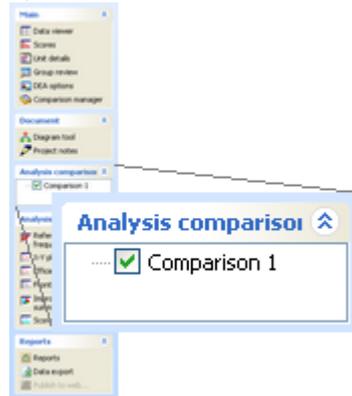
3.3 Running the analysis



Action: (running the DEA model)

1. Select the Analysis tab, Analyse Now item. This item is also available on the quick access toolbar at the top of the main window. 
2. Click on the Analyse button once to run the analysis.

Note: If nothing happens, ensure that the "Comparison 1" item is checked in the left-hand option bar.



If you change the source data and then click on a results window, Frontier Analyst will prompt to recalculate the results so the displays are always up to date. This can be set to automatically be done without prompting (and controlled using the general options button at the bottom of the [Application menu](#)^[4]).

4 STAGE 3 - RESULTS

This section outlines the principle results which Frontier Analyst provides. If you have chosen to omit Stages 1 and 2 of this workbook, then you should load the Workbook Stage 3 project (from the Frontier Analyst projects directory) now.

4.1 Main score display

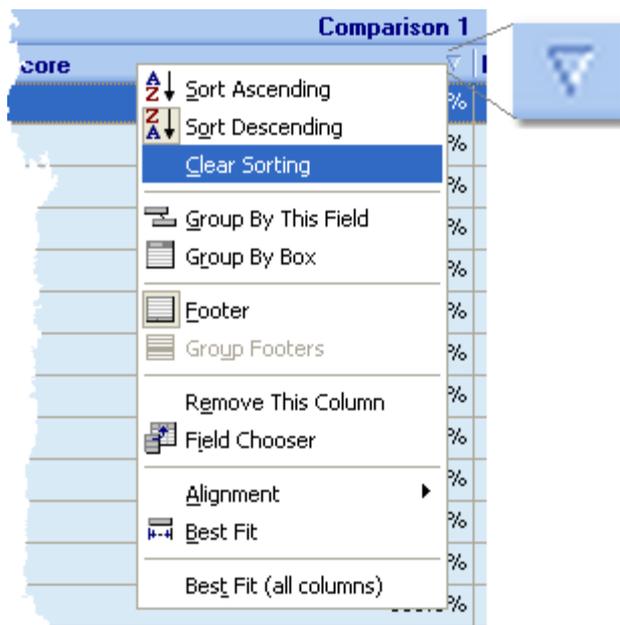
Having clicked on the [Analyse button](#) ⁽¹⁷⁾, Frontier Analyst will display a window with the efficiency scores that have been calculated for each of the units which are active in the dataset. Here, we will focus on the first tab on the window, the Efficiency scores tab. The grid displayed allows you to control various result options.

If you right click on the grid, a pop-up menu will appear. This allows you to go to the Data viewer or the Unit details window with the current unit selected.



In the Workbook Stage 3 example the results should show 38 universities as 100% efficient and 58 inefficient universities.

The title section of the grid allows you to sort the results in a number of ways. Clicking on a title will sort the data by that column. To reverse the sort order, click again. The direction of the sort is shown with an indicator. To sort by another column, just click it. If you want to sort by more than one column, hold the Shift key to add additional sorts. Finally, you can clear the sort by right-clicking a title and selecting "Clear Sorting". These options allow you to display results according to your own requirements.

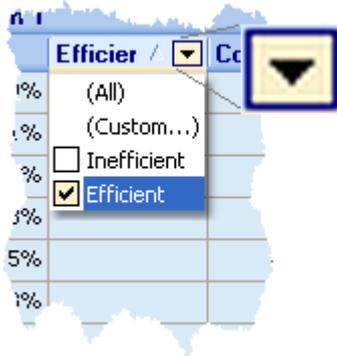


Optional activity: (experimenting with sort options)

1. Click on the Score column title. The order of the data changes.

2. Right click on the title, and select Clear sorting. The results are now in the same order in which the units were entered into the project.
3. Experiment with the other options by simply clicking on the title of the "sort" you want to view.

Another facility is to see just a sub-section of the results. If you are only interested in the units considered 100% efficient, you can click on the drop-down indicator that will appear as you move over the column title. To show only the efficient items, we can select the "Efficient" checkbox in the list shown when you click on the drop-down button of the Efficient column. If you want to see only the inefficient units click only the Inefficient box. To see all, click the (all) item.



This principle applies to all of the columns. You can filter on more than one column at a time, so you could set up complex filters if required.



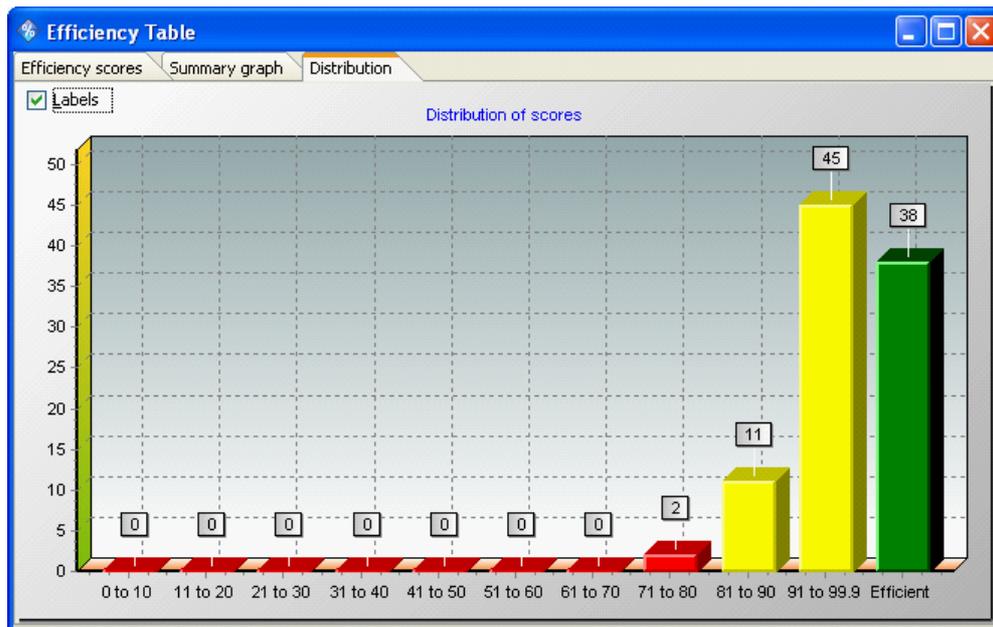
Optional activity: (experimenting with results display options)

1. Click on the drop-down filter button on the Efficient column.
2. Click on the Efficient box and then the Inefficient box to display different combinations of results.

Distribution Graph

At the top of the Efficiency Table window, there are a number of tabs. The Distribution tab displays information about the range of efficiency scores and details the number of units with scores in each range.

The Labels check box at the top left hand corner of the bar chart allows you to attach labels to the individual bars which show at a quick glance how many units are in each range. As you can see from the summary here, there are 11 units in the 81-90 range, 45 in the 91-99.9 range and 38 units in the Efficient range. i.e. they are 100% efficient.



Note: Technically, the 99.9 is not accurate, as the value could be a little greater in some cases, but it shows the general idea that the score was not 100.



Action: (displaying summary of scores)

1. Click on the Distribution tab in the Efficiency Table window. This will display a bar chart of the frequency of efficient units within each range. Check the Labels check box (in the top left of the window) to display the number of units in each score range.

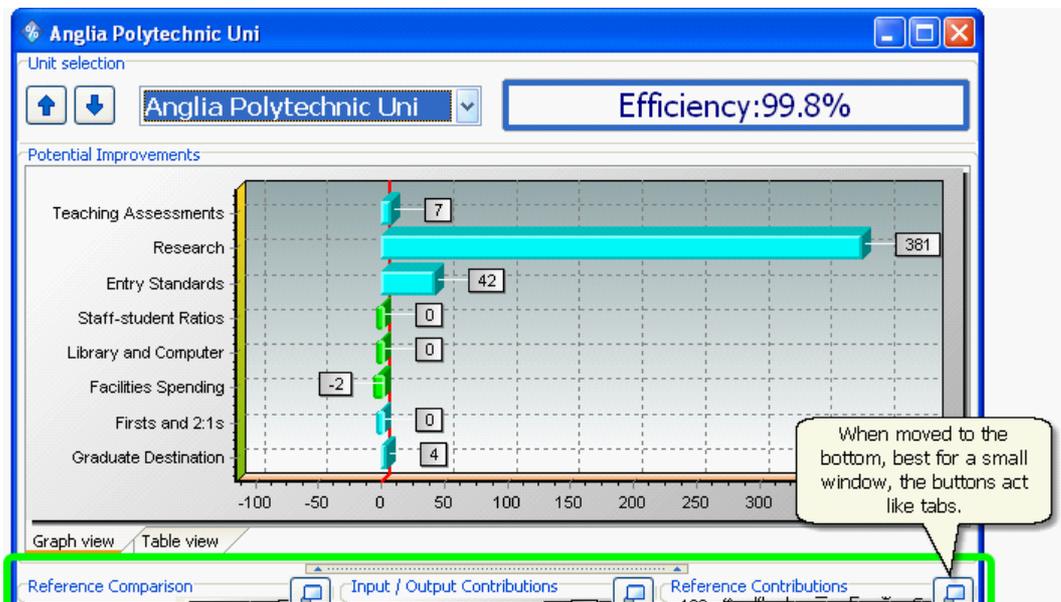
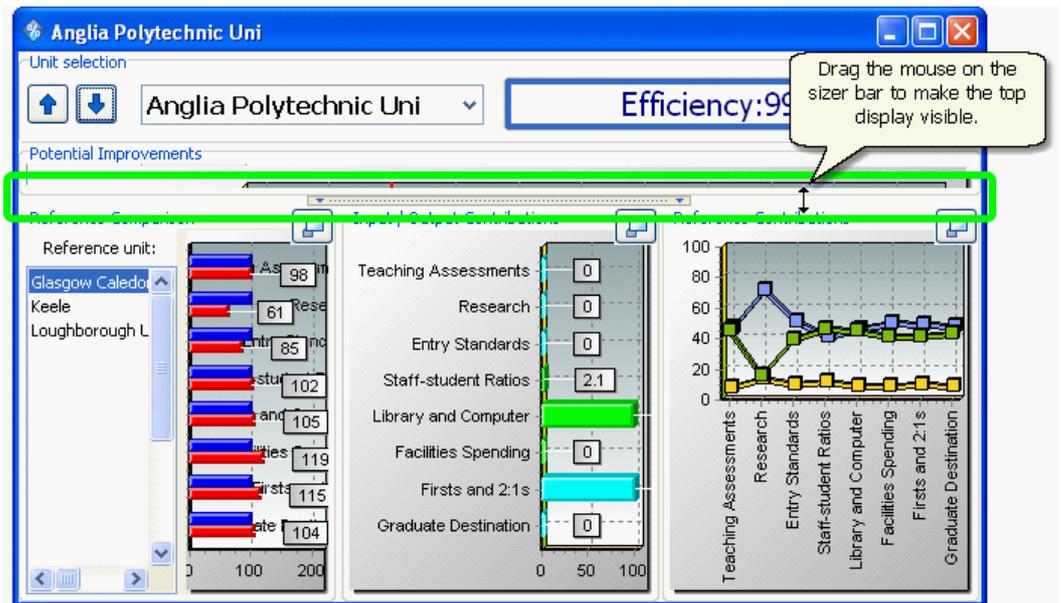
4.2 Details window

The Unit details window provides information about potential improvements, reference comparison, reference contributions, and input/output contributions on an individual unit.



Action: (opening unit display window)

1. In the Scores window, right click on a unit line and select the "View unit details" item to open the unit display window. Alternatively, use the Unit details button in the Results tab of the ribbon bar.
2. If the top section of the display, "Potential Improvements" is not visible, click and drag on the sizer-bar to make it visible. To maximize the top area, click on the button in the middle of the sizer bar.



3. Check the potential improvements display is at the top. If it is not, then click on the button next to it at the bottom to bring it to the top. 
4. Using the drop-down list at the top of the window, select Newcastle-Upon-Tyne. To do this, left click once on the button at the right of the name. Scroll the list until Newcastle-Upon-Tyne is visible and left click to select it. (You can type the first few letters to find a unit quickly.)

This will display the potential improvements for that unit.

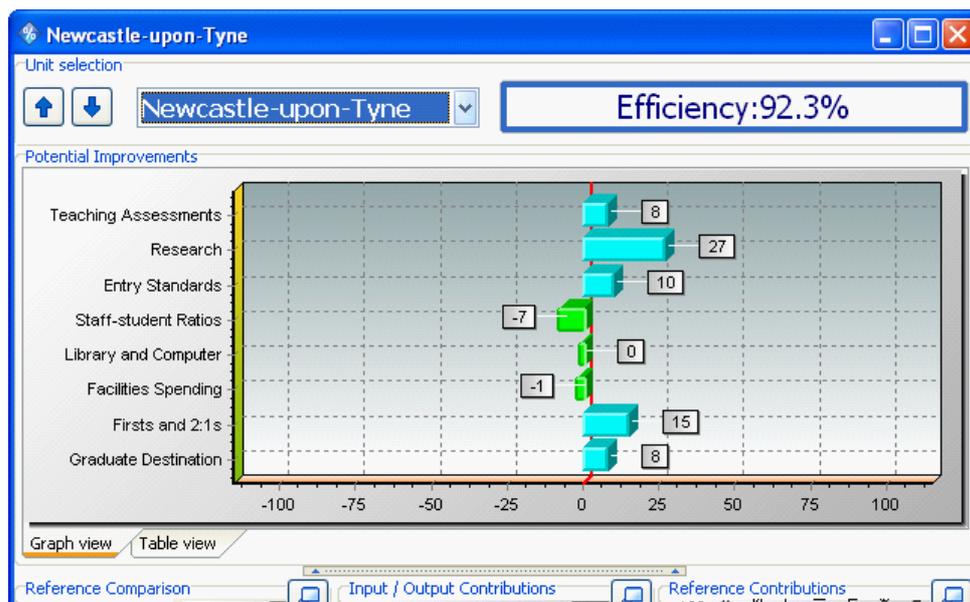
4.3 Potential improvement

The first section in the details window shows the potential improvements graph. This is the primary information display for a unit. The other graphs show the reasoning for these results. Click on the selector button  for Potential Improvements if it is not at the top of the window.

The percentage change in each input variable (output) that the unit would have to make in order to become efficient is shown in this graph. Input/output variables are along the Y axis, and the potential percentage improvement along the bottom, X axis.

If you want to view the potential improvements in tabular form, click on the Show as Table button. The Actual column displays the value that the unit is currently achieving. The Target column displays the value for the input/output that should be achievable. The percentage difference between these values is displayed in the Potential Improvement column.

In the Stage 3 example, select the unit "Newcastle-upon-tyne". You can see that the graph shows that there is room for improvement in each of the output variables (Graduate destinations by 8%, Firsts and 2:1s by 15% and so on). You will also notice that reductions can be made in two input variables, (Facilities Spending and Staff-student ratios by 1% and 7% respectively) even though we chose to optimise outputs. This is shown because to achieve the score given, the unit did not actually require all of its inputs, and this may be interesting information. The analysis is based on known performances of peers, so we can't assume that the unit could do better still, but this information may help gain a fuller understanding.



Similar summaries can be obtained for other units by selecting the unit name from the drop-down list or using the up and down buttons to scroll through the full list of units.



Optional activity: (looking at potential improvements for different units)

1. Select a different unit from the drop-down list of units.

2. Try to interpret the subsequent improvements shown by the graph.

Note: There will be no potential improvements for units found to be 100% efficient! Select those units that were found to be inefficient, to view different potential improvement graphs. If you want to see more than one view at a time, you can open more than one window for the unit using the Window menu Duplicate unit item.

4.4 Reference comparison

The reference comparison display provides information about the unit performance in comparison with its "reference units" or peers. Reference units are the 100% efficient units, against which each inefficient unit is compared. An inefficient unit will have one or more peers in its reference set.



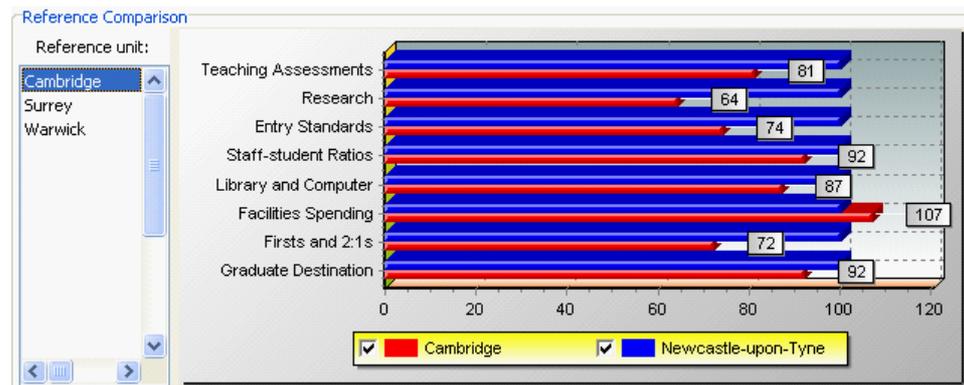
Action: (viewing reference comparison details for a unit)

1. Click on the selector button  for Reference Comparison if it is not at the top of the window.
2. If you have been viewing the details for other units, use the drop-down list of unit names and select Newcastle-Upon-Tyne from the list of Units.

The list to the left of the window (under the heading Reference Unit), lists the reference units, here shown to be Cambridge, Warwick and Surrey. Clicking on either of these units will display the comparison between the reference unit and the unit being analysed (Newcastle-Upon-Tyne).

3. Click on Cambridge in the Reference set. This will display the graph showing comparison between Cambridge and Newcastle-Upon-Tyne.

The values of Newcastle-Upon-Tyne are scaled to 100% in the graph, with the comparison values also scaled to make the relationship more obvious. In the example project, the variable values for Cambridge (shown by red bars) are 93 for Facilities Spending, 114 for Library and Computer, and 107 for Staff-student ratios (and so on).



4. Click on Surrey in the Reference set. This displays the graph showing a comparison of Surrey and Newcastle-Upon-Tyne. Compare with the Cambridge results.

The interpretation of these graphs is very much dependent on the data you have displayed. If one of

the target inputs/output is very different while the other target inputs/outputs are similar to the actual, then you should investigate why the unit is apparently so different from the reference. If all the inputs/outputs are very different from their targets then this may typify a bigger problem within the input/output conversion process. Check the reference contributions for that efficient peer. Full interpretation of the results requires an understanding of the relationship between inputs and outputs. This is where your skill as a manager comes in.

4.5 Reference contributions

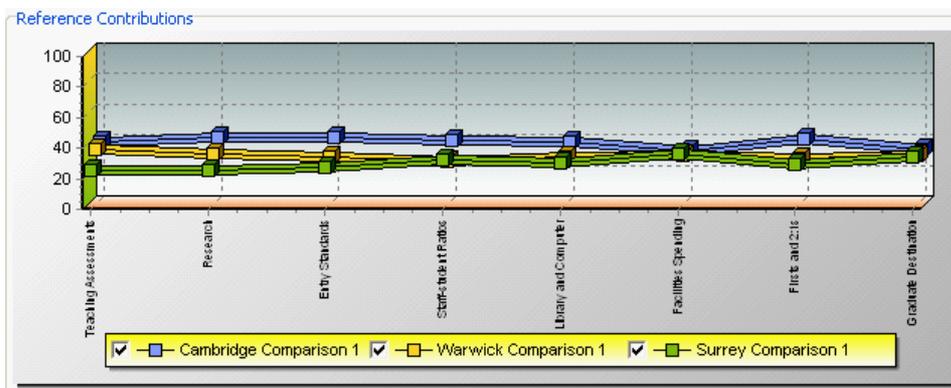
The Reference Contribution window displays the extent to which each reference unit has contributed in determining the efficiency of an inefficient unit.



Action: (viewing reference contribution details for a unit)

1. Click on the selector button  for Reference Contribution if it is not at the top of the window.
2. Choose Newcastle-Upon-Tyne as the reference unit.

Reference units are those units which are considered to be 100% efficient and against which an inefficient unit has been directly compared. The contribution of each reference unit, to the targets of an inefficient unit's input or output is displayed as a percentage. The reference contribution provides information on which members of a unit's reference set have had the most influence to setting its targets for potential improvements. This allows you to identify the key units to compare its performance against. The contribution for each variable is shown in percentage terms, with inputs and outputs each totally 100% (display rounding may cause slight imprecision in the displayed totals).



4.6 Input/output contributions

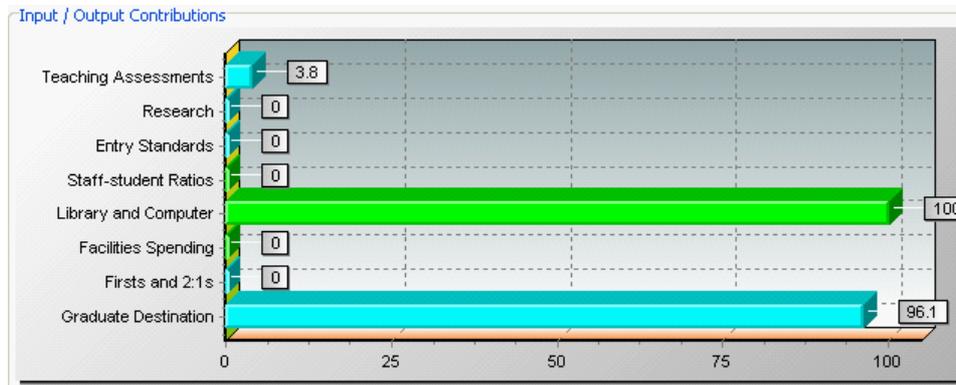
The input/output contribution panel displays information about the emphasis that the analysis has used for each input/output variable. This is a useful indication of which inputs and outputs have been used in determining efficiency, and which have been ignored. In some cases, this may help to validate the score.



Action: (viewing input/output contribution details for a unit)

1. Click on the selector button  for Input/Output Contributions if it is not at the top of the window.
2. Select Newcastle-Upon-Tyne as the unit.

Note: The values are "normalised" to show a percentage of the overall input and output contributions. Slight rounding errors may cause them to appear to not add up exactly to 100.



As you can see from the graph, the only input used in determining the efficiency score for Newcastle-Upon-Tyne is Library and Computer and the main output used is Graduate Destinations with a little of Teaching Assessments. The remaining inputs and outputs have not been used in the final result. They were considered in the analysis, but were not part of showing the unit in its best possible light. The advantage of this display is that it allows you to see which inputs and outputs were used in the analysis score (and which were not) and the importance attached to them. If this display shows that inputs and outputs that are politically important were not considered an inherent part of the process then the use of the Weighting facility may be considered. This is described in the [Other Options section of this workbook](#) ^[36].

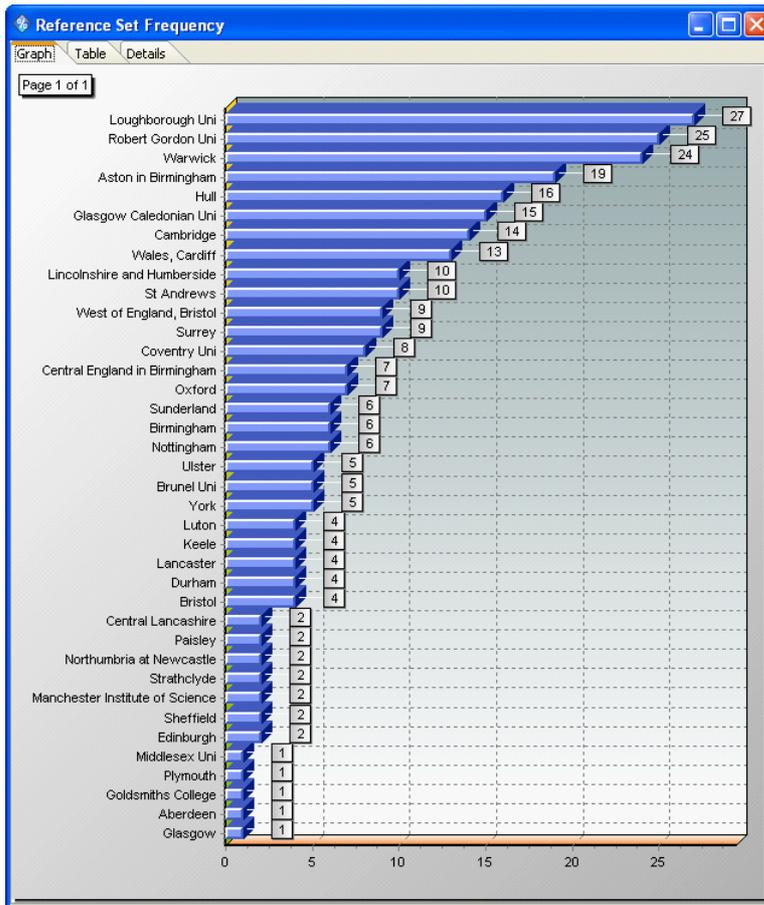
4.7 Reference Frequencies

Moving away from the unit details window, the reference set frequency window displays how many times an efficient unit appears in an inefficient unit's reference set. The higher the frequency, the more likely the efficient unit is an example of good performance.



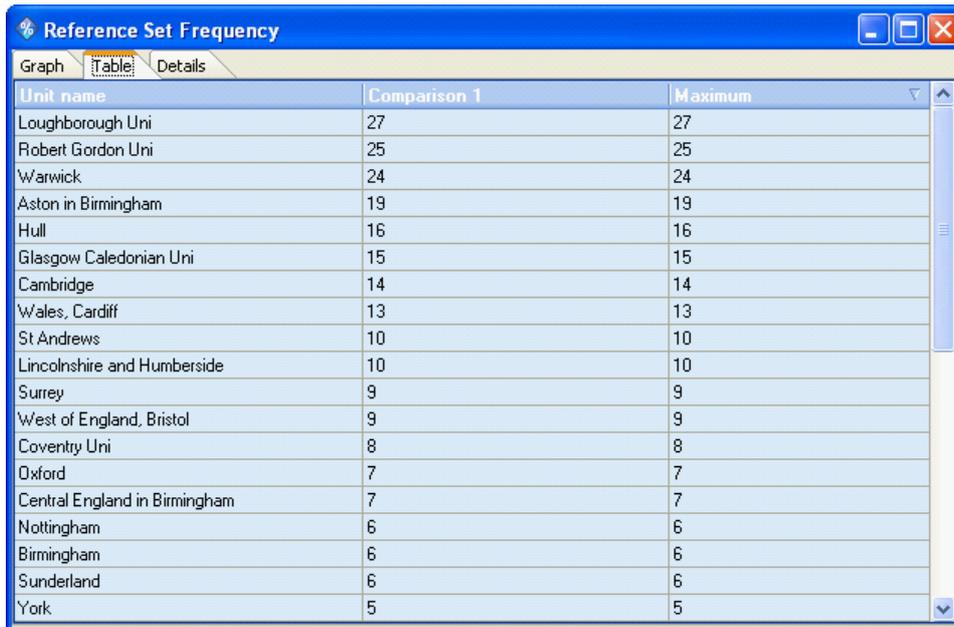
Action: (viewing reference set frequency details for a unit)

1. Locate the Reference Frequencies button situated in the Analysis section of the main form option bar. Click on this button once to view reference set frequency details.



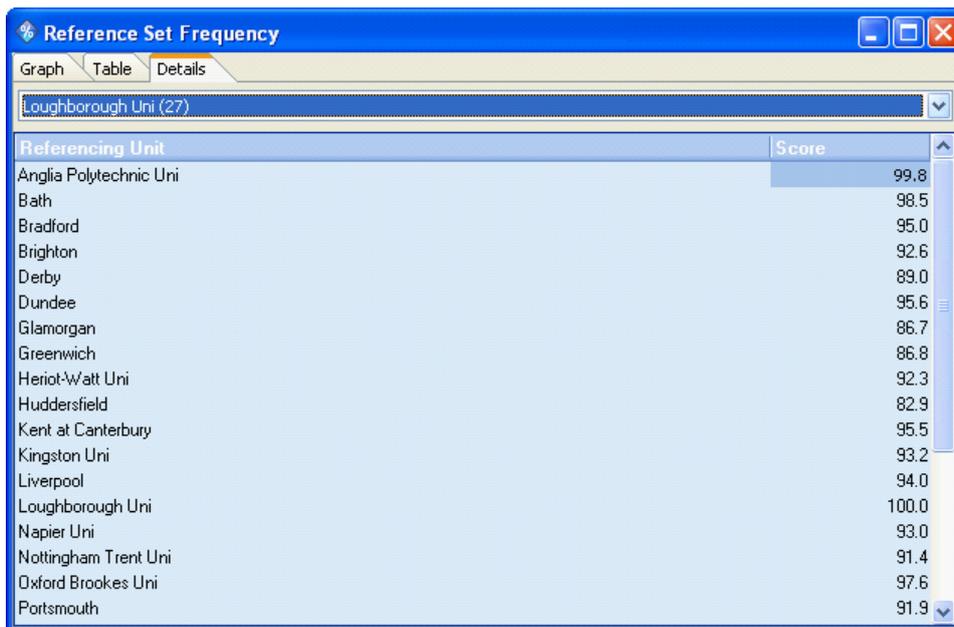
The graph displayed shows that Loughborough is the most frequently occurring reference unit (appearing in the reference sets of thirty other units). Robert Gordon and Warwick follow with 24 and 23 references. At the bottom of the graph are universities that appear only once or not at all as a reference unit and so may not be a good exemplar of performance. Efficient units which appear in only one reference set, as Edinburgh does, may have an unusual combination of inputs and outputs and as such may not offer an example of best operating practices for inefficient units to emulate. However, they may be doing something new, innovative and different and worthy of investigation. The efficient unit which appears in the most reference sets, in this case Loughborough, could be called the "Global Leader", which performs consistently well in comparison with other units.

The data is also available as a table for when there is too much data to show clearly in the graph. Click on the Table tab to see the data as text.



| Unit name | Comparison 1 | Maximum |
|-------------------------------|--------------|---------|
| Loughborough Uni | 27 | 27 |
| Robert Gordon Uni | 25 | 25 |
| Warwick | 24 | 24 |
| Aston in Birmingham | 19 | 19 |
| Hull | 16 | 16 |
| Glasgow Caledonian Uni | 15 | 15 |
| Cambridge | 14 | 14 |
| Wales, Cardiff | 13 | 13 |
| St Andrews | 10 | 10 |
| Lincolnshire and Humberside | 10 | 10 |
| Surrey | 9 | 9 |
| West of England, Bristol | 9 | 9 |
| Coventry Uni | 8 | 8 |
| Oxford | 7 | 7 |
| Central England in Birmingham | 7 | 7 |
| Nottingham | 6 | 6 |
| Birmingham | 6 | 6 |
| Sunderland | 6 | 6 |
| York | 5 | 5 |

In addition to the basic numbers, you can also use the Details tab to view the actual units that are using the particular peer.



| Referencing Unit | Score |
|------------------------|-------|
| Anglia Polytechnic Uni | 99.8 |
| Bath | 98.5 |
| Bradford | 95.0 |
| Brighton | 92.6 |
| Derby | 89.0 |
| Dundee | 95.6 |
| Glamorgan | 86.7 |
| Greenwich | 86.8 |
| Heriot-Watt Uni | 92.3 |
| Huddersfield | 82.9 |
| Kent at Canterbury | 95.5 |
| Kingston Uni | 93.2 |
| Liverpool | 94.0 |
| Loughborough Uni | 100.0 |
| Napier Uni | 93.0 |
| Nottingham Trent Uni | 91.4 |
| Oxford Brookes Uni | 97.6 |
| Portsmouth | 91.9 |

4.8 X-Y plot

The X-Y Plot window available in Frontier Analyst helps you to establish which variables should be included in the analysis. If one or more variables has a strong positive correlation with another variable then it may be possible to exclude one of the variables from the analysis (a strong positive correlation indicates that they may represent the same phenomena). The exclusion of such a variable would have the benefit of reducing the number of variables used ensuring better discrimination between the units being analysed. There is a 'rule of thumb' within DEA that the

(number of outputs * number of inputs) = number of potentially efficient units. Therefore reducing the dimensionality of the problem will result in less units being efficient and thus more knowledge gained.

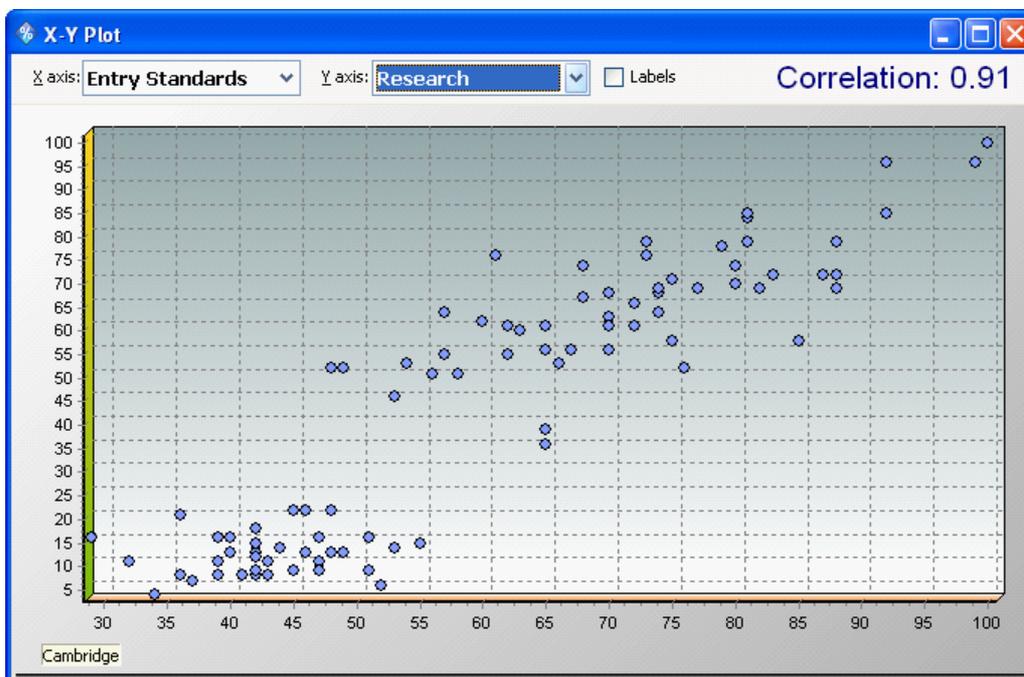


Action: (viewing X-Y Plot)

1. Click on the X-Y button on the option bar (in the Analysis section) on the left hand side of the main Frontier Analyst window.

At the top of the graph there are two drop down lists that show which variables are represented on the X and Y axes.

2. For the X-axis select Entry Standards from the list (by clicking on the button to access the drop-down list).
3. For the Y-axis select Research.



The correlation between these two variables is shown in the top right hand corner of the X-Y plot window. What you are looking for is variables with a high correlation. If two variables are highly correlated, they may both represent the same basic data. If you can eliminate a variable, it will increase the discrimination in the analysis.

For the sample project, the two variables Library and Research are fairly highly correlated and as a result, one of these variables could (potentially) be removed from the analysis. This could be achieved by making one of the variables temporarily inactive and then re-running the analysis to assess the impact this action has on the efficiency score. The skill lies in deciding what is an 'acceptable' level of correlation and you must use your judgement to decide what constitutes a high correlation, for your dataset, generally through experimentation.



Action: (viewing X-Y Plot)

1. Select Library and Computer for the X-axis and Graduate Destinations for the Y-axis

This time the correlation is 0.36. The closer the correlation is to zero the more likely it is that an increase in the value of one variable does not affect the other variable in a particular direction (either up or down). Negative correlation can also occur between two variables and this indicates that high values of one factor are associated with low values of the other factor.

The check box to the right of the Y-axis variable name shown allows you to label the points shown on the X-Y plot to determine the positioning of the units. Simply check this box to enable this facility. However, with labels turned on you may find that the display becomes crowded with the names of the units, making it difficult to see the actual positioning of the units.

If there is a cluster of units that you want to zoom in on, click with the left mouse button and keeping it pressed drag with the left mouse button down and to the right, encompassing the points you want zoom in on. As you start to drag an outline box appears. Drag the outline around the points you want to look at and then release the mouse button. The graph will zoom to display the selected region.

You can scroll the graph area by clicking and holding down the left mouse button and "sliding" the graph to the desired position. You can zoom in to resolve detail by clicking the Zoom in button on the ribbon menu.

To restore the graph to full display, click on the Zoom out button on the ribbon menu.

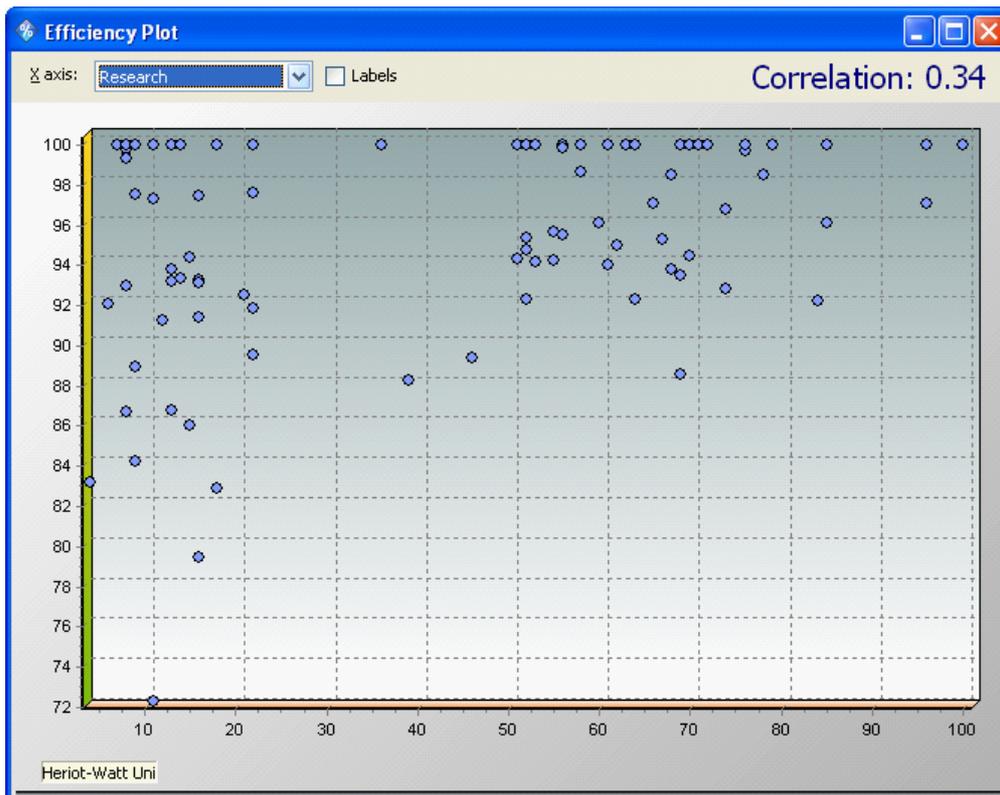
4.9 Efficiency plot (X-Efficiency) window

The efficiency plot window shows the spread of unit efficiencies plotted against the input and output variables. This plot can be useful in identifying if units with particular characteristics are either inefficient or efficient. This is done by plotting a chosen variable to assess the correlation it has with the efficiency score.



Action: (viewing efficiency plot window)

1. Click on the Efficiency plot button on the option bar on the left hand side of the main window.
2. For the variable to be represented on the X-axis, choose Research.



The correlation between efficiency score and research is 0.34, indicating that there is only a weak relationship between the amount of research conducted and the units efficiency score.

Again, the check box next to the variable name allows you to activate labels for the plot. (See X-Y Plot for details.)

A high correlation between a variable and efficiency indicates that the variable is a key driver of efficiency, and is important.



Optional activity: (experimenting with different variables)

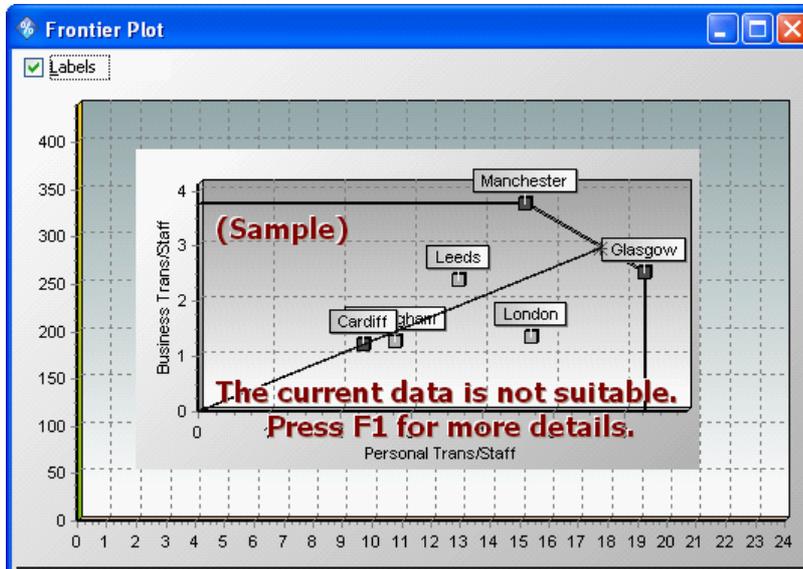
1. Choose different variables from the list of variables provided and assess the strength of the relationship between the variable and the efficiency score. You should find that the variable Graduate Destinations has the highest correlation with 0.43.

4.10 Efficiency frontier

The frontier plot allows you to see a 2-dimensional representation of the efficiency frontier. This can help you visualise the relationship between units. This is particularly useful when learning or explaining the concepts of DEA. For some people though, it is all that they use, so experiment and see how it fits into your method of working.

Important: A frontier plot is only available when you have either two inputs and one output active for output maximisation, or one input and two outputs active for input minimisation. This is because of the fact that once you add more inputs or outputs the problem becomes 'multi-dimensional' and can no longer be shown as a graph. The scaling mode for these plots must be constant returns to scale.

If you click on the Frontier button on the left hand toolbar, at present you will find that the frontier is not displayed but there is a message saying 'The current data is not suitable'. This is because there are too many inputs and outputs active in your data to produce a frontier plot. The following exercise takes you through the modifications you have to make to your dataset in order produce the frontier plot.



Action: (creating a frontier plot using two inputs and one output)

1. Click on the Data button to return to the data viewer in the Workbook Stage 3 project.
2. Make the following output variables inactive: "Teaching Assessments", "Research", "Entry Standards", "Graduate Destinations" (and leaving "Firsts and 2:1's" still active). To mark a variable inactive, use the buttons on the Source data tab of the ribbon menu. (Alternatively, use the DEA Options dialog in advanced mode, and use the Variable Configuration tab.)
3. Make the following input variable inactive: "Staff-student Ratios" (leaving "Library and Computer" and "Facilities Spending" still active).
4. Click on the DEA options button and choose Max Out as the optimisation mode and Constant as the scaling mode. Close the DEA Options window.
5. Run the analysis by clicking on the Analyse button (Analysis tab and the Quick Access Toolbar at the top).
6. Open the Scores window (using the Scores button, on the Options bar at the left hand side of the main Frontier Analyst window) and from it the Summary window. You should find that there are now 37 units in the range of 71-80% efficiency, 22 units between 81-90% efficient, 4 units which are 91-100% efficient and 2 units which are efficient. The two units which are efficient are St. Andrews and Cambridge (you can check this by looking at the Scores details).
7. Click on the Frontier plot button on the Results tab on the main ribbon toolbar to produce

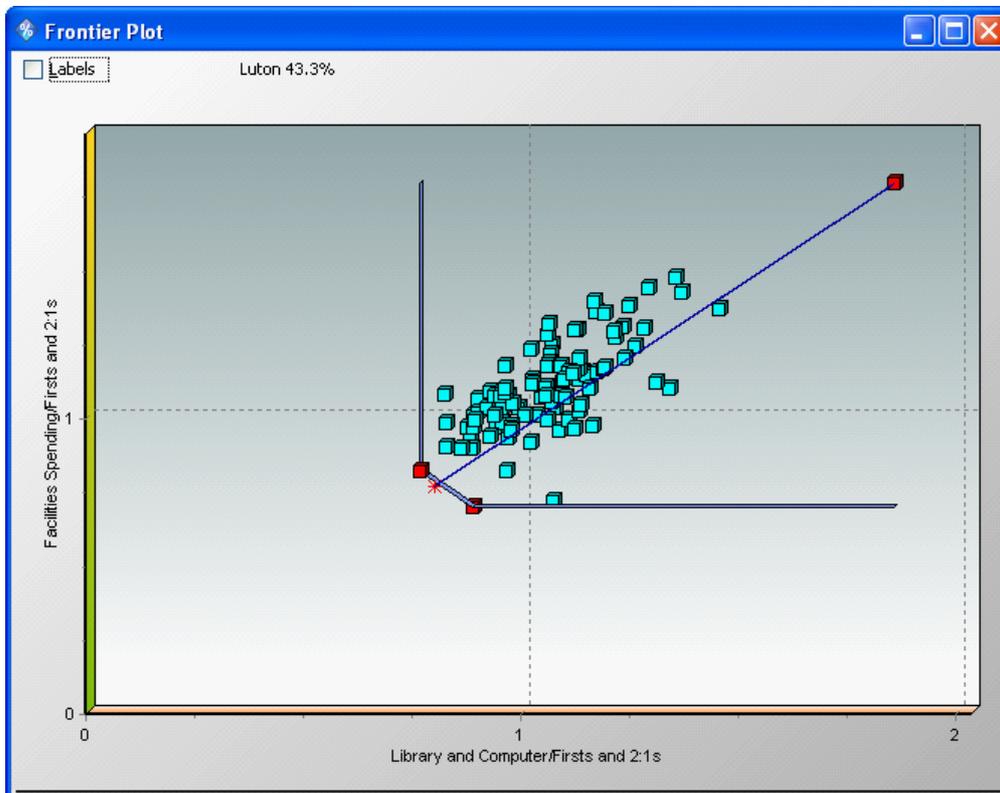
the frontier plot for your data.

The combination of constant returns to scale and output maximisation gives a concave frontier. The X and Y axes are ratios of the input/output variables that are active. Each unit is plotted with respect to these ratios and the 'frontier' is drawn to envelop the results. The bigger the output, the smaller the ratio input/output hence the efficient frontier is "below" the units plotted.

There are two units which form the frontier and shown on the plot (on your screen) as red squares. These two units are St. Andrews and Cambridge (enable the labels facility to view the names of the units). The inefficient units appear as light blue squares.

Targets for inefficient units are identified by drawing a straight line from the unit to the origin. This is the target for the inefficient unit.

Frontier Analyst will illustrate the projection from an inefficient unit to the frontier if you click on a point representing an inefficient unit. The unit display colour will change to red and a line will be drawn through the unit, onto the frontier. The point of intersection with the frontier is also marked in red. This point represents the target for the inefficient unit.



Take for example, the unit which is furthest away from the frontier, (Luton). Click on this unit to show its 'target unit'. This target unit, (call it 'L') is representative of an efficient unit (albeit an imaginary one), the characteristics of which demonstrate the improvement in output needed to move Luton onto the efficient frontier, at 'L'. Similarly, you can click on other inefficient units see where their targets fall on the frontier



Action: (creating a frontier plot using one input and two outputs)

1. Click on the Data button to return to your input data.
2. Re-activate the output variable Graduate Destinations.
3. Make the following input variable inactive: Library and Computer.
4. Click on the DEA options button and choose Min In as the optimisation mode and Constant as scaling mode. Close this window.
5. Run the analysis by clicking on the Analyse button.

You should now find that there are 11 units in the range of 61-70% efficiency, 35 units between 71-80% efficient, 39 units which are 81-90% efficient and 3 units which are efficient. This time the efficient units are Cambridge, Oxford and Hull.

6. Click on the Frontier button on the option bar on the left-hand side of the main Frontier Analyst window to show the frontier plot for your data.

This type of frontier is termed a convex cone or conical hull. The efficient units lie on the upper and outer surfaces of the frontier, while the inefficient units are "enveloped" by the cone. The mode used here was input minimisation, so for any given value of input the smaller the input, the greater the output/input ratio so that the targets for the inefficient units move away from the origin.

The advantage of this display is that it shows clearly the best practice units. It shows the performance gap between best practice units and under-performers, and highlights their performance targets. With the convex plot people seem to be able to conceptualise the concepts of DEA more easily. When explaining the principles of DEA this is the plot most often used. New users are sometimes "thrown" when they model results in a concave plot.

4.11 Summary window

The improvement summary graph provides a graphical summary of the possible improvements identified by the analysis. This option allows you to determine the potential improvement calculated by the DEA analysis for each variable and by unit count. The benefit is that the user has a quick visual summary of the results of the analysis and can see quickly, where changes should be made.

There are two options available:

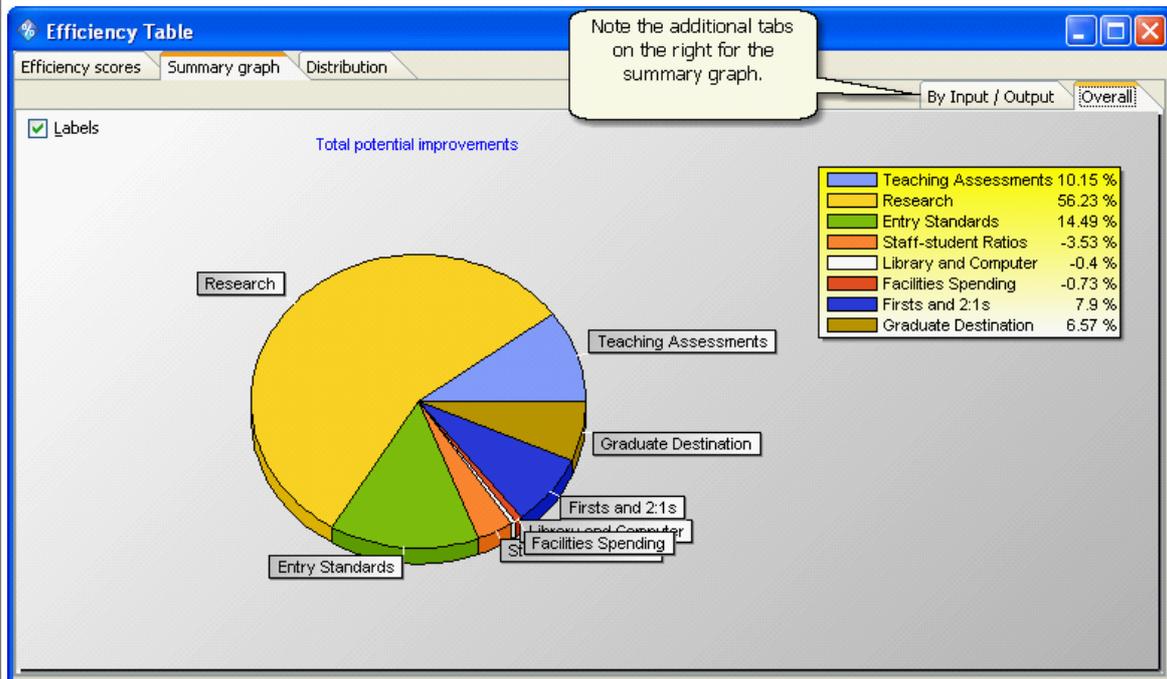
1. Overall summary display - showing a pie chart of relative percentages of potential improvement for each input/output variable. (This is derived by adding up the potential improvements for each unit - no weightings are applied). If a variable's "slice" of the pie is large then the potential improvement across units is large. Similarly if the potential improvement of one variable is found to be very small, then it may not be worth expending effort to improve that variable.
2. Potential improvement by input/output (shown as a distribution graph). For each input/output variable the graph shows the number of units that show a potential improvement in a certain range. This range goes up to 700% after which the graph shows 'over 700%'. A large number of units with a lot of potential improvement in a particular variable indicates that some effort should be made to improve that particular variable across all units.



Action: (looking at the overall improvement summary)

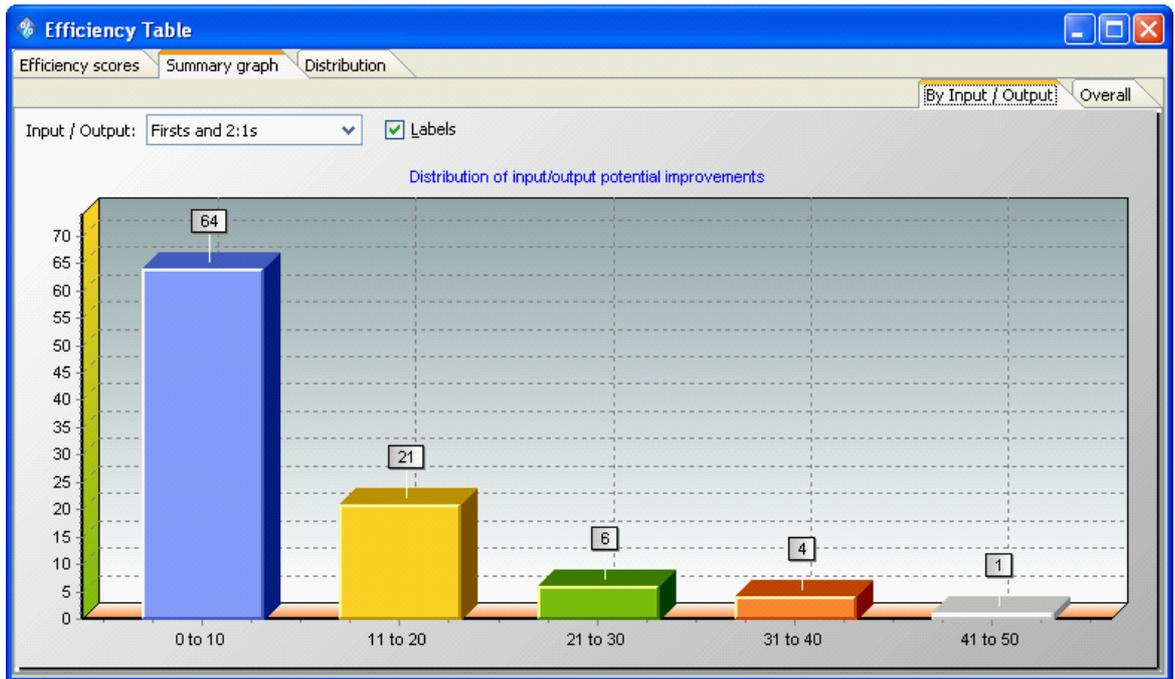
1. Reload the Workbook Stage 3 project to ensure that all the right variables are active after the Frontier Plot section. The easiest way is to select the Workbook Stage 3 item in the Recent documents section of the application menu. Alternatively, use the Open project option to select the file on disk.
2. Left-click once on the Improvement summary button in the option bar at the left-hand side of the main Frontier Analyst window. Click on the 'Overall' tab to view the pie chart.

You should find that the largest slice of potential improvements is for Research at 57.4%, and the next one is Entry standards at 14.55%. Graduate Destinations shows the lowest potential improvement. Those variables which have a large slice of the pie are the primary ones to target, and so the ways and means for increasing (or decreasing for inputs) these variables should be investigated.



3. Left-click on the By Input/Output tab to view the distribution graph.
4. Select First and 2:1's as the input/output variable.

You should find that 64 units lie in the 0-10% range, 21 lie in the 11-20% range, 6 lie in the 21-30% range, 4 lie in the 31-40% range and 1 unit lies in the 41-50% range (with all units, maximize outputs, varying returns to scale set). These results do not show a large number of units with large potential improvements in the variable but there is one unit which could be improved between 41-50%. This unit could improve its efficiency by attempting to change the value of this input and this should be investigated.



Optional: (viewing overall improvement for Graduate Destination and Facilities Spending)

1. Select Graduate Destination as the input/output variable.

You should find that the potential improvements highlighted are for all 17 variables and are in the range of 0-10% i.e. all 17 units could to be improved in this area but by only a small percentage.

2. Select Facilities Spending as the variable.

You should now find that 2 units show between 0-10% potential improvements, 10 between 11-20%, 4 between 21-30% and 1 between 31-40%.

This finishes the Introductory tutorial. You may want to review the following sections for future use.

5 OTHER OPTIONS IN FRONTIER ANALYST

This section outlines some additional features of Frontier Analyst. In particular, the weighting and filtering options.

5.1 Weighting

The purpose of weighting is to ensure that certain key variables are taken into consideration in the analysis. This is particularly useful when an input or output variable, considered to be an important part of the process being analysed, is almost completely ignored in the analysis (which you would see in the unit details Input / Output contributions display). The weighting option allows you to apply subjective judgements to the maximum and minimum weight which should be attached to particular input/output variables.

We advise that you use this option carefully and suggest that you carry out an unweighted analysis and review the results before manually adjusting the variable's weights. Using this option restricts the analysis and removes its objectivity. Certain schools of thought suggest that allowing users to influence the analysis adds bias. It undermines the theoretical basis of DEA which is to provide an objective, comparative peer based analysis. However, "real world" situations and politics have a different emphasis - if you are to implement an improvement process, you have to be able to justify the basis for it. If a unit is judged to be efficient, on the basis of a ratio that is meaningless to the business, it may be a problem. The weighting facility provided in Frontier Analyst allows you to ensure that every unit is judged at least to some extent on something that is critical to your business.

Our previous analysis of the Workbook Stage 3 exercise revealed that the only input used in determining the efficiency score for Newcastle-Upon-Tyne was Library and Computer, and the main output used was Graduate Destination. The remaining inputs and outputs were not used in the optimal solution. It may be though that you feel that one or more important variables cannot be ignored, probably for political reasons, so weighting can be used to overcome this.



Action: (applying weight restrictions to input/output variables)

1. Go back to the Data viewer window.
2. Make all inputs/outputs active.
3. Open the DEA options window and set the optimisation mode to "Max Out" and the scaling mode to "Varying".
4. Click on the "Advanced>>" button under the scaling options in the same dialog to show the tabs. Then click on the Weight control tab.
5. Enter the weighting values given in the table below.
6. Re-run the DEA analysis when prompted.

| | MIN WEIGHT | MAX WEIGHT |
|----------------------|------------|------------|
| Teaching Assessments | 0 | 100 |
| Research | 10 | 100 |
| Entry Standards | 0 | 90 |
| Staff-student ratios | 0 | 100 |
| Library and Computer | 0 | 100 |
| Facilities Spending | 10 | 100 |
| First and 2:1's | 0 | 100 |
| Graduate Destination | 10 | 100 |

Note: The total of the minimum weights must be less than 100 - you are specifying a minimum percentage weight that each variable can have. Specifying more than 100% would result in an infeasible solution. In general, you should use the smallest minimum weights that you can - minimising the effect of subjective judgements. If you get anywhere near 100%, ease off! You should be aiming to add a little weight only to key variables.

The total of the maximum weights entered must be at least 100, typically it is 100 for each variable.

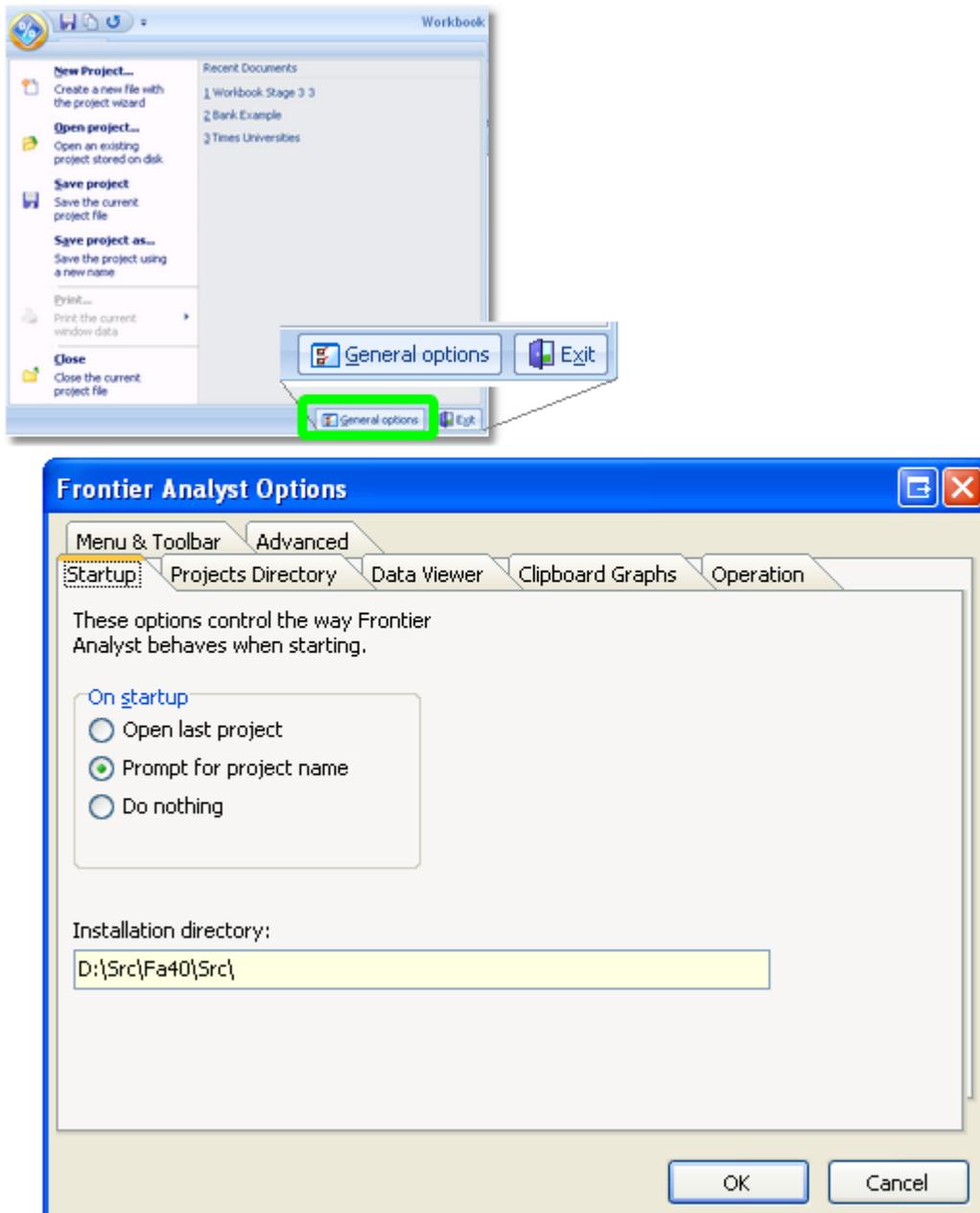
The only variables on which weight restrictions were not applied were the variables which were taken into account in the first analysis. Again, if you want to restrict the importance attached to these variables you would set minimum and maximum weight levels for these as well.

From the results, you should now find that 29 universities are 100% efficient, a drop of 10 from unweighted due to the increased restriction placed. If you check the Score Summary graph, this has changed in comparison to previously.

Having re-run the analysis, if you now look at the input/output contributions for Newcastle-Upon-Tyne using the unit details window you will find that the input/output variables with weights are now within the ranges specified. This illustrates how the weighting facility can ensure that important variables are taken into account.

5.2 Options dialog - Data viewer

The Options dialog allows you to control various aspects of the operation of Frontier Analyst and is found in the main Frontier Analyst application menu at the bottom.



If you click on the Data Viewer tab you will find options relating to column colours and automatic recalculation. The column colours allows you to control whether Frontier Analyst colours the columns according to their input/output type or whether it will use a standard white background in some of the displays. Similar control over copying of graphs to the clipboard are available on the Clipboard graphs tab.

The recalculation option allows you to control whether or not Frontier Analyst prompts you (when

you have changed the DEA options) that the analysis needs to be re-done or whether it will do the re-analysis automatically. If for example you change the optimisation or scaling mode, edit the input data, or apply user defined weights, then Frontier Analyst will prompt you to re-run the analysis (when set to 'Ask when required'). We suggest that with large datasets you use the "Ask when required" mode.

Decimal Places

Frontier Analyst allows you to control the number of decimals to which variables are displayed. To change the number of decimal places for any variable use the Variable Configuration tab in the advanced mode of the Analysis options dialog. Each variable can be displayed to a different number of decimal places as required.