

## Chapter 16

# DEA SOFTWARE TOOLS AND TECHNOLOGY

### *A State-of-the-Art Survey*

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**Abstract:** Today's DEA practitioners and researchers have a wide range of solution technology choices. Clearly, software is no longer an impediment to the incorporation of DEA into decision-support systems and benchmarking processes. This is evidenced by the availability of interoperable tools with a variety of user interfaces, advanced modeling options, and the power to evaluate large-scale data sets on inexpensive computing platforms. This survey describes and critiques prominent DEA software packages, both commercial and non-commercial, and summarizes the current state of the art.

**Key words:** Data envelopment analysis (DEA); Software; Optimization

## 1. INTRODUCTION

As the field of Data Envelopment Analysis has grown and blossomed, so have the varieties of models, data, and types of analyses. Similarly, as DEA software technology has emerged from its academic roots into production usage, it has been accompanied by expectations of advanced modeling options and professional implementations, including graphical user interfaces, interoperability with other applications, and the ability to quickly evaluate large populations.

This chapter surveys the best of the commercial and non-commercial DEA tools available today. Provided are descriptions of individual packages, comparisons of their features and capabilities, and links to further information on each.

While close to 20 software options were explored, eight packages emerged as viable alternatives for general DEA application.<sup>1</sup> Half of the eight are commercial packages and half are distributed at no charge (some with use restrictions). Most were developed for Windows platforms. Each excelled on one or more dimensions, and trailed in at least one other, i.e. were technically efficient without assurance region constraints.

The packages provided a wide range of available models, features and capabilities, user interfaces, reporting options, model solution speeds, and acquisition costs. The categories below describe the commercial and non-commercial packages individually, and evaluate each one in terms of model selection, DEA features, user interface, interoperability, reporting capabilities, documentation, test performance, and affordability.

A summary table of key elements invites the reader's own comparisons of the various software options for his or her own needs. Further information is available from an accompanying website, including links to software sources.

## **2. EVALUATION CRITERIA**

To compare the various software options, over 70 criteria were identified, and organized into eight categories, A-H. These criteria and categories are listed in Figures 16.1 and 16.2, along with values for each DEA package. The Categories below describe these evaluation criteria in more detail.

### **2.1 Available Models (Category A)**

The software packages vary widely in their selection of available DEA models. The classics—CCR/CRS and BCC/VRS—are universally included, but others vary by package. Evaluation Criteria Category A contains a non-exhaustive list of DEA models and indicates those that are included with each code. (See other chapters for model formulations and descriptions.)

<sup>1</sup> The others, listed in the Appendix (Section 6), were either no longer available, not designed specifically for DEA models, proprietary applications, suitable only for research, or required other specialized software to operate.

	COMMERCIAL				NON-COMMERCIAL			
	DEA Solver Pro	Frontier Analyst	OnFront	Warwick DEA	DEA Excel Solver	DEAP	EMS	Pioneer
	Version 4.0	3.1.5	2.02	1.0	1.0	2.1	1.3.0	2.0
From	SAITECH	Banxia Software	EMQC	Warwick Univ.	Zhu	Colletti	Scheel	Barr, McLeod
<b>A. Models</b>								
1 CCR/CRS	●	●	●	●	●	●	●	●
2 BCC/VRS	●	●	●	●	●	●	●	●
3 NIRS, NDRS, GRS	●	·	●	·	●	·	●	●
4 Additive/slack-based method	●	·	·	●	●	·	●	·
5 Malmquist	●	●	●	·	●	●	●	·
6 Non-convex	●	·	·	·	●	·	●	·
7 Non-radial	●	·	·	●	●	·	·	·
8 Preference-structure	·	·	·	·	●	·	·	·
9 Undesirable-measure	·	·	·	·	●	·	·	·
10 Context-dependent	·	·	·	·	●	·	·	·
11 Free-disposal hull (FDH)	●	·	·	·	●	·	●	●
12 Cost efficiency	●	·	●	·	●	●	·	·
13 Revenue efficiency	●	·	●	·	●	·	·	·
14 Profit, revenue/cost efficiency	●	·	·	·	●	·	·	·
15 Target, mixed improvement	●	·	·	●	·	·	·	·
16 Capacity utilization	·	·	●	·	·	·	·	·
17 Variable-benchmark	·	·	·	·	●	·	·	·
18 Fixed-benchmark	·	·	·	·	●	·	·	·
19 Minimum-efficiency	·	·	·	·	●	·	·	·
20 Value chain	·	·	·	·	●	·	·	·
21 Weak disposability	·	·	●	·	●	·	·	·
22 New cost, revenue, profit	●	·	·	·	·	·	·	·
23 Congestion	●	·	●	·	●	·	·	·
24 Scale elasticity	●	·	·	·	·	·	·	·
<b>B. Features</b>								
1 Orientation (i/o) control	●	●	●	●	●	●	●	●
2 Window/multi-period analysis	●	●	●	·	·	·	●	·
3 Weight constraints	Conical, UB, LB	UB, LB	·	Conical CRS	·	·	Conical	Conical
4 Super-efficiency scores	●	·	·	●	●	·	●	●
5 Non-discretionary/fixed factors	●	●	●	●	●	·	●	·
6 Categorical variables	●	·	·	·	·	·	·	·
7 Variable priorities	·	·	·	●	·	·	·	·
8 Sensitivity analysis	·	·	·	·	●	·	·	·
9 Multi-phase/multi-step	·	·	·	●	·	·	·	·
10 Nested frontiers (tiers, layers)	·	·	·	·	●	·	·	●
11 Disposability controls	·	·	●	·	●	·	·	·
12 Scenario comparison	·	·	●	·	·	·	·	·
13 Efficiency components analysis	·	·	●	·	·	●	·	·
14 Zero substitution	·	●	·	·	·	·	·	·
15 Benchmarking comparisons	●	·	●	·	●	·	·	●

● Included/available      · Not included/not available      ○ Limited capability

Figure 16-1. Evaluation Criteria, Categories A and B

## 2.2 Key DEA Features and Capabilities (Category B)

There are variants of the models listed in Category A—such as input- or output-orientation—listed in Category B as DEA features.<sup>2</sup> All codes allow selection of input or output orientation (and possibly non-oriented). Some provide a window analysis or other multi-period evaluation capability (B2), super-efficiency scores<sup>3</sup> (B3), non-discretionary or categorical factors (B5, B6), priorities on variables (B7), sensitivity analysis (B8), and multi-phase or multi-step analysis (B9).

Criteria B3 indicates the types of user-specified constraints—if any—that can be imposed on the input and output factor weights. Such assurance-region or cone-ratio-envelopment restrictions can take the form of upper and lower bounds on individual factor weights (UB, LB) or the more general conical form (Conical):  $\sum_r a_r u_r + \sum_i b_i v_i \leq 0$ , where  $u_r$  and  $v_i$  are variables in an input-oriented DEA multiplier model, and  $a_r$  and  $b_i$  are arbitrary real numbers.

Tiered DEA<sup>4</sup> involves recursively uncovering a nested hierarchy of efficient frontiers, or layers (B10). Controls on disposability (e.g., weak, strong) may be included (B11), feature B12 allows accumulation of results from multiple scenarios, and B13 reports on each DMU's technical efficiency components. The zero substitution option (B14) permits users to specify a constant to replace any zero data values, and B15 lets users define baseline/reference DMUs for benchmarking analyses

## 2.3 Platform and Interoperability (Category C)

Evaluation criteria C1 indicates the operating system(s) supported: Microsoft Windows (☐), PC DOS (☐),<sup>5</sup> Unix (☐), and Microsoft Excel for Windows (☐). The acceptable forms of data input and results output (C2, C3) are indicated for each code as: a Microsoft Excel spreadsheet (SS), a text file (TXT), the clipboard (Clip), the current selection in an Excel worksheet (SS select), an SPSS-formatted file (SPSS), direct manual entry (manual), Adobe's Portable Document Format (PDF), and the HyperText Markup Language (HTML).

<sup>2</sup> Some authors refer to such features as separate DEA models.

<sup>3</sup> As documented in Andersen and Petersen (1993)

<sup>4</sup> Per Barr, Durchholz, and Seiford (1994)

<sup>5</sup> Note that DOS programs can be run in a Command Prompt window under MS Windows.

	COMMERCIAL				NON-COMMERCIAL			
	DEA Solver Pro	Frontier Analyst	OnFront	Warwick DEA	DEA Excel Solver	DEAP	EMS	Pioneer
Version	4.0	3.1.5	2.0	1.0	1.0	2.1	1.3.0	2.0
From	SAITECH	Banxia Software	EMQC	Warwick Univ.	Zhu	Colletti	Scheel	Barr, McLoud
<b>C. Platform and Interoperability</b>								
1 Platform(s)	☒	☒	☒	☒	☒	☒	☒	☒
2 Input file types: ☒=Excel, TXT=text file, Clip=clipboard, select=current SSy selection, SPSS=SPSS data file, manual=direct manual entry	SS, manual	TXT, Clip, SS, SS select, SPSS, manual	TXT, Clip, manual	TXT	SS, manual	TXT	TXT, SS	TXT
3 Output file types	SS	SS, Clip, TXT, PDF, HTML, ☒	TXT	TXT	SS	TXT	TXT, Clip	TXT
<b>D. User Interface</b>								
1 GUI	☒	●	●	●	☒	.	●	.
2 Spreadsheet format	☒	●	●	●	☒	.	.	.
3 Interactive data manip	☒	●	●	●	☒	.	.	.
4 Individual observation editing	☒	●	●	●	☒	.	.	.
5 DMU, i/o factor subset control	☒	●	●	●	☒	.	○	.
6 Data filters	.	●	.	.	.	.	.	.
7 Data and results sorting	☒	●	●	○	☒	.	.	.
<b>E. Reporting</b>								
1 # standard reports	12	5	9	5	3	8	2	3
2 Custom reports	☒	○	.	○	☒	.	.	.
3 # std. graphs and charts	4	12	.	.	.	.	.	.
4 Custom charts	☒	○	●	.	☒	.	.	.
5 Efficiency scores report	●	●	●	●	●	●	●	●
6 Projected/target factors report	●	●	.	●	●	●	.	●
7 Optimal factor weights report	●	●	●	●	●	●	●	●
8 Efficient reference sets report	●	●	●	●	●	●	●	●
9 Slacks report	●	●	.	●	●	.	.	●
10 RTS analysis	●	.	●	●	●	.	.	.
11 Cross-efficiencies	.	○	.	.	.	.	.	.
<b>F. Documentation and Support</b>								
1 Tutorial (pages)	.	26	.	.	.	.	.	.
2 Users guide (pages)	.	99	38	19	43	49	12	2
3 Reference manual (pages)	43	.	52	○	☒	.	.	.
4 Built-in help	.	●	●	.	.	.	.	.
5 Technical support	●	●	.	●	.	.	.	.
6 Web site tech info	.	●	.	.	●	.	.	.
<b>G. Testing</b>								
1 Time 431 dnu, CCRi (rmss)	0:17	0:05	0:06	0:53	2:30	<0:01	0:11	<0:01
2 Time 431 dnu, BCC, superE	0:16	.	.	18:45	4:40	.	0:12	<0:01
<b>H. Availability</b>								
1 Free demo available	☒	●	●	●	.	●	●	●
2 Conml license cost	\$1,600	£395 - £2395	\$1,750	£200 - £500	☒	\$0	.	.
3 Academic cost	\$800	£195 - £595	\$750	£800+ (site)	☒	\$0	\$0	\$0
4 Maintenance available	.	●	●	●	.	.	.	.

☒ Microsoft Windows      ☒ DOS      ● Included/available      ○ Optional  
 ☒ Uses Microsoft Excel as a GUI      ☒ Unix      . Not included/not available  
 ☒ Included with book purchase      ○ Limited capability

Figure 16-2. Evaluation Criteria, Categories C-H

## 2.4 User Interface (Category D)

User interfaces can range from elaborate graphical user interfaces (GUIs) to simple command-line controls. Two of these DEA packages use Microsoft Excel as a GUI for data entry, reporting, and graphics and its Solver tool as a linear program optimizer. The advantages of Excel-based products are: input and output are simplified, reports and graphs can be easily added by the developer and user, interoperability with other Microsoft products is straightforward, and connection to enterprise data sources via ODBC is possible. The disadvantages of the Excel environment are: the default Excel Solver limits application to small populations, larger instances require purchase of a replacement optimizer, and the interpreted execution speed is typically slower than compiled, stand-alone applications.

Category D criteria include: availability of a GUI (D1), ability to display data in spreadsheet or matrix format (D2) and ability to edit datasets and individual observations within the application (D3, D4). D5 indicates whether a DEA can be executed for user-selected subsets of the DMUs and the input/output factors and whether such subsets can be based on a user-defined rule or data filter (D6). D7 is flagged when a user can interactively sort the population data or the results of an analysis

## 2.5 Reporting (Category E)

The reporting criteria in Category E include the number of standard reports included (which may be tabs in a worksheet or separate tables within a longer report (E1), whether the user can create ad hoc customized reports (E2), and similar information about graphs and charts (E3, E4). Criteria E5-E11 indicate whether specific reports are available from the application.

## 2.6 Documentation and Support (Category F)

Category F reports on the length, in pages, of a hands-on software tutorial for new users (F1), a users guide to the operation of the software (F2), and a technical reference manual with modeling details (F3). Also indicated is the availability of a built-in help facility (F4), technical support by phone or email (F5) and technical support information on the provider's web site (F6).

## 2.7 Test Performance (Category G)

Each of the packages was installed and tested on a Dell Precision Workstation 340, 1.8 GHz Pentium 4, with 512MB RAM running under Windows 2000. The standard Excel solver was replaced with the Premium Solver Platform V5.0 from Frontline Systems.<sup>6</sup>

The Unix version of one code was also tested on a DEC Personal Workstation 600 AU with a 600 MHz Alpha processor and 576 MB RAM, running OSF1 (Unix) and using the `cxx` compiler.

To evaluate the software's operating speed, the following problems were solved and the run times reported in minutes and seconds in Category G:

1. 1991 Quarter 4, U.S. Bank data set, with six inputs, three outputs, and 431 DMUs; model: CCR-I (G1)<sup>7</sup> and
2. The same dataset processed with BCC-I and super-efficiency scores (G2).

This dataset is available from the web site listed at the end of this chapter. Since processing effort is affected by report generation, run times were collected with minimal reporting options selected.

## 2.8 Availability (Category H)

Category H reports on the availability of a demonstration version (H1), the cost range for a single-user commercial license as of this writing (H2), and similar cost information for academic users (H3). Also indicated is whether annual software maintenance contracts are available (H4).

## 3. COMMERCIAL DEA SOFTWARE

The commercial packages explored are: DEA-Solver-Pro 4.0 from SAITECH, Frontier Analyst 3.1.5 from Banxia Software, OnFront 2.02 from Economic Measurement and Quality Corporation, and Warwick DEA from Warwick University. The evaluation criteria values for each are given in the first four columns of Figures 16.1 and 16.2. The individual product sections below detail the system requirements, known developers, distributor, current (2003) single-user licensing costs, and points of contact (✉ mailing address, ☎ phone numbers, 🌐 web site URL, and ✉ email address.)

<sup>6</sup> Cost: \$1295, August 2003, details at: <http://solver.com>.

<sup>7</sup> See Barr et al (2001) for model details.

### 3.1 DEA-Solver-Pro

- *Software title:* DEA-Solver-Pro, Version 4.0
- *System requirements:* Microsoft Windows, Microsoft Excel 97 or newer
- *Available from:* SAITECH, Inc; demonstration version included with Cooper, Seiford, and Tone (2000)
- *Licensing:* \$1600 (190,000¥) plus shipping and taxes; \$800 (100,000¥) academic
- *Contact:*
  - ✉ SAITECH, Inc., 1 Bethany Road, Hazlet, NJ 07330
  - ☎ (732) 264-4700, fax (732) 264-1538
  - 🌐 [www.saitech-inc.com](http://www.saitech-inc.com)
  - ✉ [dea@saitech-inc.com](mailto:dea@saitech-inc.com)

DEA-Solver-Pro from SAITECH, is an application that runs within Microsoft Excel. Population data is input via a worksheet, arranged in a specific format, and results are generated in tab sheets of a separate workbook. The process is guided by an onscreen wizard (initiated when the application spreadsheet is loaded), which prompts for file names and processing options. Hence the operation is straightforward.

The input data for most models must be in a single Excel worksheet, with variable labels in the first row and individual DMU values in subsequent rows, each with a label in the first column. Input variables' labels must begin with "(I)" and output variables are indicated by a label beginning with "(O)." Variants of this format are used to specify assurance region constraints, multi-period values, and new-cost/revenue/profit data.

DEA-Solver-Pro provides an enormous compendium of models, including some not yet available in the literature. The documentation lists "118 models in 31 clusters" (e.g., models CCR-I and CCR-O make up the CCR cluster). The feature set is strong, including window analysis, conical weight constraints, non-discretionary variables, and three types of categorical variables.

A dozen different reports can be generated, along with four standard graphs and charts (efficiency score histogram, plus time-windows-statistics, and Malmquist-index plots). See Figure 16.3 for sample reports. The Excel environment permits the sorting of result tables and the creation of ad hoc, custom reports and graphs.

The indexed 43-page manual, SAITECH (2003), is an updated and expanded version of the appendix to Cooper, Seiford, and Tone (1999). It focuses on documenting the various mathematical models and output values, rather than program operation.



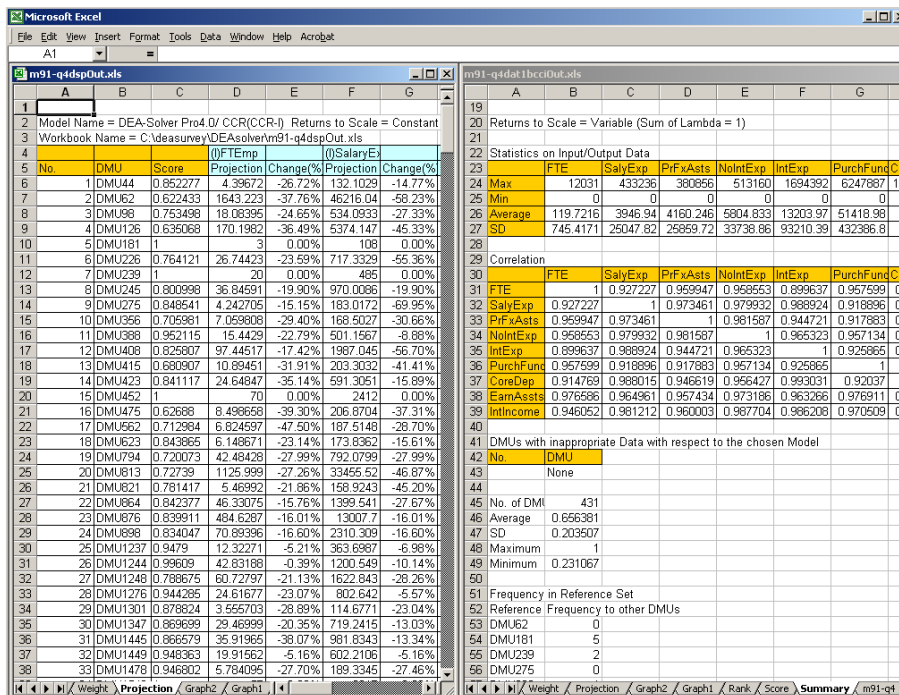


Figure 16-3. DEA-Solver Pro

As expected, DEA-Solver-Pro’s solution time for the 431-DMU model was slower than most of the compiled programs (17 seconds vs. one to five seconds), but certainly fast enough for all but the largest of instances. Note that the standard Excel solver is limited to small problems, and the Premium Solver Platform V5.0 from Frontline Systems was used in this testing.

The pricing is mid-to-upper range for the commercial packages, but the cost of an updated optimizer must be considered if larger instances are to be analyzed. A size-limited demonstration version accompanies Cooper, Seiford, and Tone (2000), so a test drive is readily available.

With its strong technical capabilities and full compliment of features, this software should appeal to DEA researchers, sophisticated program managers, and decision-support-system developers. Documentation geared to non-technical users would enhance its appeal to an even wider audience.

### 3.2 Frontier Analyst

- *Software title:* Frontier Analyst, Version 3.1.5
- *System requirements:* Microsoft Windows 95/98/2000/NT/XP
- *Available from:* Banxia Software Ltd.

- *Licensing:* £395-£2395 (£195-£595 academic) plus shipping and taxes; “Plus Packs” for publish-to-web and cross-efficiencies are an additional £95-£195 each; annual maintenance £229.
- *Contact:*
  - ✉ Banxia Software Ltd., P.O. Box 134, Kendal, LA9 4TP, UK
  - ☎ +44 (0) 870 787 2994, fax +44 870 787 2995
  - 🌐 [www.banxia.com](http://www.banxia.com)
  - ✉ [info@banxia.com](mailto:info@banxia.com)

Frontier Analyst from Banxia Software is a stand-alone Windows application, with the most professional user interface and documentation of those packages evaluated. Analyses are organized as projects, with population data accessible from a wide range of sources, including text, Excel, and SPSS files, the Windows clipboard, the current Excel selection, and direct entry. Once input, DMU data is displayed as a matrix where individual DMUs and factors can easily be included, excluded, deleted, added, or edited. Each factor is interactively categorized as output, input, or uncontrolled input (non-discretionary); population DMUs can be screened by filtering rules to form subsets for analysis. Bounds on individual factor weights can be specified.

The interface is intuitive, provides strong user control over the data and reports, and has exceptional drill-down analytical tools at the DMU level. For example, a given inefficient unit can have its factors charted against those of its efficient-reference-set counterparts, and a series of other charts and graphs displayed to help identify the sources of inefficiency and promising areas of improvement. Language localization enables customization of the terminology displayed in the user interface.

A large number of useful and attractive graphs and tables provide a wide variety of analytical viewpoints for the results and make analysis easy and even fun. Graphs of the efficiency-scores distribution, reference frequencies for the efficient units, efficiency and x-y plots for all factors, four DMU-level exploratory graphs, and a frontier plot for small instances quickly provide new insights into the population’s dynamics. All graphics can be transferred via the clipboard to other applications.

Frontier Analyst generates a set of standard reports: DMU efficiency scores, actual versus target factors by DMU (with and without charts), and complete details by unit; each report can be sorted four ways and can include efficient, inefficient, or all units (see Figure 16.4 for an example report). Extra-cost report options are: a custom report designer, publish-to-web HTML generator, and a cross-efficiency analysis feature, which recalculates each DMU’s efficiency score using other DMUs’ optimal weights, for additional peer and efficiency analysis.

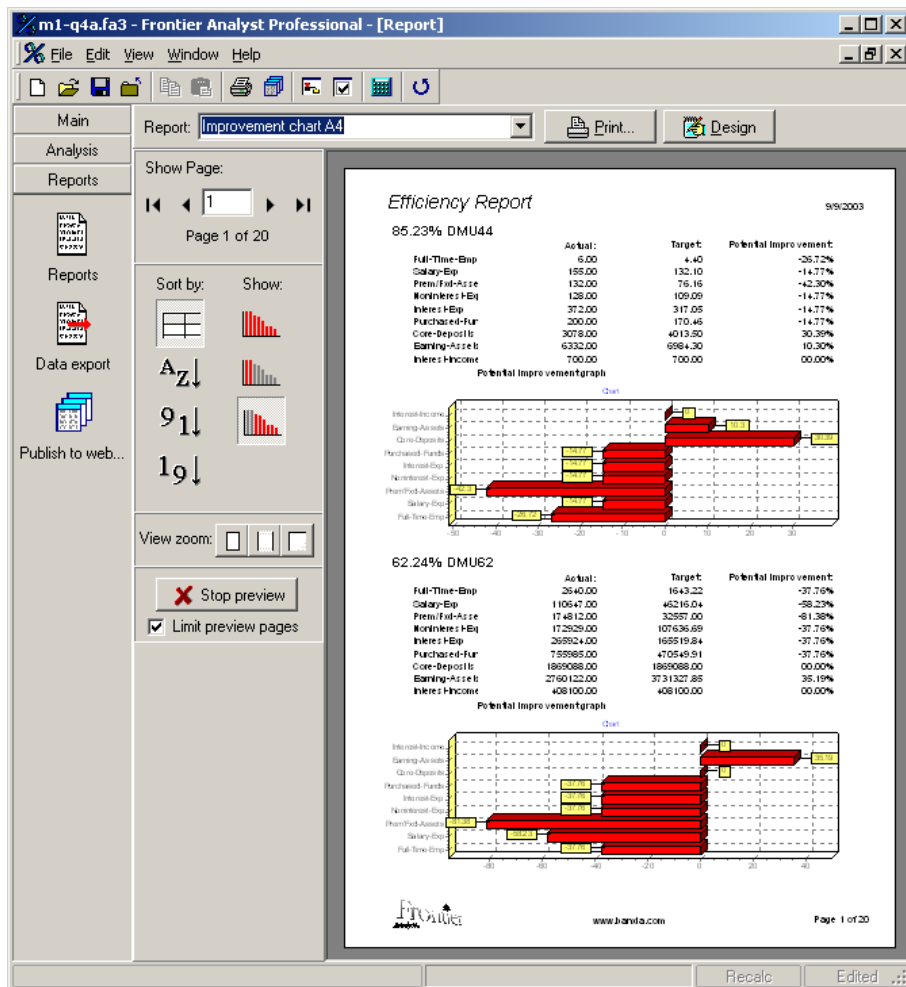


Figure 16-4. Frontier Analyst

The indexed users guide, Banxia (2003), is excellent: well-written and user-oriented, with clear explanations and examples of each program feature, accompanied by screen shots. A separate tutorial guide, Hussain and Jones (2001), is designed to help new users become productive quickly. The two optional modules are accompanied by their own documentation [Banxia (2001a, 2001b)].

The program's built-in optimizer is fast, requiring only five seconds to evaluate the 431-DMU test problem. Only the DOS applications were faster.

The only disappointing aspect of Frontier Analyst is its limited selection of DEA models and a few missing features. It has the classic CCR (CRS) and BCC (VRS) models, performs window analysis, computes Malmquist

indices, and supports non-discretionary variables and a limited form of weight constraints. These by themselves are sufficient to handle a majority of business and not-for-profit applications. The developers have created such an attractive analytical environment that it seems unfortunate that some of the newer techniques (see Categories A and B) are not included. From Pareto and marketing aspects, this may be the right product for them (new model types do not help sales as much as flashy analysis graphics). It just could be so much better with a modest effort on the modeling side.

The cost of Frontier Analyst varies with the maximum number of DMUs to be considered. The lowest price is for 75 DMUs, the highest posted price is for 2500 units. An unlimited version is available at an unspecified price. While it is one of the more expensive tools available, it has many features that the others do not.

With its exceptional user interface, wide-ranging interoperability options, handsome and insightful graphs and charts, and excellent documentation, this package should appeal to managers and other practitioners for putting classic DEA to work for program analysis, benchmarking, process improvement, etc. While the limited repertoire of models and lack of some important supporting features—such as categorical variables, super-efficiency scores, and conical weight constraints—limits its range of application and audience appeal, Banxia has created an impressive DEA application.<sup>8</sup>

### 3.3 OnFront

- *Software title:* OnFront, Version 2.02
- *System requirements:* Microsoft Windows 95/98/2000/NT, 16 MB memory, 8MB disk space
- *Developers:* Rolf Färe and Shawna Grosskopf
- *Available from:* Economic Measurement and Quality Corporation
- *Licensing:* \$1750 (\$750 academic), plus shipping and taxes
- *Contact:*
  - ✉ EMQ AB, Box 2134, SE-220 02 Lund, Sweden;
  - ☎ +46 40 369 565, fax +46(0)40 164 511
  - 🌐 [www.emq.com](http://www.emq.com)
  - ✉ [emq@emq.com](mailto:emq@emq.com)

OnFront 2.02, from the Economic Measurement and Quality Corporation (EMQC), is a fast and elegant Windows DEA package. Its operation is

<sup>8</sup> For another evaluation of Frontier Analyst, see Nyhan (1998), available at [www.informs.org](http://www.informs.org)

straightforward: load population data from a text file or the clipboard into a data table, click the table's rows and columns to select factors and DMUs for evaluation, choose the desired model and output options, request optimization, and view the resulting tables. All results can be saved in Excel-readable text files. All tables can be sorted, based on any column; any table's columns can be selected and graphed within the program. See Figure 16-5 for an example.

While nine different tables can be generated, the "reporting" capability consists of printing out these spreadsheets as is, with no special formatting. Users will likely prefer to transfer these values to another application with report-generation features.

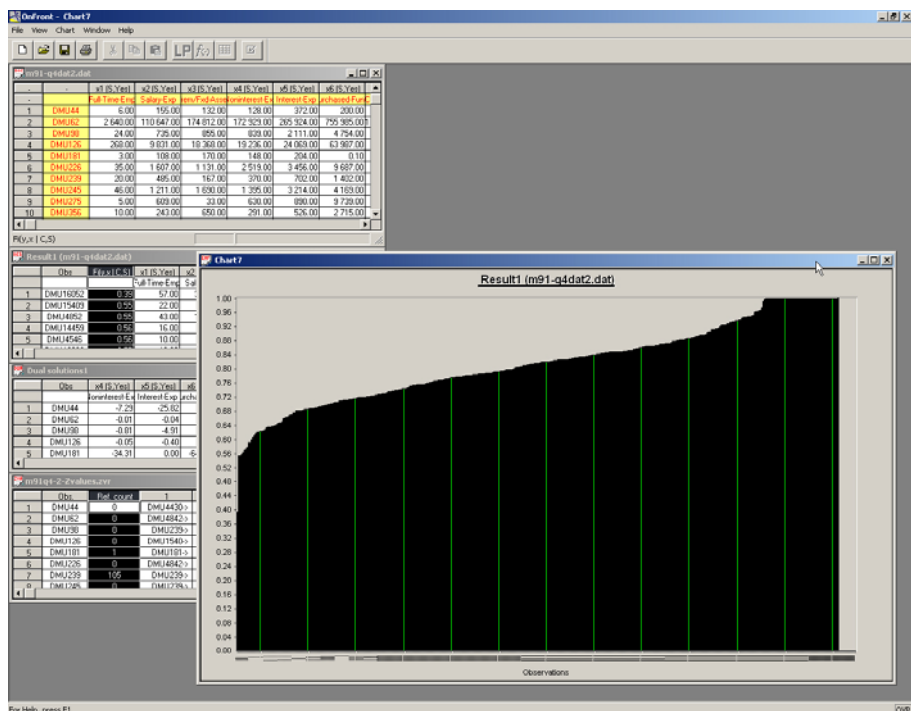


Figure 16-5. OnFront Example Windows

OnFront provides a good selection of models and features, including window analysis and congestion models, although it is missing any form of weight constraints for managerial applications. Users will need to learn the authors' terminology and abbreviations to choose the desired model. For example, for an input-oriented CCR analysis, one selects the  $F(y,x)$

efficiency and *CRS* technology-scale options. To designate an input variable as non-discretionary, uncheck the “Subvector Include” box.

Fortunately, the models and features are nicely documented in the accompanying reference guide, Färe and Grosskopf (2000). The attractively produced users guide, EMQC (2000), is clearly and succinctly written. The built-in help consists of having these two PDF documents accessible from the Help menu.

Solution times with the built-in optimizer were quick, taking only six seconds for our 431-DMU test-problem, as well as subsequent runs for different models and orientations. A nice feature is OnFront’s ability to accumulate different efficiency scores for the same population in the same table, allowing comparisons of alternative models, features, or DMU scenario values. The rapid solution times permit extensive use of such interactive features.

While other packages seem oriented to managerial application, OnFront’s emphasis appears to be economists, researchers, and DEA-savvy users. Its clean, minimalist user interface gets the job done quickly, once the terminology and notation are mastered. While some users may prefer a more full-featured interface, others will find OnFront’s elegant approach refreshing.

### 3.4 Warwick DEA

- *Software title:* Warwick DEA
- *System requirements:* Microsoft Windows, DOS
- *Developers:* Emmanuel Thanassoulis, Keith Halstead, Mike Stelliarios, Robert Dyson, A. Athanassopoulos, A. Emrouznejad
- *Available from:* University of Warwick; demonstration version included with Thanassoulis (2001)
- *Licensing:* £200-£500, site license £800-£1600 (£400-£800 academic) plus shipping and taxes
- *Contact:*
  - ✉ Emmanuel Thanassoulis, Aston Business School, University of Aston, Birmingham B4 7ET, UK
  - ☎ +44 (0) 121 359 3611 Ext 5033, fax +44 (0) 121 359 5271
  - 🌐 [www.deazone.com](http://www.deazone.com)
  - ✉ [dea.et@btinternet.com](mailto:dea.et@btinternet.com)

The Warwick DEA package, developed at the University of Warwick, has a straightforward graphical user interface consisting of two windows: a data table and output (“log file”) text display. Population data is read from text files (prepared in a specific format) and displayed in the table. Two

dialog windows enable selection of DMU subsets for analysis and designation of input and output variables; the latter can be avoided through variable naming conventions. Model types, orientations, variable priorities, and other options are selected via the menu bar and on the execution dialog box prior to performing the analysis.

The model selection is limited, but covers the most important cases. The feature set includes priorities for variables, super-efficiency scores, and conical weight constraints (for CCR models only).

The selected text reports are generated, displayed on-screen, and saved on disk. The reporting options include: (1) a list of DMUs, sorted by efficiency score; (2) a peer report giving—for each inefficient unit—the optimal  $\lambda$ -weights, inputs, and outputs for all efficient-reference-set members; (3) a report of each unit's optimal  $\mu$ ,  $\nu$  multipliers; and (4) each unit's projected inputs and outputs, with associated percentage deviations from current values. See examples in Figure 16-6. Report customization consists of DMU sorting options, partial reports based on efficiency ranges and DMU name, and peer-scaling choices. Results can be exported in text files formatted for spreadsheet or database importing.

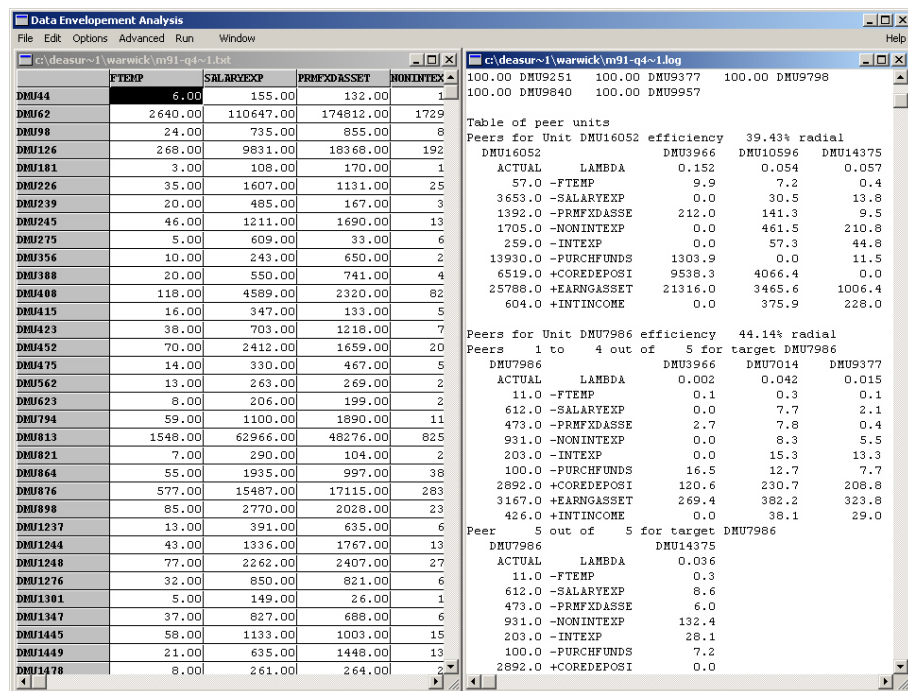


Figure 16-6. Warwick DEA

The software documentation consists of a reprint of Chapter 10 from Thanassoulis (2001). While this is sufficient to operate the software, the source book (sold separately) forms a comprehensive reference manual and user guide, with detailed model developments, illustrative examples, and advanced operating instructions for the software, including how to derive Malmquist indices from other calculated values. The book includes a demonstration version of the software.

Warwick DEA's execution speed for the test problem was slower than the other commercial packages, requiring 53 seconds for our base test problem. Surprisingly, the same problem required over 18 minutes when super-efficiency scores were requested. Other codes did not exhibit such behavior.

The pricing of Warwick's package was the lowest of the commercial offerings, and varied with the maximum number of DMUs accommodated. Academic discounts are only available for site licenses. Technical support responded promptly to questions.

## 4. NON-COMMERCIAL SOFTWARE

The following DEA solution systems are distributed at little or no cost: DEA Excel Solver, DEAP, EMS, and PIONEER 2. Their evaluation criteria are given in the rightmost four columns of Figures 16.1 and 16.2.

### 4.1 DEA Excel Solver

- *Software title:* DEA Excel Solver
- *System requirements:* Microsoft Windows, Microsoft Excel
- *Developer:* Joe Zhu
- *Available from:* Included Zhu (2002)
- *Licensing:* included with Cooper, Seiford, and Zhu (2003)
- *Contact:*
  - ✉ Joe Zhu, Department of Management, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA 01609
  - ☎ (508) 831-5467, fax (508) 831-5720
  - 🌐 [www.deafrontier.com](http://www.deafrontier.com)
  - ✉ [jzhu@wpi.edu](mailto:jzhu@wpi.edu)

The DEA Excel Solver software is included with, and documented in, Zhu (2002). When loaded, this Microsoft Excel add-in appends a "DEA" drop-down menu to the standard menu bar, from which specific models and actions can be invoked.



User-provided data and processing results are stored as different worksheets in a common file. The population data is supplied as columns containing: DMU names, input values, a blank column, and output values. The generated report sheets follow prescribed naming conventions.

The DEA Excel Solver provides an abundance of model choices, many of which are unique to this package (see Figure 16.1). Its rich feature set provides sensitivity analyses, benchmarking evaluations, superefficiencies, and nested frontiers; missing are categorical variables, multi-period analyses, and weight constraints.

The three generated results tables provide as much information as other programs do in five to eight separate reports. Color-coding designates different sections within a table. In some reports, DMU text-name cells have comments with the corresponding DMU index numbers, to expedite cross-references—a nice touch. Figure 16-7 shows two example reports.

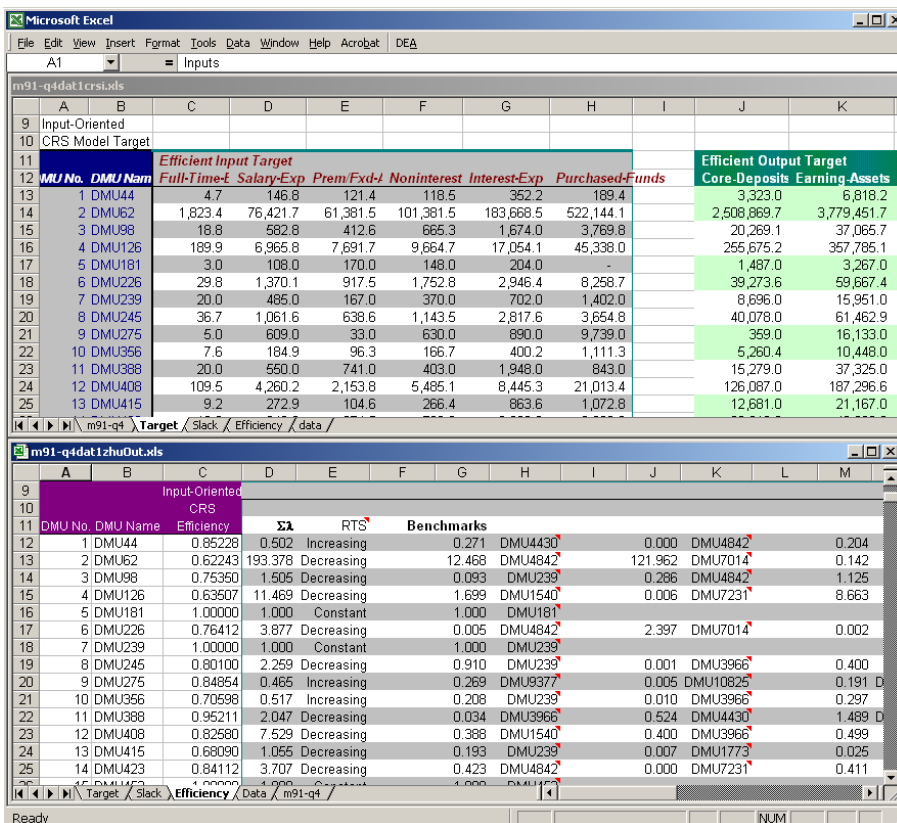


Figure 16-7. DEA Excel Solver

The solution times in tests were slowest of all of the codes on problem G1, and second slowest on problem G2. As with Warwick DEA, but unlike other codes, super-efficiency scores increased runtimes significantly. While the Excel framework imposes a processing overhead and DEA Excel Solver does extensive cell formatting, some improvements are needed in this area.

Zhu (2002) provides a user guide, comprehensive reference manual, and the software itself. The only other expense might be the cost of a replacement optimizer if problem instances exceed the capacity of the standard Excel Solver.

In summary, DEA Excel Solver provides researchers and practitioners an extensive collection of models (some unique) and an appealing user interface. It is an impressive contribution to DEA research and industry application.

## 4.2 DEAP

- *Software title:* DEAP, Version 2.1
- *System requirements:* DOS
- *Developer:* Tim Coelli
- *Available from:* Centre for Efficiency and Productivity Analysis
- *Licensing:* Free download
- *Contact:*
  - ✉ Tim Coelli, CEPA, School of Economics, University of Queensland, Brisbane Australia
  - ☎ (+61 7) 336 56470
  - 🌐 [www.uq.edu.au/economics/cepa/software.htm](http://www.uq.edu.au/economics/cepa/software.htm)
  - ✉ [t.coelli@economics.uq.edu.au](mailto:t.coelli@economics.uq.edu.au)

The Data Envelopment Analysis Program (DEAP) is a fast, batch-oriented DOS program, distributed by its author, Tim Coelli, and the Center for Efficiency and Productivity Analysis. DEAP is guided by two text files: one with input, output, and price values (where appropriate) and another with operating instructions: numbers of DMUs, inputs, outputs, and time periods; model selection; and file names. Execution of the program creates a text file of reports.

Analysis options include the classic CCR and BCC models, plus cost-efficiency and Malmquist formulations. The reports are simple and complete. DMUs are referenced by their sequence numbers, rather than by alphanumeric data labels.

DEAP's operation was too fast to allow timing of the 431-DMU test problem. The DOS window was on-screen so briefly that the program appeared to have malfunctioned; it was just finished.

This freeware is distributed with Coelli (1996), a straightforward user guide with examples of each model type. The user can find further information on the software and models in Coelli, Rao, and Battese (1997).

DEAP's rudimentary user interface disguises a program that is quite capable, providing all of Frontier Analyst's models and more. Its remarkable speed enables efficient operation on old and new PCs alike and its cost is, well, hard to beat.

### 4.3 EMS: Efficiency Measurement System

- *Software title:* EMS: Efficiency Measurement System, Version 1.3
- *System requirements:* Microsoft Windows
- *Developer:* Holger Scheel
- *Available from:* Holger Scheel
- *Licensing:* Free download for academic users
- *Contact:*
  - ✉ Holger Scheel, Operations Research und Wirtschaftsinformatik, Universität Dortmund, D-44221 Dortmund, Germany
  - ☎ fax +49-(0)231-755-5408
  - 🌐 [www.wiso.uni-dortmund.de/lsg/or/scheel/ems](http://www.wiso.uni-dortmund.de/lsg/or/scheel/ems)
  - ✉ [h.scheel@wiso.uni-dortmund.de](mailto:h.scheel@wiso.uni-dortmund.de)

The Efficiency Measurement System (EMS) is a standalone Windows application, developed by Holger Scheel and distributed at no cost to academic users. The user interface is clean and efficient, simplifying the tasks of importing data values from a tab-delimited-text or Excel file, selecting processing options, and running the solver to create a data table.

All data editing must be handled outside of EMS and the inability to display the input data is disconcerting at first. Inputs, outputs, and non-discretionary values are indicated by data labeling conventions and DMU subsets may be selected for analysis. Results are displayed in a single data table (in one of two formats, per Figure 16-8), which can be saved to a text file or copied to the clipboard.

DMU	Score	FTEr (I/V)	Salas (I/V)	PFxh (I/V)	Nonir (I/V)	IntEx (I/V)	PucF (I/V)	CoreC (I/V)	Earnh (I/V)	Inflnc (I/V)	Benchmarks	(S) FTEr (I)	(S) Salas (I)	(S) PFxh (I)	(S) Nonir (I)	(S) IntEx (I)	(S) PucF (I)	(S) CoreC (I)	(S) Earnh (I)	(S) Inflnc (I)	
1 DMU44	85.23%	0.00	0.08	0.00	0.16	0.73	0.04	0.00	0.00	0.85	103(0.27) 113(0.00) 172(0.20) 239	0.72	0.00	36.34	0.00	0.00	0.00	0.00	35.50	52.30	0.00
2 DMU62	62.24%	0.10	0.00	0.00	0.15	0.74	0.01	0.04	0.00	0.59	113(12.47) 172(121.96) 181(0.14)	0.00	54.26	51.71	0.00	0.00	0.00	0.00	0.02	05.35	0.00
3 DMU98	75.35%	0.08	0.00	0.00	0.12	0.78	0.02	0.00	0.00	0.75	7(0.09) 113(0.29) 172(1.13) 181	0.00	19.73	80.31	0.00	0.00	0.00	0.00	31.97	23.15	0.00
4 DMU126	63.51%	0.12	0.00	0.00	0.16	0.73	0.00	0.08	0.00	0.55	34(1.70) 181(0.01) 239(8.66) 377	0.00	69.21	04.93	0.00	0.00	0.00	43.78	0.00	86.44	0.00
5 DMU181	132.21%	0.98	0.00	0.00	0.02	0.00	0.34	0.98	0.00	0.00		0									
6 DMU226	76.41%	0.10	0.00	0.00	0.17	0.72	0.01	0.05	0.00	0.72	113(0.00) 172(2.40) 181(0.00) 239	0.00	10.61	33.85	0.00	0.00	0.00	0.00	0.00	49.39	0.00
7 DMU239	108.32%	0.00	0.00	0.02	0.14	0.81	0.04	0.00	0.00	1.08		109									
8 DMU245	80.10%	0.03	0.08	0.00	0.12	0.76	0.02	0.00	0.04	0.78	7(0.91) 85(0.00) 113(0.40) 172	0.00	0.00	06.45	0.00	0.00	0.00	0.00	43.72	0.00	0.00
9 DMU275	84.85%	0.37	0.00	0.10	0.00	0.53	0.00	0.00	0.85	0.00	239(0.27) 281(0.01) 318(0.19)	0.00	33.74	0.00	72.09	0.00	0.00	34.37	59.18	0.00	03.70
10 DMU356	70.60%	0.11	0.00	0.00	0.13	0.74	0.02	0.00	0.95	0.66	7(0.21) 85(0.01) 172(0.30) 181	0.00	3.05	50.41	0.00	0.00	0.00	31.80	0.00	0.00	
11 DMU388	95.21%	0.00	0.00	0.00	0.83	0.00	0.17	0.43	0.00	0.53	85(0.03) 103(0.53) 305(1.43)	3.60	22.51	21.37	0.00	4.10	0.00	0.00	17.53	0.00	
12 DMU408	82.58%	0.09	0.00	0.01	0.18	0.73	0.00	0.10	0.00	0.72	34(0.39) 85(0.40) 172(0.50) 181	0.00	02.58	0.00	0.00	0.00	0.00	0.00	35.99	0.00	
13 DMU415	68.09%	0.04	0.00	0.03	0.10	0.81	0.01	0.12	0.00	0.57	7(0.19) 36(0.01) 85(0.03) 239(0.65)	0.00	32.97	0.00	0.00	0.00	0.00	0.00	85.44	0.00	
14 DMU423	84.11%	0.00	0.11	0.00	0.11	0.77	0.02	0.00	0.00	0.84	113(0.42) 181(0.00) 239(0.41) 383	7.31	0.00	11.70	0.00	0.00	0.00	88.06	91.24	0.00	
15 DMU452	100.30%	0.13	0.00	0.00	0.16	0.71	0.00	0.18	0.00	0.82		0									
16 DMU475	62.68%	0.00	0.10	0.00	0.18	0.69	0.03	0.04	0.00	0.59	7(0.07) 85(0.01) 172(0.92) 274	0.28	0.00	80.00	0.00	0.00	0.00	0.00	12.63	0.00	

Figure 16-8. Efficiency Measurement System (EMS)

EMS has a good selection of available models and strong feature-set., including conical weight constraints, window analysis, Malmquist indices, super-efficiency scores, and program efficiencies from selecting evaluation and technology DMU subsets. This is all documented clearly and succinctly in the user's manual, Scheele (2000).

Problems are optimized with Csaba Mészáros' BPMPD interior-point solver (available from [www.netlib.org](http://www.netlib.org)), and problem sizes are limited only by available memory. While solution times are slower than most of the other native optimizers, EMS is significantly faster than the Excel-based packages and quick enough to be acceptable even for large instances.

EMS is a solid, straightforward DEA solution tool with many models and features to recommend it. While the niceties of a more professional user interface are missing, this software is a valuable contribution to the field of DEA.

## 4.4 PIONEER 2

- *Software title:* PIONEER, Version 2.0
- *System requirements:* Microsoft Windows, DOS, or Unix
- *Developers:* Thomas McLoud and Richard Barr, under sponsorship by Eclectic Computing Concepts, McKinney, TX
- *Available from:* Richard Barr
- *Licensing:* Free for non-commercial use
- *Contact:*
  - ✉ Richard Barr, Engineering Management, Information, and Systems Department, Southern Methodist University, P.O. Box 750123, Dallas, TX 75275

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✉ [barr@engr.smu.edu](mailto:barr@engr.smu.edu)

PIONEER 2 is a new C++ implementation of the research software by Barr and Durchholz (1997) for large-scale DEA problems.<sup>9</sup> It implements the Hierarchical Decomposition (HDEA) algorithm, a divide-and-conquer method for expediting the solution of large problem instances, and automates the Tiered DEA (TDEA) procedure for identifying nested frontiers and rank-ordering all DMUs based on tier number and super-efficiency scores, per Barr, Durchholz, and Seiford (1994). Convex constraints on the multiplier weights can be included, with several options on how they are to be applied.

The text-based user interface accepts problems from text files, while user options (model, orientation, super-efficiency, and constraint choices) are selected interactively. Program execution generates text files with three test-file reporting options: a summary report, efficiency scores by tier, and DMU detail report (with multipliers, slacks, efficient reference set,  $\lambda$  values, and projection for each unit, tier-by-tier). See Figure 16-9 for example reports, as displayed from Unix Xterm windows. Being a research code, documentation is minimal and assumes familiarity with DEA models and terminology.

The code is fast and designed for large data sets. This speed—due to the HDEA method and built-in optimizer—is needed for TDEA processing, which requires separate optimization of the dataset for each tier.

PIONEER 2 is distributed at no cost to non-commercial users. Both Windows and Unix versions are available from its web site.

## 5. SUMMARY AND FURTHER INFORMATION

Today's DEA practitioners and researchers have a wide range of solution technology choices. Clearly, software is no longer an impediment to the incorporation of DEA into decision-support systems and benchmarking processes. This is evidenced by the availability of interoperable tools with a variety of user interfaces, advanced modeling options, and the power to evaluate large-scale data sets on inexpensive computing platforms.

Besides the eight prominent DEA software packages highlighted in this survey, other solution options are documented in the Appendix below. Updated results, resources, and links to additional information are maintained at the accompanying DEA Software Portal:

<http://faculty.smu.edu/barr/deahandbook/>

<sup>9</sup> Pioneer 1 was written in Fortran for parallel computers and tested on problem instances with 25,000 DMUs.

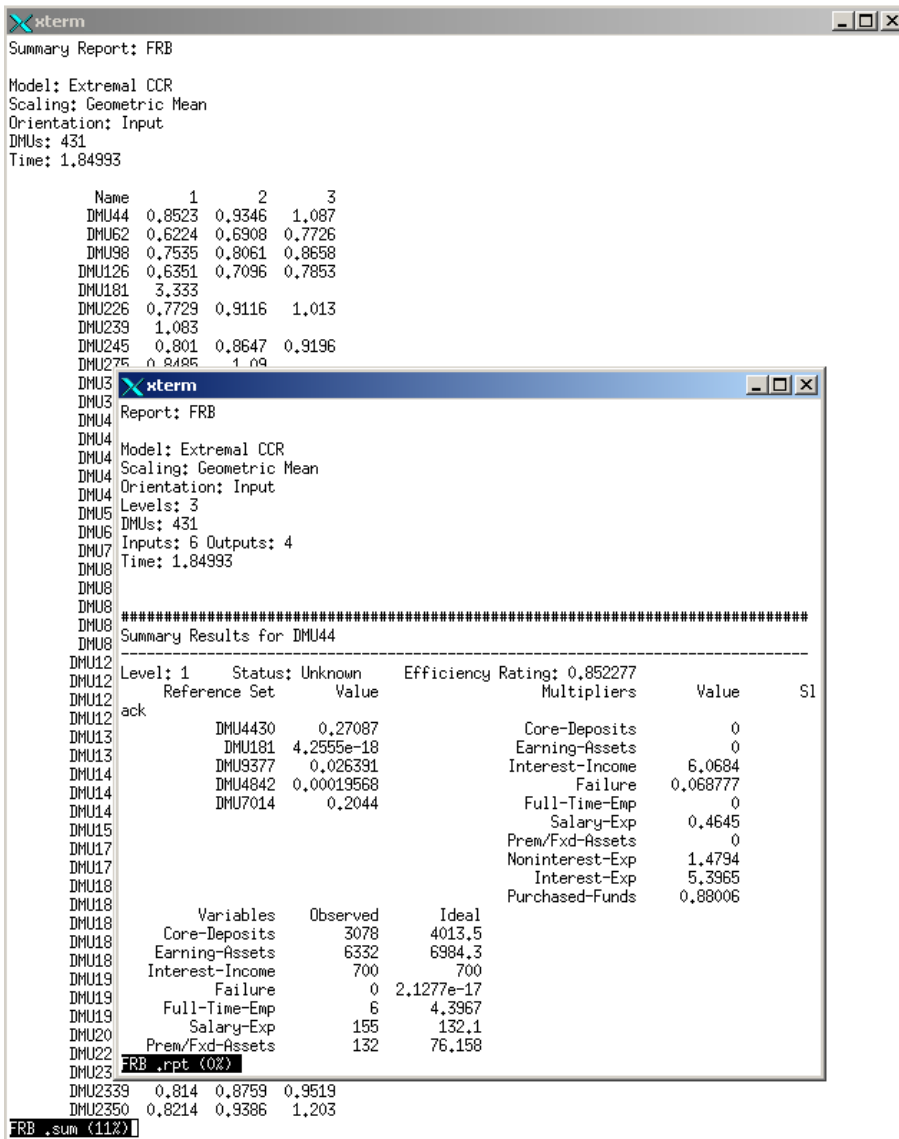


Figure 16-9. PIONEER 2 Example Reports

## 6. APPENDIX. OTHER DEA-RELATED SOFTWARE

The following software packages and libraries related to the solution of DEA models were not included in this survey, for the reasons noted below. Many are research codes, some address more general problems.

### 6.1 BYU-DEA

This early PC Fortran code for DEA problems was developed by Donald L. Adolphson and Lawrence C. Walters at Brigham Young University in Provo, UT. It solves CCR, BCC, and multiplicative models and handles non-discretionary and categorical variables. It is not being distributed at this time.

### 6.2 cdd/cdd+/cddlib

- *Software title:* cdd/cdd+/cddlib
- *System requirements:* C++ compiler
- *Developer:* Komei Fukuda of McGill University, Montreal, Canada
- *Licensing:* Free source code available from website
- *Contact:*
  - 🌐 [http://www.cs.mcgill.ca/~fukuda/soft/cdd\\_home/cdd.html](http://www.cs.mcgill.ca/~fukuda/soft/cdd_home/cdd.html)
  - ✉ [fukuda@cs.mcgill.ca](mailto:fukuda@cs.mcgill.ca)

The program `cdd+` is a C++ implementation of the Double Description Method of Motzkin et al. (1953) for generating all vertices, extreme rays, and the convex hull of a general convex. Hence, `cdd/cdd+/cddlib` is general software that can be used for DEA, but it is not tailored for this type of analysis.

### 6.3 Frame DEA

- *Software title:* Frame DEA
- *System requirements:* Fortran compiler and CPLEX callable library
- *Developer:* José Dulá
- *Contact:*
  - ✉ José Dulá, School of Business Administration, University of Mississippi, University, MS
  - ✉ [jdula@olemiss.edu](mailto:jdula@olemiss.edu)

These research codes were written to test the author's "frame algorithms" for large-scale variable-returns-to-scale (BCC) models "using additive LP formulations." Dulá (1997) documents the methodology and computational testing on problem instances with up to 10,000 DMUs.

## 6.4 GAMS Implementations

- *Software title:* Generalized Algebraic Modeling System (GAMS)
- *System requirements:* Microsoft Windows, Linux, Solaris, HP-UX 10, Digital Unix 4.0, AIX 4.3, or IRIX
- *Developers:* Anthony Brooke, David Kendrick, and Alex Meeraus
- *Available from:* GAMS Development Corporation
- *Licensing:* \$3200 (\$640 academic) + optional optimizers
- *Contact:*
  - ✉ GAMS Development Corporation, 1217 Potomac Street, NW, Washington, DC 20007 USA
  - ☎ (202) 342-0180, fax: (202) 342-0181
  - 🌐 [www.gams.com](http://www.gams.com)
  - ✉ [sales@gams.com](mailto:sales@gams.com)

The Generalized Algebraic Modeling System (GAMS) was one of the first modeling languages for optimization problems. Algebraic model formulations can be solved by a variety of commercial and noncommercial packages for linear, mixed integer, and nonlinear optimization, with user reports generated from the results.

Several DEA implementations have been developed in GAMS. These include:

- *GAMS/DEA module*, providing language extensions specifically for DEA. The Cplex solver is required, and the "slice" modeling technique is documented in Ferris and Voelker (2001). Example applications, including standard DEA models, cross-validations, and quadratic programming models for support vector machines are available at [www.gams.com/contrib/gamsdea/dea.htm](http://www.gams.com/contrib/gamsdea/dea.htm)
- *dea.gms*, free contributed software for classic DEA formulations, available from [www.gams.com](http://www.gams.com) and documented in Kalvelagen (2002)
- *GAMS DEA code*, published in Olesen and Petersen (1995)



## 6.5 IDEAS

This strong commercial DEA package was developed by Iqbal Ali of the University of Massachusetts at Amherst and distributed by 1 Consulting of Amherst, MA. The company is closed for business and the software is no longer distributed.

## 6.6 Qhull

- *Software title:* qhull
- *System requirements:* DOS
- *Licensing:* Free source code available from website
- *Contact:*  
🌐 <http://www.thesa.com/software/qhull/>

This software computes convex hull based on the Quickhull algorithm of Barber, Dobkin and Huhdanpaa (1996). Website description: “Qhull computes convex hulls, Delaunay triangulations, halfspace intersections about a point, Voronoi diagrams, furthest-site Delaunay triangulations, and furthest-site Voronoi diagrams.” Hence it can be adapted to determine an envelopment surface.

## 6.7 SAS/OR Implementations

- *Software title:* SAS/OR
- *Available from:* SAS Institute Inc.
- *Contact:*  
✉ SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513-2414 USA  
☎ (919) 677-8000, fax: (919) 677-4444  
🌐 [www.sas.com](http://www.sas.com)

Two DEA implementations for the SAS/OR software system have been published: SAS/DEA, a CCR-I macro, and SAS/MALM, with macros for CCR-O and Malmquist index calculations. The papers—Emrouznejad (2000, 2002)—contain source-code listings and are available at [www.deazone.com](http://www.deazone.com).

## 6.8 Web Implementation

- *Software title:* Internet-Based Data Envelopment Analysis System (iDEAs)
- *System requirements:* Internet access

- *Developer:* Leon McGinnis
- *Availability:* For registered warehousing companies only
- *Contact:*
  - ✉ Leon McGinnis, School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, GA
  - 🌐 [www.isye.gatech.edu/ideas](http://www.isye.gatech.edu/ideas)
  - ✉ [leon.mcginis@isye.gatech.edu](mailto:leon.mcginis@isye.gatech.edu)

Georgia Institute of Technology's website for warehouse benchmarking, iDEAs, "makes the DEA methodology accessible via the Internet, and enables firms to perform a self-assessment and benchmark themselves against other firms in their industry" (from website). The current database of 200 warehouse operations supports benchmarking of all participating organizations against each other.

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