# FSDA – Free Software for Decision Analysis (SLAD – Software Livre de Apoio a Decisão): A Software Package for Data Envelopment Analysis Models


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## Abstract

Data Envelopment Analysis models are based on linear programming problems (LPP) to determine the efficiency of Decision-Making Units (DMUs). This process can be computationally intense, as a LPP has to be run for each unit. Besides, a typical DEA LPP has a large number of redundant constraints concerning the inefficient DMUs. That results in degenerate LPPs and in some cases multiple efficient solutions. The developed work intends to fill out a gap in current DEA software packages, i.e., the lack of a software capable of producing full results in classic DEA models, as well as the capability of using more advanced DEA models. Basic and advanced DEA models are allowed in the package. The developed software was named as ISYDS – Integrated System for Decision Support – and has been useful in several theoretical and applied papers. Further developments would include multicriteria models, which justifies the package name.


**Keywords:** *Software, Data Envelopment Analysis, Decision support.*


## 1. Introduction

Data Envelopment Analysis (DEA) is an approach to evaluate efficiency and uses Linear Programming Problems (LPP) to assess the performance of Decision-Making Units (DMUs). In recent years there has been an increasing interest for DEA and its corresponding LPPs. Several real case applications have led to a need for new developments in the classic models, the CCR (Charnes et. al., 1978) and BCC (Banker et al., 1984) DEA models, in order to include new situations. Thus, several researchers have been aware to the results yielded by the models in terms of efficiency indexes, benchmarks and targets.

On the other hand, a LPP has to be solved for each DMU. Thus, the task for efficiency evaluation can be hard and very time consuming without adequate specific software, particularly for a large number of DMUs. Several software packages were developed so to minimise those problems. However, in several situations, the results produced by those packages either are not complete or are not consistent to the ones produced by other softwares for the same model. That leads to some questions about the fairness of the model computational implementation in those softwares.

That indicates a reliable software package must be developed, yielding complete results and covering new theoretical developments regarding DEA models. That was the motivation for FSDA (Free Software for Decision Analysis) software development which, besides covering the classic DEA models and producing complete results (as explained in section 2), it also includes advanced models that were not considered by other DEA software packages (Angulo-Meza et al., 2003). The current version of this software package is presented in Portuguese and is called SLAD (Software Livre de Apoio à Decisão), although an English version is also under development.

This package has been very useful for testing new models and is already used in many papers written by these researchers.

## 2. Data Envelopment Analysis

Data Envelopment Analysis (DEA) was developed by Charnes et al. (1978) and uses linear programming for the comparative evaluation of DMUs efficiencies. The purpose is to compare a certain number of DMUs performing similar tasks and that distinguish themselves in the number of used inputs and produced outputs. There are basically two classic DEA models: the Constant Return Scale (CRS) model, also known as CCR (Charnes, Cooper and Rhodes, 1978), and the Variable Return Scale (VRS) model or BCC (Banker, Charnes and Cooper, 1984). The first model considers constant returns to scale; the second one assumes variable returns to scale and no proportionality among inputs and outputs.

Each $k^{th}$ DMU, k = 1, ..., n, is considered to be a production unity that uses r inputs $x_{ik}$, i = 1, …, r, to produce s outputs $y_{jk}$, j =1, …, s. The CCR model described by (1) maximises the ratio between the linear combination of outputs and the linear combination of inputs, with the constraint that for each DMU that ratio cannot be greater than one. So, for a particular DMU o, $h_o$ is its efficiency; $x_{io}$ and $y_{jo}$ are its inputs and outputs and $v_i$ and $u_j$ are the calculated weights for the inputs and outputs. After some mathematical manipulations, the model can be rewritten, yielding in a Linear Programming Problem (LPP). As a LPP is solved for each DMU, if we have n DMUs n LPPs must be solved, with r + s decision variables. The model just presented is the basis for all other DEA models.

$$
\begin{aligned}
&\max \ h_o = \frac{\sum_{j=1}^{s} u_j y_{jo}}{\sum_{i=1}^{r} v_i x_{io}} \\
&\text{subject to} \\
&\frac{\sum_{j=1}^{s} u_j y_{jk}}{\sum_{i=1}^{r} v_i x_{ik}} \le 1, \quad k = 1,\ldots,n \\
&u_j, v_i \ge 0 \quad \forall i, j
\end{aligned} \qquad (1)
$$

Besides the efficiency index, DEA models yield, for each DMU, the variables weights, benchmarks and targets for the inefficient DMUs. The last two elements are determined from the values of the dual variables, i.e., by solving the dual LPPs or by the use of the complementary slack theorem. The set of all those results defines what we call in this paper "complete results".

In recent years, DEA software packages were developed due to the great interest and the large number of applications using the DEA approach. Those softwares include mostly basic models and were mainly developed to avoid the effort of running separately LPPs for each DMU in order to get the final evaluation (see, for example, Angulo-Meza and Estellita-Lins, 2000, for a review of software packages for DEA).
On the other hand, theoretical developments have been proposed and are widely used. Thus, the use of some advanced developments have been essential for DEA analysis and a number of software packages already include some advanced models.
Although latest theoretical developments were introduced in DEA packages and there exist many options available, we can frequently observe that DEA results can vary from package to package. This happens even for the basic models. Besides, most software packages show only efficiency indexes, benchmarks, and targets, leaving out the actual values for variable weights, which may be useful in a thorough analysis of the DMUs and in later theoretical developments (Angulo-Meza and Estellita-Lins, 2000).
Such problems motivated the authors to build a software in order to produce complete results involving the basic DEA models CCR and BCC, input or output oriented (Cooper et al., 2000), with open code access to check eventual problems or discrepancies among results. It has also the possibility of including new theoretical advanced developments.

## 3. FSDA – Free Software for Decision Analysis

A fundamental step for the development of any DEA software is the set-up and choice of the algorithm to solve the LPPs associated with this methodology. The Simplex algorithm (Dantzig, 1963) is widely used for solving LPPs; the Interior Points algorithm is mostly used for large scale LPPs (the EMS package uses this algorithm for solving DEA LPPs – Scheel, 2000). FSDA uses Simplex algorithm for solving the DEA LPPs. This implementation uses Kuenzi et al. (1971) approach, which includes a subroutine to avoid degenerating problems, a common problem in DEA models, due to the typical structure of DEA LPPs.

### 3.1 Software Description

FSDA (SLAD in Portuguese version) was developed for Windows platform with Delphi 7.0. It is capable of dealing with 150 DMUs, 20 variables (inputs or outputs), and works with a six decimals accuracy. Although for other research areas 150 units might be insufficient, for DEA applications this number is able to deal with large-scale situations, once in the literature there are few applications dealing with more than 100 DMUs. As far as the number of variables is concerned, it should be pointed out that in most applications 10 variables are sufficient.

```
5       1       2
 DMUs   INPUT  Output1       Output2
 DMU1     4.00000      10.00000       8.00000
 DMU2     1.00000       5.00000       9.00000
 DMU3     2.00000       7.00000      10.00000
 DMU4     1.00000       8.00000      11.00000
 DMU5     6.00000       6.00000      15.00000
```

Figure 1: Entry data format.

The software allows the data input in two ways: directly inside the program using a table with the choice of the number of DMUs and variables, and by the use of a text file. For the first case, there is a window in which the user must indicate the number of DMUs, inputs and outputs. In the second one, the data is retrieved from a text file into the table. The text file must be in the following format (Figure 1): in the first line must appear the number of DMUs, inputs and outputs, in this specific order, separated by blanks of tabs. The second line must contain the names for the DMUs columns and variables, inputs and output, e.g., if you're trying to analyse countries using one input and two outputs you can write: DMUs Input1 Output1 Output2. The names must not contain blanks. The next lines contain the information for each of the aforementioned DMUs, always in the same order: name of the DMU, without blanks) followed by the data, inputs and outputs. If the data contains decimals, a point must be used instead of a comma to separate them.

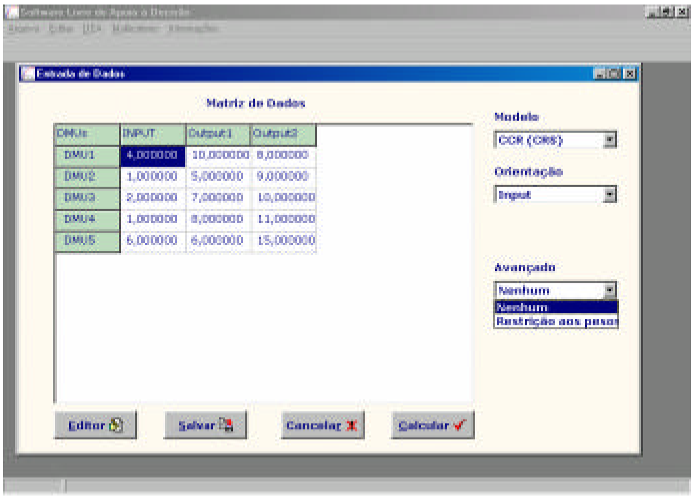


Figure 2. Data Editor.

In the window shown in Figure 2, we also have a Saving option, which saves the data from the table in a "txt" format into an existing or new file. Another useful option is the Editing one. In this option it's possible to modify variables and DMUs names. The Saving option will include also the changes made in the "txt" file.
Returning to Figure 2, in the same window that shows the data, there are possible choices of basic models (CCR or BCC) and orientation (input or output). The user can choose only one model and one orientation at a time, and can also change data details, as values and variables names, with the edition option.
As one of the objectives of the FSDA package is to allow new DEA models, advanced options are also included in this software. They are chosen along with the model and its orientation. The user has also the possibility of using weight restrictions. This option leads the user to an additional window indicating the number of restrictions to be included in the chosen model. These restrictions are in the format "greater or equal than zero" and they must be include as a variable coefficient in the table. There is also an option to increase restrictions for virtual weights. This options leads to a window where we are able to indicate virtual restrictions for each variable.
Results for any model, advanced or not, are presented in an additional window as illustrated in Figure 3 that shows the efficiency indexes for all DMUs. Besides, additional options are presented to display other results: inverted frontier, which expands the result window to include the efficiency scores in the inverted frontier and the composed index (standard and inverted frontier efficiencies).
It should be noticed that the results window just shows the efficiencies of the DMUs, whereas the other results (the complete results) are shown only when asked for, by clicking the appropriate icon on the same window. Weights variables, benchmarks for all DMUs, and the targets for the inefficient ones are individually displayed. This last option shows the actual variable levels, the slacks and the final target level for the variable for each DMU (Figure 3. Individual windows were implemented for the sake of easing the visualisation of the results, once the presentation of the complete results in one window might be difficult to visualise, particularly for a case study with large number of variables and DMUs.

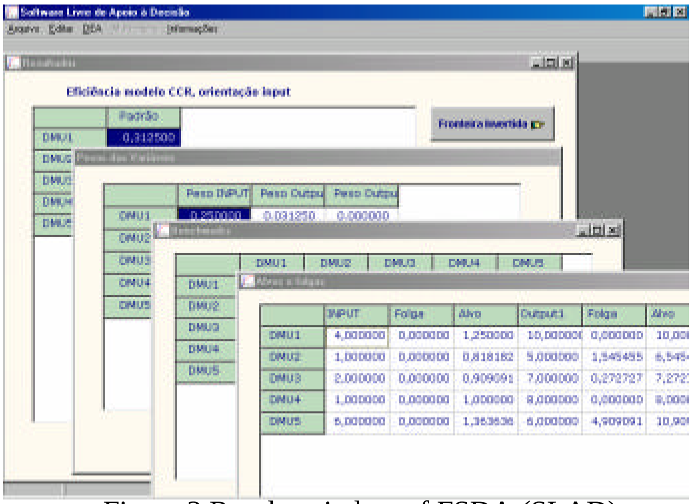

Figure 3 Results window of FSDA (SLAD).

One important option in this window is the possibility of saving the results of the analysis in a "txt" file. In this file are saved model and orientation, efficiency scores (all of them), weights (multipliers), targets and benchmarks for each DMU. If weight restrictions were used, the file will also include those restrictions.

### 3.2 Implemented models

Basic DEA CCR and BCC models are already included in FSDA. Both models include input or output orientation, producing complete results (efficiency scores, weights, benchmarks, targets, and slacks.).

Moreover, some advanced models were included, retrieving also complete results, which were:

a) Inverted frontier, that is a way to measure the inefficiency of a DMU (Entani et al., 2002; Novaes, 2002), altogether with a composed efficiency, obtained from the common a inverted frontier (Angulo-Meza et al., 2003). This composed efficiency index is computed as shown in (3). It means that the optimist and the pessimist evaluation are both considered. Normalized composed efficiency is obtained by dividing each DMU composed efficiency index by the major one along all DMUs.
b) Weight restrictions, using the assurance region, and virtual weights (Allen et al., 1997).

$$\text{Composed efficiency index} = \frac{\text{Classic efficiency} - \text{Inverted efficiency} + 1}{2} \qquad (3)$$

It's important to point out that even using weight restrictions the results show the inverted frontier efficiency index.

## 4. Conclusions

The recent years growing interest in DEA models and the theoretical developments due to real world applications have indicated the need of a reliable software package. This package must jointly have a friendly user interface, must yield reliable, consistent and complete results and should be capable of working with more advanced DEA models. There are available many DEA software packages, but the lack of complete and reliable results in those softwares led to the development of a software package that met our demands.

The FSDA (SLAD) includes, besides the classic models, advanced models such as DEA models with weight restrictions and the use of a inverted frontier. The complete results produced by this software are suitable for a deep analysis of the DMUs and are also useful for the development of new theoretical models. It's important to say that the performance of the FSDA in large-scale problems has been computationally satisfactory: the response time for problems involving 80 DMUs and 7 variables was less than one second.

The great motivation for the FSDA development was the possibility of including other models in the package. This implementation has been very useful for our new developments and in testing new models. The latest beta version of the software can be downloaded from <http://www.uff.br/decisao>.
Finally, new models developed by us are under way to be considered in the FSDA such as the DEA-GSZ model (Estellita-Lins et al., 2003; Gomes, 2003), models considering uncertainties using a fuzzy approach (Soares de Mello et al., 2003), and the smoothed DEA frontier model (Soares de Mello et al, 2004, 2002). A multicriteria module and a Game Theory one are also under development.

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