User's Guide to DEA-Solver-Learning Version
(LV 8.0)

Contents

Preface to DEA-Solver

This is an introduction and manual for the attached DEA-Solver-LV. There are two versions of DEA-Solver, the "Learning Version" (called DEA-Solver-LV), in the attached CD, 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. , $L \leq \lambda_1 + \lambda_2 + \cdots + \lambda_n \leq U$. The *constant* RTS (-C) corresponds to $(L = 0, U = \infty)$, and the variable RTS (-V) to $(L = 1, U = 1)$, 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 $(L = 1, U = \infty)$ and the *decreasing* RTS to $(L = 0, U = 1)$, 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 $L \leq \lambda_1+\lambda_2+\ldots+\lambda_n \leq U$. The values of L ($\leq 1$) and U ($\geq 1$) 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

$$1 \leq v(1)/v(2) \leq 5.$$

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

$$0.2 \leq u(1)/u(2) \leq 0.5.$$

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

$$1 \leq v(1)/u(2) \leq 5.$$

	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 $\boldsymbol{x}^*$ of this LP, the cost efficiency of DMUo is defined as

$$E_C = \boldsymbol{c}_o\boldsymbol{x}^* / \boldsymbol{c}_o\boldsymbol{x}_o.$$

This implies that if we double the unit costs $\boldsymbol{c}_o$ to 2 $\boldsymbol{c}_o$, the cost efficiency E_C 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 $\boldsymbol{y}^*$ of this LP, the revenue efficiency of DMUo is defined as

$$E_R = \boldsymbol{p}_o\,\boldsymbol{y}_o / \boldsymbol{p}_o\boldsymbol{y}^*$$

This implies that if we double the unit prices $\boldsymbol{p}_o$ to 2 $\boldsymbol{p}_o$, the revenue efficiency E_R 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 ($\boldsymbol{x}^*$, $\boldsymbol{y}^*$) of this LP, the profit efficiency of DMUo is defined as

$$E_P = (\boldsymbol{p}_o \boldsymbol{y}_o - \boldsymbol{c}_o \boldsymbol{x}_o) / (\boldsymbol{p}_o \boldsymbol{y}^* - \boldsymbol{c}_o \boldsymbol{x}^*)$$

This implies that if we double the unit prices $\boldsymbol{p}_o$ to 2 $\boldsymbol{p}_o$, and the unit costs $\boldsymbol{c}_o$ to 2 $\boldsymbol{c}_o$, the profit efficiency E_P 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 (λ_B=0.9) and D (λ_D=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 $\lambda_1 + \lambda_2 + \ldots + \lambda_n \geq L$ and u(0) to $\lambda_1 + \lambda_2 + \ldots + \lambda_n \leq U$. 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.

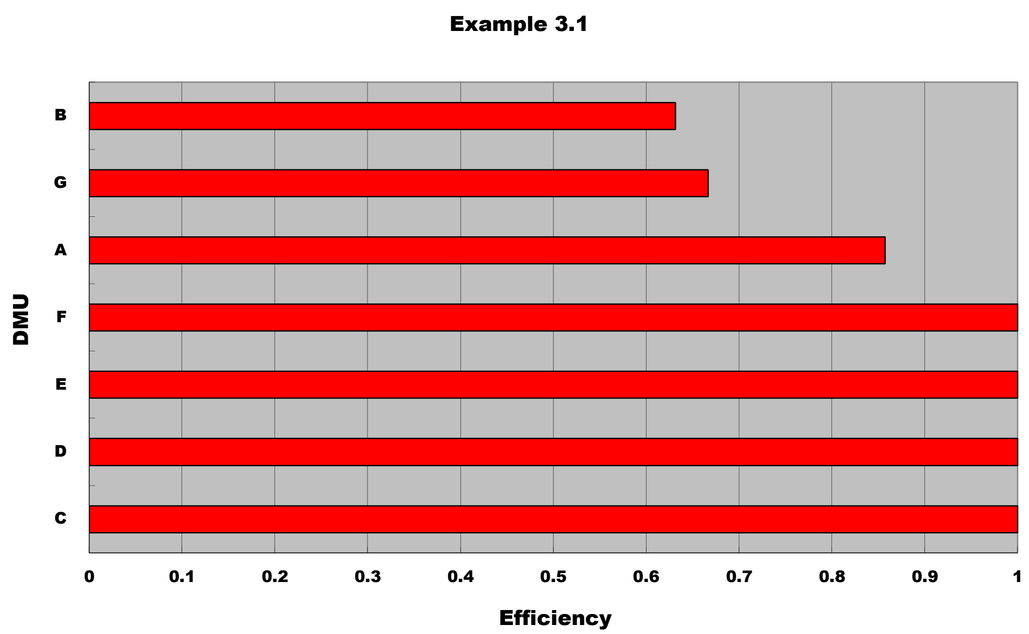

Figure 11: A Sample Graph2

(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

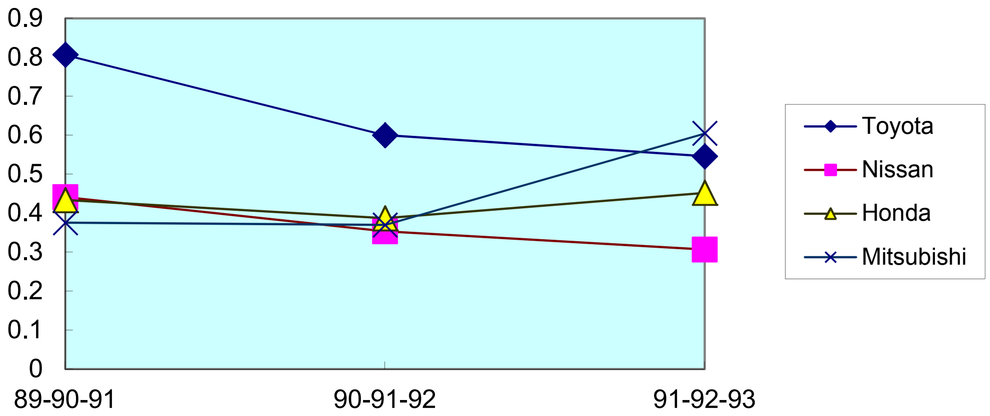

Figure 13: Variations through Window

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.

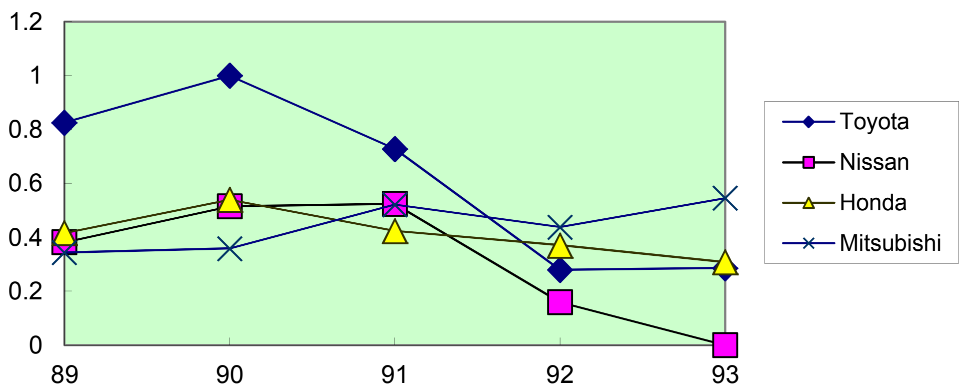

Figure 14: Variations by Term

(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.

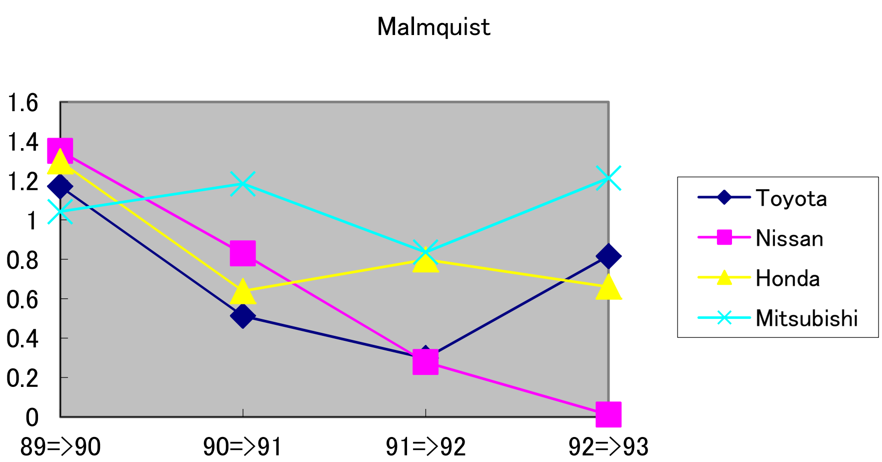

Figure 16: Malmquist Index

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 $xmax \leq 0$ 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 $ymax \leq 0$ 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., $xmax \leq 0$ 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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