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# User’s Guide to DEA-Solver-Learning Version

**(LV 8.0)**

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# Preface to DEA-Solver

This is an introduction and manual for the DEA-Solver-LV. There are two versions of DEA-Solver, the “Learning Version" (called DEA-Solver-LV) and the “Professional Version" (called DEA-Solver-PRO). DEA-Solver-PRO can be viewed in website at: http://www.saitech-inc.com/. DEA-Solver-LV 8.0 includes 28 clusters of DEA models and can solve up to 50 DMUs, while DEA-Solver-PRO 10.0 includes 45 clusters and can deal with large-scale problems within the capacity of Excel worksheet. DEA-Solver was developed by Kaoru Tone. All responsibility and intellectual property rights are attributed to Tone, but not to others in any dimension.

We can classify all DEA models into three types: (1) Radial, (2) NonRadial and Oriented, (3) and NonRadial and NonOriented. ‘Radial’ means that a proportionate change of input/output values is the main concern and hence it neglects the existence of slacks (input excesses and output shortfalls remaining in the model) as secondary or freely disposable, whereas ‘NonRadial’ deals with slacks directly and does not stick to a proportionate change of input/output. ‘Oriented’ indicates the input or output orientation in evaluating efficiency, i.e., the main target of evaluation is either input reduction or output expansion. For example, input oriented models first aim to reduce input resources to the efficient frontier as far as possible, and then to enlarge output products as the second objective. ‘NonOriented’ models deal with input reduction and output expansion at the same time. We can classify them into the three categories as displayed below.

|  |  |
| --- | --- |
| Category | Cluster or Model |
| Radial | CCR, BCC, IRS, DRS, AR, ARG, NCN, NDSC, BND, CAT, SYS, Bilateral, Window, Malmquist-Radial, FDH |
| NonRadial and Oriented | SBM-Oriented, Super-efficiency-Oriented |
| NonRadial and NonOriented | Cost, New-Cost, Revenue, New-Revenue, Profit, New-Profit, Ratio, SBM-NonOriented, Super-SBM-NonOriented, Weighted SBM |

# 1. Platform

The platform for this software is Microsoft Excel 97 (a trademark of Microsoft Corporation) or later. If DEA-Solver does not work correctly on your PC, please try to change the Regional Settings of your PC through the Windows Control Panel. This manual is for use of English (United States) Regional Settings.

# 2. Notation of DEA Models

DEA-Solver applies the following notation to describe DEA models.

**Model Name - I or O – C, V or GRS**

where I or O corresponds to “Input”- or “Output”-orientation, and C or V to “Constant” or “Variable” returns to scale, respectively. For example, “AR-I-C” means the Input-oriented Assurance Region model under Constant returns-to-scale assumption. In some cases, “I or O” and/or “C or V” are omitted. For example, “CCR-I” indicates the Input oriented CCR model that is naturally under constant returns-to-scale. “GRS” indicates the “General” returns to scale model. Models with the GRS extension demand to input two parameters through keyboard. The one is the lower bound *L* of the sum of lambdas (λ) and the other its upper bound *U*. “Bilateral” and “FDH” have no extensions. The abbreviated model names correspond to the following models.

1. CCR = Charnes-Cooper-Rhodes model
2. BCC = Banker-Charnes-Cooper model
3. IRS = Increasing Returns-to-Scale model
4. DRS = Decreasing Returns-to-Scale model
5. GRS = Generalized Returns-to-Scale model
6. AR = Assurance Region model
7. NCN = Non-controllable variable model
8. NDSC = Non-discretionary variable model
9. BND = Bounded variable model
10. CAT = Categorical variable model
11. SYS = Different Systems model
12. SBM-Oriented = Slacks-Based Measure model in input/output orientation
13. SBM-NonOriented = Slacks-Based Measure without orientation
14. Supper-SBM-Oriented = Super-efficiency model in input/output orientation
15. Super-SBM-NonOriented =Super-efficiency model without orientation.
16. Super-Radial = Super-efficiency model using Radial inputs and outputs.
17. Cost = Cost efficiency model
18. New-Cost = New cost efficiency model
19. Revenue = Revenue efficiency model
20. New-Revenue = New revenue model
21. Profit = Profit efficiency model
22. New-Profit = New profit model
23. Ratio = Ratio efficiency model
24. Bilateral = Bilateral comparison model
25. Window = Window Analysis
26. FDH = Free Disposal Hull model
27. Malmquist-Radial = Malmquist productivity index model under the radial scheme
28. Weighted SBM = Weighted Slacks-Based Measure model

# 3. DEA Models Included

Version 8.0 consists of 28 clusters.

|  |  |  |
| --- | --- | --- |
| No. | Cluster | Model |
| 1 | CCR | CCR-I, CCR-O |
| 2 | BCC | BCC-I, BCC-O |
| 3 | IRS | IRS-I, IRS-O |
| 4 | DRS | DRS-I, DRS-O |
| 5 | GRS | GRS-I, GRS-O |
| 6 | AR (Assurance Region) | AR-I-C, AR-I-V, AR-I-GRS, AR-O-C, AR-O-V, AR-O-GRS |
| 7 | NCN (Non-Controllable) | NCN-I-C, NCN-I-V, NCN-O-C, NCN-O-V |
| 8 | NDSC (Non-Discretionary) | NDSC-I-C, NDSC-I-V, NDSC-I-GRS, NDSC-O-C, NDSC-O-V, NDSC-O-GRS |
| 9 | BND (Bounded Variable) | BND-I-C, BND-I-V, BND-I-GRS, BND-O-C, BND-O-V, BND-O-GRS |
| 10 | CAT (Categorical Variable) | CAT-I-C, CAT-I-V, CAT-O-C, CAT-O-V |
| 11 | SYS (Different Systems) | SYS-I-C, SYS-I-V, SYS-O-C, SYS-O-V |
| 12 | SBM-Oriented (Slacks-based Measure) | SBM-I-C, SBM-I-V, SBM-I-GRS, SBM-O-C, SBM-O-V, SBM-O-GRS, SBM-AR-I-C, SBM-AR-I-V, SBM-AR-O-C, SBM-AR-O-V |
| 13 | SBM-NonOriented | SBM-C, SBM-V, SBM-GRS, SBM-AR-C, SBM-AR-V |
| 14 | Weighted SBM | WeightedSBM-C, WeightedSBM-V, WeightedSBM-I-C,  WeightedSBM-I-V, WeightedSBM-O-C, WeightedSBM-O-V |
| 15 | Super-SBM-Oriented | Super-SBM-I-C, Super-SBM-I-V, Super-SBM-I-GRS, Super-SBM-O-C, Super-SBM-O-V, Super-SBM-O-GRS |
| 16 | Super-SBM-NonOriented | Super-SBM-C, Super-SBM-V, Super-SBM-GRS |
| 17 | Super-Radial | Super-CCR-I, Super-CCR-O, Super-BCC-I, Super-BCC-O |
| 18 | Cost | Cost-C, Cost-V, Cost-GRS |
| 19 | New-Cost | New-Cost-C, New-Cost-V, New-Cost-GRS |
| 20 | Revenue | Revenue-C, Revenue-V, Revenue-GRS |
| 21 | New-Revenue | New-Revenue-C, New-Revenue-V, New-Revenue-GRS |
| 22 | Profit | Profit-C, Profit-V, Profit-GRS |
| 23 | New-Profit | New-Profit-C, New-Profit-V, New-Profit-GRS |
| 24 | Ratio (Revenue/Cost) | Ratio-C, Ratio-V |
| 25 | Bilateral | Bilateral-CCR-I, Bilateral-BCC-I, Bilateral-SBM-C, Bilateral-SBM-V |
| 26 | Window | Window-I-C, Window-I-V, Window-I-GRS, Window-O-C, Window-O-V, Window-O-GRS |
| 27 | FDH | FDH |
| 28 | Malmquist-Radial | Malmquist-Radial-I-C, Malmquist-Radial-I-V, Malmquist-Radial-I-GRS, Malmquist-Radial-O-C, Malmquist-Radial-O-V, Malmquist-Radial-O-GRS |

The meanings of the extensions -C, -V and -GRS are as follows. Every DEA model assumes a returns to scale (RTS) characteristics that is represneted by the ranges of the sum of the intensity vector λ, i.e. ,  The *constant* RTS (-C) corresponds to , and the variable RTS (-V) to , respectively. In the models with the extension GRS, we have to supply *L* and *U* through keyboard, the defaults being *L*=0.8 and *U*=1.2. The *increasing* RTS corresponds to  and the *decreasing* RTS to , respectively. It is recommended to try several sets of (*L, U*) in order to identify how the RTS chracteristics exerts an influence on the efficiency score.

# 4. Preparation of Data File

The data file should be prepared in an Excel Workbook prior to execution of DEA-Solver. The formats are as follows:

## (1) The CCR, BCC, IRS, DRS, GRS, SBM and FDH Models

Figure 1 shows an example of data file for these models.

### (a) The first row (Row 1)

The first row (Row 1) contains Names of the problem and Input/Output Items, i.e.,

Cell (A1) = Problem Name

Cell (B1), (C1), … = Names of I/O items.

The heading (I) or (O), showing them as being input or output, should head the names of I/O items. The items without an (I) or (O) heading will not be considered as inputs and outputs. The ordering of (I) and (O) items is arbitrary.

### (b) The second and subsequent rows

The second row contains the name of the first DMU and I/O values for the corresponding I/O items. This continues up to the last DMU.

### (c) The scope of data area

A data set must have at least by one blank column at right and one blank row at bottom. This is a necessity for knowing the end of the data area. The data set should start from the top-left cell (A1).

### (d) Data sheet name

A preferable sheet name is “DAT” (not “Sheet 1”). Never use names “Summary”, “Score”, “Projection”, “Weight”, “WeightedData”, “Slack”, “RTS”, “Window”, “Malmquist”, “Rank” and “Graph” for the data sheet. They are reserved for this software.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | A | B | C | D | E | F |
| 1 | Hospital | (I)Doctor | (I)Nurse | (O)Outpatient | (O)Inpatient |  |
| 2 | A | 20 | 151 | 100 | 90 |  |
| 3 | B | 19 | 131 | 150 | 50 |  |
| 4 | C | 25 | 160 | 160 | 55 |  |
| 5 | D | 27 | 168 | 180 | 72 |  |
| 6 | E | 22 | 158 | 94 | 66 |  |
| 7 | F | 55 | 255 | 230 | 90 |  |
| 8 | G | 33 | 235 | 220 | 88 |  |
| 9 | H | 31 | 206 | 152 | 80 |  |
| 10 | I | 30 | 244 | 190 | 100 |  |
| 11 | J | 50 | 268 | 250 | 100 |  |
| 12 | K | 53 | 306 | 260 | 147 |  |
| 13 | L | 38 | 284 | 250 | 120 |  |
| 14 |  |  |  |  |  |  |

**Figure 1: Sample.xls in Excel Sheet**

The above sample problem “Hospital” has 12 DMUs with two inputs “(I)Doctor” and “(I)Nurse” and two outputs “(O)Outpatient” and “(O)Inpatient”. The data set is bordered by one blank column (F) and by one blank row (14). The GRS model has the constraint L ≤λ1+λ2+….+λn≤ U. The values of L (≤1) and U (≥1) must be supplied through the Message-Box on the display by request. Defaults are L=0.8 and U=1.2.

## (2) The AR Model

Figure 2 exhibits an example of data for the AR (Assurance Region) model. This problem has the same inputs and outputs as in Figure 1. The constraints for the assurance region should be denoted in rows 15 and 16 after “one blank row” at 14. This blank row is necessary for separating the data set and the assurance region constraints. These rows read as follows: the ratio of weights “(I)Doctor” vs. “(I)Nurse” is not less than 1 and not greater than 5 and that for “(O)Outpatient” vs. “(O)Inpatient” is not less than 0.2 and not greater than 0.5. Let the weights for Doctor and Nurse be v(1) and v(2), respectively. Then the first constraint implies

1 ≤ v(1)/v(2) ≤ 5.

Similarly, the second constraint means that the weights u(1) (for Outpatient) and u(2) (for Inpatient) satisfies the relationship

0.2 ≤ u(1)/u(2) ≤ 0.5.

Notice that the weight constraints can be applied between inputs and outputs, e.g.,

1 ≤ v(1)/u(2) ≤ 5.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | A | B | C | D | E | F |
| 1 | Hospital | (I)Doctor | (I)Nurse | (O)Outpatient | (O)Inpatient |  |
| 2 | A | 20 | 151 | 100 | 90 |  |
| 3 | B | 19 | 131 | 150 | 50 |  |
| 4 | C | 25 | 160 | 160 | 55 |  |
| 5 | D | 27 | 168 | 180 | 72 |  |
| 6 | E | 22 | 158 | 94 | 66 |  |
| 7 | F | 55 | 255 | 230 | 90 |  |
| 8 | G | 33 | 235 | 220 | 88 |  |
| 9 | H | 31 | 206 | 152 | 80 |  |
| 10 | I | 30 | 244 | 190 | 100 |  |
| 11 | J | 50 | 268 | 250 | 100 |  |
| 12 | K | 53 | 306 | 260 | 147 |  |
| 13 | L | 38 | 284 | 250 | 120 |  |
| 14 |  |  |  |  |  |  |
| 15 | 1 | (I)Doctor | (I)Nurse | 5 |  |  |
| 16 | 0.2 | (O)Outpatient | (O)Inpatient | 0.5 |  |  |
| 17 | 1 | (I)Doctor | (O)Inpatient | 5 |  |  |
| 18 |  |  |  |  |  |  |

**Figure 2: Sample-AR.xls in Excel Sheet**

## (3) The Super-efficiency Model

In most DEA models, the best performers have the full efficient status denoted by unity (1), and from experience, we know that plural DMUs usually have this “efficient status.” The “Super-efficiency models” rank these efficient DMUs by assigning an efficiency score greater than 1. The larger the efficiency score, the more efficient the DMU is judged to be. For this, we have two clusters: nonradial and radial. NonRadial model bases on the slacks-based measure (SBM) of efficiency. This SBM type model has nine variations. The first six: Super-SBM-I-C, Super-SBM-I-V, Super-SBM-I-GRS, Super-SBM-O-C, Super-SBM-O-V and Super-SBM-O-GRS are “Oriented”, while the other three: Super-SBM-C, Super-SBM-V and Super-SBM-GRS, are “NonOriented”. They have the same data format as the CCR model. We also include 4 radial type super-efficiency models; Super-CCR-I, Super-CCR-O, Super-BCC-I and Super-BCC-O.

## (4) The NCN and NDSC Models

The non-controllable variable (NCN) and non-discretionary variable (NDSC) models have basically the same data format as the CCR model. However, the non-controllable/non-discretionary inputs or outputs must have the headings (IN) or (ON), respectively. Figure 3 exhibits the case where ‘Doctor'

is a non-controllable/non-discretionary input and ‘Inpatient' is a non-controllable/non-discretionary output.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | A | B | C | D | E | F |
| 1 | Hospital | (IN)Doctor | (I)Nurse | (O)Outpatient | (O)Inpatient |  |
| 2 | A | 20 | 151 | 100 | 90 |  |
| 3 | B | 19 | 131 | 150 | 50 |  |
| 4 | C | 25 | 160 | 160 | 55 |  |
| 5 | D | 27 | 168 | 180 | 72 |  |
| 6 | E | 22 | 158 | 94 | 66 |  |
| 7 | F | 55 | 255 | 230 | 90 |  |
| 8 | G | 33 | 235 | 220 | 88 |  |
| 9 | H | 31 | 206 | 152 | 80 |  |
| 10 | I | 30 | 244 | 190 | 100 |  |
| 11 | J | 50 | 268 | 250 | 100 |  |
| 12 | K | 53 | 306 | 260 | 147 |  |
| 13 | L | 38 | 284 | 250 | 120 |  |
| 14 |  |  |  |  |  |  |

**Figure 3: Sample-NCN.xls in Excel Sheet**

Here, we describe the difference between the NCN and NDSC models. In the **NCN** (non-controllable variable) model, Non-controllable input/output = A nonnegative combination of non-controllable inputs/outputs of all DMUs.

However, if other situations (constraints) are preferred, i.e., ‘greater than or equal (≥)’ constraints in input and ‘less than or equal (≤)’ constraints in output, the **NDSC** (non-discretionary variable) model can be utilized. Thus, in this model, we assume the following inequality constraints:

Non-discretionary input ≥ A nonnegative combination of non-discretionary input of all DMUs.

Non-discretionary output ≤ A nonnegative combination of non-discretionary output of all DMUs.

## (5) The BND Model

The bounded inputs or outputs must have the headings (IB) or (OB). The columns headed by (LB) and (UB) supply the lower and upper bounds, respectively. Also, these (LB) and (UB) columns must be inserted immediately after the corresponding (IB) or (OB) column. Figure 4 implies that ‘Doctor' and ‘Inpatient' are bounded variables and their lower and upper bounds are given by the columns (LB)Doc., (UB)Doc., (LB)Inpat., and (UB)Inpat, respectively.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | A | B | C | D | E | F | G | H | I | J |
| 1 | Hospital | (IB)Doc. | (LB)Doc. | (UB)Doc. | (I)Nurse | (O)Outpat. | (OB)Inpat. | (LB)Inpat. | (UB)Inpat. |  |
| 2 | A | 20 | 15 | 22 | 151 | 100 | 90 | 80 | 100 |  |
| 3 | B | 19 | 15 | 23 | 131 | 150 | 50 | 45 | 55 |  |
| 4 | C | 25 | 20 | 25 | 160 | 160 | 55 | 50 | 60 |  |
| 5 | D | 27 | 21 | 27 | 168 | 180 | 72 | 70 | 76 |  |
| 6 | E | 22 | 20 | 25 | 158 | 94 | 66 | 60 | 80 |  |
| 7 | F | 55 | 45 | 56 | 255 | 230 | 90 | 80 | 100 |  |
| 8 | G | 33 | 31 | 36 | 235 | 220 | 88 | 80 | 95 |  |
| 9 | H | 31 | 29 | 33 | 206 | 152 | 80 | 70 | 90 |  |
| 10 | I | 30 | 28 | 31 | 244 | 190 | 100 | 90 | 110 |  |
| 11 | J | 50 | 45 | 50 | 268 | 250 | 100 | 90 | 120 |  |
| 12 | K | 53 | 45 | 54 | 306 | 260 | 147 | 130 | 160 |  |
| 13 | L | 38 | 30 | 40 | 284 | 250 | 120 | 110 | 130 |  |
| 14 |  |  |  |  |  |  |  |  |  |  |

**Figure 4: Sample-BND.xls in Excel Sheet**

## (6) The CAT, SYS and Bilateral Models

These models have basically the same data format as the CCR model. However, in the last column they must have an integer showing their category, system or bilateral group, as follows.

*For the CAT model*, the number starts from 1 (DMUs under the most difficult environment or with the most severe competition), 2 (in the second group of difficulty) and so on. It is recommended that the numbers are continuously assigned starting from 1.

*For the SYS model*, DMUs in the same system should have the same integer starting from 1.

*For the Bilateral model*, DMUs must be divided into two groups, denoted by 1 or 2.

Figure 5 exhibits a sample data format for the CAT model.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | A | B | C | D | E | F | G |
| 1 | Hospital | (I)Doctor | (I)Nurse | (O)Outpatient | (O)Inpatient | Cat. |  |
| 2 | A | 20 | 151 | 100 | 90 | 1 |  |
| 3 | B | 19 | 131 | 150 | 50 | 2 |  |
| 4 | C | 25 | 160 | 160 | 55 | 2 |  |
| 5 | D | 27 | 168 | 180 | 72 | 2 |  |
| 6 | E | 22 | 158 | 94 | 66 | 1 |  |
| 7 | F | 55 | 255 | 230 | 90 | 1 |  |
| 8 | G | 33 | 235 | 220 | 88 | 2 |  |
| 9 | H | 31 | 206 | 152 | 80 | 1 |  |
| 10 | I | 30 | 244 | 190 | 100 | 1 |  |
| 11 | J | 50 | 268 | 250 | 100 | 2 |  |
| 12 | K | 53 | 306 | 260 | 147 | 2 |  |
| 13 | L | 38 | 284 | 250 | 120 | 2 |  |
| 14 |  |  |  |  |  |  |  |

**Figure 5: Sample-CAT.xls in Excel Sheet**

## (7) The Cost and New-Cost Models

The unit cost columns must have the heading (C) followed by the *input* name. The ordering of columns is arbitrary. If an input item has no cost column, its cost is regarded as zero. Figure 6 is a sample.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | A | B | C | D | E | F | G | H |
| 1 | Hospital | (I)Doctor | (C)Doctor | (I)Nurse | (C)Nurse | (O)Outpat. | (O)Inpat. |  |
| 2 | A | 20 | 500 | 151 | 100 | 100 | 90 |  |
| 3 | B | 19 | 350 | 131 | 80 | 150 | 50 |  |
| 4 | C | 25 | 450 | 160 | 90 | 160 | 55 |  |
| 5 | D | 27 | 600 | 168 | 120 | 180 | 72 |  |
| 6 | E | 22 | 300 | 158 | 70 | 94 | 66 |  |
| 7 | F | 55 | 450 | 255 | 80 | 230 | 90 |  |
| 8 | G | 33 | 500 | 235 | 100 | 220 | 88 |  |
| 9 | H | 31 | 450 | 206 | 85 | 152 | 80 |  |
| 10 | I | 30 | 380 | 244 | 76 | 190 | 100 |  |
| 11 | J | 50 | 410 | 268 | 75 | 250 | 100 |  |
| 12 | K | 53 | 440 | 306 | 80 | 260 | 147 |  |
| 13 | L | 38 | 400 | 284 | 70 | 250 | 120 |  |
| 14 |  |  |  |  |  |  |  |  |

**Figure 6: Sample-Cost.xls / -New-Cost.xls in Excel Sheet**

**Attention:**

Using the optimal solution ***x***\* of this LP, the cost efficiency of DMUo is defined as

EC = ***c***o***x***\* / ***c***o***x***o.

This implies that if we double the unit costs ***c***o  to 2 ***c***o, the cost efficiency EC still remains invariant. If you feel that this is strange and wish to modify the model in such a way that the magnitude of unit costs directly influences the cost efficiency, you can utilize the New-Cost model. The input data format for this model is the same as the Cost model.

## (8) The Revenue and New-Revenue Models

The unit price columns must have the heading (P) followed by the *output* name. The ordering of columns is arbitrary. If an output has no price column, its price is regarded as zero. See Figure 7 for an example.

**Attention:**

Using the optimal solution ***y***\* of this LP, the revenue efficiency of DMUo is defined as

ER = ***p***o ***y***o / ***p***o***y***\*

This implies that if we double the unit prices ***p***o to 2 ***p***o, the revenue efficiency ER still remains invariant. If you feel that this is strange and you wish to modify the model in such a way that the magnitude of unit prices directly influences the revenue efficiency, you can utilize the New-Revenue model. The input data format is the same as the Revenue model.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | A | B | C | D | E | F | G | H |
| 1 | Hospital | (I)Doctor | (I)Nurse | (O)Outpat. | (P)Outpat. | (O)Inpat. | (P)Inpat. |  |
| 2 | A | 20 | 151 | 100 | 550 | 90 | 2010 |  |
| 3 | B | 19 | 131 | 150 | 400 | 50 | 1800 |  |
| 4 | C | 25 | 160 | 160 | 480 | 55 | 2200 |  |
| 5 | D | 27 | 168 | 180 | 600 | 72 | 3500 |  |
| 6 | E | 22 | 158 | 94 | 400 | 66 | 3050 |  |
| 7 | F | 55 | 255 | 230 | 430 | 90 | 3900 |  |
| 8 | G | 33 | 235 | 220 | 540 | 88 | 3300 |  |
| 9 | H | 31 | 206 | 152 | 420 | 80 | 3500 |  |
| 10 | I | 30 | 244 | 190 | 350 | 100 | 2900 |  |
| 11 | J | 50 | 268 | 250 | 410 | 100 | 2600 |  |
| 12 | K | 53 | 306 | 260 | 540 | 147 | 2450 |  |
| 13 | L | 38 | 284 | 250 | 295 | 120 | 3000 |  |
| 14 |  |  |  |  |  |  |  |  |

**Figure 7: Sample-Revenue.xls /-New-Revenue.xls in Excel Sheet**

## (9) The Profit, New-Profit and Ratio Models

As a combination of *Cost* and *Revenue* models, these models have cost columns headed by (C) for inputs and price columns headed by (P) for outputs.

**Attention:**

Using the optimal solution (***x***\*, ***y***\*) of this LP, the profit efficiency of DMUo is defined as

EP = (***p***o ***y***o- ***c***o***x***o) / (***p***o***y***\*- ***c***o***x***\*)

This implies that if we double the unit prices ***p***o to 2 ***p***o, and the unit costs ***c***o  to 2 ***c***o, the profit efficiency EP still remains invariant. If you feel that this is strange and wish to modify the model in such a way that the magnitude of unit prices and unit costs directly influences the profit efficiency, you can utilize the New-Profit model.

## (10) The Window and Malmquist-Radial Models

Figure 8 exhibits an example of the data format for the Window and Malmquist models. The top-left corner (A1) contains the problem name, e.g., “Car” as shown below. The next right cell (B1) must include the first time period, e.g., “89”. The second row beginning from column B exhibits “(I)/(O) items”, e.g., “(I)Sales” and “(O)Profit”. The names of the DMUs appear from the third row in column A. The contents (observed data) follow in the third and subsequent rows. This style is repeated until the last time period. Note that each time period is placed at the top-left corner of the corresponding frame and (I)/(O) items have the same names throughout the time period. It is not necessary to insert headings (I)/(O) to the I/O names of the second and subsequent time periods. I/O items are determined as designated in the first time period. Figure 8 demonstrates performance of 4 car-manufacturers, i.e., Toyota, Nissan, Honda and Mitsubishi, during 5 time periods, i.e., from (19)89 to (19)93, in terms of the input “Sales” and the output “Profit”.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | A | B | C | D | E | F | G | H | I | J | K | L |
| 1 | Car | 89 |  | 90 |  | 91 |  | 92 |  | 93 |  |  |
| 2 | DMU | (I)Sales | (O)Profit | Sales | Profit | Sales | Profit | Sales | Profit | Sales | Profit |  |
| 3 | Toyota | 719 | 400 | 800 | 539 | 850 | 339 | 894 | 125 | 903 | 103 |  |
| 4 | Nissan | 358 | 92 | 401 | 139 | 418 | 120 | 427 | 34 | 390 | 0 |  |
| 5 | Honda | 264 | 74 | 275 | 100 | 280 | 65 | 291 | 54 | 269 | 33 |  |
| 6 | Mitsubishi | 190 | 44 | 203 | 49 | 231 | 66 | 255 | 56 | 262 | 57 |  |
| 7 |  |  |  |  |  |  |  |  |  |  |  |  |

**Figure 8: Sample-Window.xls / -Malmquist.xls /Malmquist-Radial.xls in Excel Sheet**

## (11) The Weighted SBM Model

This model requires weights to inputs/outputs as data. They should be given at the rows below the main body of data set with one inserted blank row. See Figure 9. The first column (A) has **WeightI** or **WeightO** designating input or output, respectively, and the weights to inputs or outputs follow consecutively in the order of input (output) items recorded at the top row. In this example, the weights to Doctor and Nurse are 10:1, and those to Outpatient and Inpatient are 1:5. The values are relative, since the software normalizes them properly. If they are vacant, weights are regarded as even.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | A | B | C | D | E | F |
| 1 | WSBM | (I)Doctor | (I)Nurse | (O)Outpatient | (O)Inpatient |  |
| 2 | A | 20 | 151 | 100 | 90 |  |
| 3 | B | 19 | 131 | 150 | 50 |  |
| 4 | C | 25 | 160 | 160 | 55 |  |
| 5 | D | 27 | 168 | 180 | 72 |  |
| 6 | E | 22 | 158 | 94 | 66 |  |
| 7 | F | 55 | 255 | 230 | 90 |  |
| 8 | G | 33 | 235 | 220 | 88 |  |
| 9 |  |  |  |  |  |  |
| 10 | WeightI | 10 | 1 |  |  |  |
| 11 | WeightO | 1 | 5 |  |  |  |
| 12 |  |  |  |  |  |  |

**Figure 9: Sample WeightedSBM.xls in Excel Sheet**

# 5. Starting DEA-Solver

After completion of the data file in an Excel worksheet on an Excel workbook as mentioned above, save the data file and click the file “DEA-Solver-LV(V7)” . This starts DEA-Solver. Then follow the instructions on the window.

This Solver proceeds as follows,

## (1) Selection of a DEA model

## (2) Selection of a data set in Excel Worksheet

## (3) Selection of a Workbook for saving the results of computation and

## (4) DEA computation

# 6. Results

The results of computation are stored in the selected Excel workbook. The following worksheets contain the results, although some models lack some of them.

## (1) Worksheet “Summary”

This worksheet shows statistics on data and a summary report of results obtained.

## (2) Worksheet “Score”

This worksheet contains the DEA-score, reference set, λ -value for each DMU in the reference set, and ranking of efficiency scores.

A part of a sample Worksheet “Score” is displayed in Figure 10, where it is shown that DMUs A, B and D are efficient (Score=1) and DMU C is inefficient (Score=0.8827083) with the reference set composed of B (λB=0.9) and D (λD=0.13888889) and so on.

The ranking of DMUs in the descending order of efficiency scores is listed in the worksheet “Rank”.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No. | DMU | Score | Rank | Reference set (lambda) | | |  |  |  |
| 1 | A | 1 | 1 | A | 1 |  |  |  |  |
| 2 | B | 1 | 1 | B | 1 |  |  |  |  |
| 3 | C | 0.8827083 | 8 | B | 0.9 | D | 0.13888889 |  |  |
| 4 | D | 1 | 1 | D | 1 |  |  |  |  |
| 5 | E | 0.7634995 | 12 | A | 0.5794409 | B | 5.72E-02 | D | 0.1526401 |
| 6 | F | 0.8347712 | 10 | B | 0.2 | D | 1.11111111 |  |  |
| 7 | G | 0.9019608 | 7 | A | 0.2588235 | B | 1.29411765 |  |  |
| 8 | H | 0.7963338 | 11 | A | 0.3866921 | B | 1.35E-02 | D | 0.6183983 |
| 9 | I | 0.9603922 | 4 | A | 0.6470588 | B | 0.83529412 |  |  |
| 10 | J | 0.8706468 | 9 | D | 1.3888889 |  |  |  |  |
| 11 | K | 0.955098 | 6 | A | 0.86 | D | 0.96666667 |  |  |
| 12 | L | 0.9582043 | 5 | A | 0.6470588 | B | 1.23529412 |  |  |

**Figure 10: A Sample Score Sheet**

## (3) Worksheet “Projection”

This worksheet contains projections of each DMU onto the efficient frontier analyzed by the chosen model.

## (4) Worksheet “Weight”

Optimal weights v(i) and u(i) for inputs and outputs are exhibited in this worksheet. v(0) corresponds to the constraints λ1 +λ2 +…+λn ≥ L and u(0) to λ1 +λ2 +…+λn≤ U. In the BCC model where L=U=1 holds, u(0) stands for the value of the dual variable for this constraint.

## (5) Worksheet “WeightedData”

This worksheet shows the optimal weighted I/O values, *x*ij*v*(i) and *y*rj*u*(r) for each DMU*j* (for *j*=1,…, *n*).

## (6) Worksheet “Slack”

This worksheet contains the input excesses *s*- and output shortfalls *s*+ for each DMU.

## (7) Worksheet “RTS”

In case of the BCC, AR-I-V and AR-O-V models, the returns-to-scale characteristics are recorded in this worksheet. For BCC inefficient DMUs, returns-to-scale characteristics are those of the (input or output) projected DMUs on the frontier.

## (8) Graphsheet “Graph1”

This graphsheet exhibits the bar chart of the DEA scores. You can redesign this graph using the Graph functions of Excel.

## (9) Graphsheet “Graph2”

This graphsheet exhibits the bar chart of the DEA scores in the ascending order. Figure 11 shows a sample Graph2.

**Figure 11: A Sample Graph2**

## (10) Worksheets “Window*k*”

These sheets are only for Window models and *k* ranges from 1 to L (the length of the time periods in the data). They also include two graphs, ‘Variations through Window' and ‘Variations by Term'.

Let *k*=3 (so we deal with three adjacent years, for example). The results of computation in the case of “Window-I-C” are summarized in Figure 12.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 89 | 90 | 91 | 92 | 93 |  | Average | C-Average |
| Toyota | 0.8257 | 1 | 0.5919 |  |  |  | 0.8059 |  |
|  |  | 1 | 0.5919 | 0.2075 |  |  | 0.5998 |  |
|  |  |  | 1 | 0.3506 | 0.286 |  | 0.5455 | 0.6504 |
| Nissan | 0.3814 | 0.514 | 0.4261 |  |  |  | 0.4407 |  |
|  |  | 0.514 | 0.4261 | 0.1182 |  |  | 0.3529 |  |
|  |  |  | 0.7198 | 0.1997 | 0 |  | 0.3065 | 0.3667 |
| Honda | 0.416 | 0.54 | 0.3446 |  |  |  | 0.4334 |  |
|  |  | 0.54 | 0.3446 | 0.2754 |  |  | 0.3866 |  |
|  |  |  | 0.5821 | 0.4653 | 0.3076 |  | 0.4517 | 0.4239 |
| Mitsubishi | 0.3437 | 0.358 | 0.4241 |  |  |  | 0.3753 |  |
|  |  | 0.358 | 0.4241 | 0.3259 |  |  | 0.3694 |  |
|  |  |  | 0.7164 | 0.5506 | 0.5455 |  | 0.6042 | 0.4497 |

**Figure 12: Window Analysis by Three Adjacent Years**

From this table we can see row-wise averages of scores for each maker, which we call “Average

**Figure 13: Variations through Window**

through Window.” The graph “Variations through Window” exhibits these averages. See Figure 13.

We can also evaluate column-wise averages of scores for each maker, which we call “Average by Term.” The graph “Variations by Term” exhibits these averages. See Figure 14.

**Figure 14: Variations by Term**

## (11) Worksheets “Malmquist*k*”

These sheets are only for Malmquist models and *k* ranges from 1 to L (the length of the time periods in the data). The worksheet “Malmquist*k*” exhibits the results regarding the Malmquist index with the time interval *k*. For example, for the data set in Figure 8, the worksheet “Malmquist1” contains the three indices: “Catch-up”, “Frontier-shift” and “Malmquist”, with respect to the time period pairs: (89=>90), (90=>91), (91=>92) and (92=>93). (Time interval = 1). The worksheet “Malmquist2” includes the above indices with the time period pairs: (89=>91), (90=>92) and (91=>93). (Time interval = 2). Figure 15 shows the Malmquist index (“Malmquist1”) for the data set in Figure 8 as evaluated by the Malmquist-I-C (input-oriented and constant returns-to-scale) model.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Malmquist | 89=>90 | 90=>91 | 91=>92 | 92=>93 | Average |
| Toyota | 1.170124 | 0.512571 | 0.297443 | 0.815787 | 0.698981 |
| Nissan | 1.348856 | 0.828199 | 0.277361 | 2.75E-08 | 0.613604 |
| Honda | 1.297297 | 0.638393 | 0.799366 | 0.66109 | 0.849037 |
| Mitsubishi | 1.04232 | 1.183673 | 0.83616 | 1.212713 | 1.068717 |
| Average | 1.214649 | 0.790709 | 0.552583 | 0.672398 | 0.807585 |

**Figure 15: Sample Malmquist Index**

This worksheet also contains the graph of the above table. See Figure 16. The graphs for the “Catch-up” and “Frontier-shift” tables are also exhibited in each worksheet.

**Figure 16: Malmquist Index**

**Note.** The BCC, AR-I-V and AR-O-V models contain all the worksheets except “Window” and “Malmquist”. The CCR, IRS, DRS, GRS, AR-I-C, AR-O-C, SBM and Super-efficiency models contain all sheets except “RTS”, “Window” and “Malmquist”. The NCN, NDSC, BND, CAT, SYS, Cost, Revenue, Profit, Ratio and FDH models produce “Summary”, “Score,” “Projection,” “Graph1” and “Graph2.” The Bilateral model shows “Summary” and “Score” sheets. The Window (Malmquist) model contains “Window (Malmquist)” and “Summary” sheets.

# 7. Data Limitations

## (1) Problem size

**The number of DMUs must be less than or equal to 50**.

## (2) For the sake of numerical accuracy

Comparing an extremely large scale DMU with an extremely small scale DMU within a data set may result in the loss of numerical accuracy in the score obtained. In some cases, this leads to infeasible or unbounded LP solutions. We recommend that, within an input or output item, the ratio min/max of data is greater than 10-4 on average. In order to avoid such troubles, grouping DMUs within a comparable size and analyzing each group separately will be helpful.

# 8. Inappropriate Data for Each Model

DMUs with the following irregular data are excluded from the comparison group as “inappropriate” DMUs. They are listed in the Worksheet “Summary.” We will adopt the following notations for this purpose.

***xmax* (*xmin*)** = the max (min) input value of the DMU concerned

***ymax* (*ymin*)** = the max (min) output value of the DMU concerned

***costmax* (*costmin*)** = the max (min) unit cost of the DMU concerned

***pricemax* (*pricemin*)** = the max (min) unit price of the DMU concerned

## (1) For the CCR, BCC-I, IRS, DRS, GRS, CAT, SYS and Adjusted Projection models

DMUs with no positive value in inputs, i.e., *xmax* ≤ 0, will be excluded from computation. Zero or minus values are permitted if there is at least one positive value in the inputs of the DMU concerned.

## (2) For the BCC-O model

DMUs with no positive value in outputs, i.e., *ymax* ≤ 0, will be excluded from computation.

## (3) For the AR and ARG models

DMUs with a non-positive value in inputs/outputs regarding AR-constraints are excluded from the comparison group.

## (4) For the FDH model

DMUs with no positive input value, i.e., *xmax* ≤ 0, or a negative input value, i.e., *xmin* < 0, will be excluded from computation.

## (5) For the Cost and New-Cost models

DMUs with *xmax* ≤ 0, *xmin* < 0*, costmax* ≤ 0, or *costmin* < 0 will be excluded. DMUs with non-positive current input cost (≤ 0) will also be excluded.

## (6) For the Revenue, New-Revenue, Profit, New-Profit and Ratio models

DMUs with no positive input value, i.e., *xmax* ≤ 0, no positive output value, i.e., *ymax* ≤ 0, or with a negative output value, i.e., *ymin* < 0, will be excluded from computation. Furthermore, in the **Revenue** and **New-Revenue** models, DMUs with *pricemax* ≤ 0, or *pricemin* < 0 will be excluded from the comparison group. In the **Profit** and **New-Profit** models, DMUs with *costmax* ≤ 0 or *costmin* < 0 will be excluded. Finally, in the **Ratio** model, DMUs with *pricemax* ≤ 0*, pricemin* < 0, *costmax* ≤ 0 or *costmin* < 0 will be excluded.

## (7) For the NCN, NDSC and BND models

Negative input and output values are set to zero by the program. DMUs with *xmax* ≤ 0 in the controllable (discretionary) input variables will be excluded from the comparison group as “inappropriate” DMUs. In the BND model, the lower bound and the upper bound must enclose the given (observed) values; otherwise these values will be adjusted to the given data.

## (8) For the Window model

For the Window-I-C, Window-I-V and Window-O-C models, no restriction exists for output data, i.e., positive, zero or negative values for outputs are permitted. However, DMUs with *xmax* ≤ 0 will be characterized as being zero efficiency. For the Window-O-V model, no restriction exists for input data, i.e., positive, zero or negative values for inputs are permitted. However, DMUs with *ymax* ≤ 0 will be characterized as being zero efficiency. This is for the purpose of completing the score matrix. So, you must take care in interpreting the results in this case.

## (9) For the SBM and Super-efficiency models

We exclude DMUs with no positive input value, i.e., *xmax* ≤ 0 from computation.

## (10) For the Bilateral model

We cannot compare two groups if there is an input item in which one group has all zero-value while the other group has positive values for the corresponding input items.

## (11) For the Malmquist model

We insert a small positive number (10-8) to any non-positive value in inputs or in outputs.

# 9. Sample Problems and Results

This version includes sample problems and results for all clusters in the folder “Sample- DEA-Solver-LV(V8)”.

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