

Efficiency Evaluation Information System Based on Data Envelopment Analysis

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Abstract—As data envelopment analysis (DEA) has been developed both in theory and application, the calculation of models become more and more important. Although many DEA software tools have been built for the calculation of the DEA models, there are some deficiencies in embedding them into enterprise management information system (MIS). As an extension of this work, an idea was generated in this paper, which could both calculate the DEA and further support the decision making for decision making units (DMUs), i.e., the organizations, in the information environment. This is an attempt to bridge between DEA and MIS. And we could demonstrate this approach for building efficiency evaluation information system. Furthermore, an efficiency evaluation information system of company A, which was built by ourselves, was shown to illustrate our purpose.

Index Terms—Data envelopment analysis; Management information system; Efficiency evaluation information system; Decision support

I. INTRODUCTION

The efficiency evaluation is becoming more and more considerable in companies' daily management operating. By looking at the efficiency evaluation, the enterprises can be aware of their specific position, and find out the gap between them and their competitors, so as to determine how they could improve the quality of products on practical and scientific aspects.

Data envelopment analysis (DEA), as a non-parametric programming technique, has becoming more and more popular in evaluating the performance efficiency of a set of homogenous decision making units (DMUs). It was first proposed by Charnes, Cooper and Rhodes in 1978 [1] and extensively applied in multiple inputs and multiple outputs complex systems. Since the CCR model, there has been an impressive growth both in theoretical developments and applications of DEA. DEA researchers have developed a number of updated models, such as BCC model [2], additive model [3], multilevel models [4, 5], super efficiency models [6] and so on. At the same time, DEA has also been extensively applied in performance evaluation and benchmarking of hospitals, universities, cities, courts, business firms, and others, including the performance of regions, countries etc [7].

However, the applications of DEA in the enterprise management information system are few.

There have been several DEA software tools in market. They can be divided into two groups: one group is professional, such as DEA Solver pro, DEAP, Efficiency Measurement System (EMS), DEA excel solver and so on [8]. For these DEA software tools, we can get the results just by inputting the DMUs' data and choosing the appropriate model. The other is universal, such as Matlab, Lingo, Lindo and so on. Using these universal software tools, we must program the procedure by ourselves. However, all DEA software tools mentioned above can't be embedded into management information system (MIS) perfectly. This limits their application strongly. Based on the theory of DEA, this paper tries to set up an evaluation information system for company A upon the platform of DEA in order to supply some useful management information for it. Company A's MIS may contain a lot of sub-systems, such as staff information management, salary management, performance management and so on. We focused on the evaluation system and its relationship with others. For simplifying illustration, we construct the efficiency evaluation information system just based on CCR and BCC for real company A.

This paper is aimed at evaluating DMUs and benchmarking by using efficiency evaluation information system. This approach has some applied advantages, especially in the information management. Section 2 briefly reviews the traditional DEA models of CCR and BCC. Section 3 introduces the efficiency evaluation sub-system. In Section 4, we apply the idea to build MIS of a real company A which contains the efficiency evaluation sub-system. Finally, Conclusions are given in Section 5.

II. DEA MODELS

We assume that there are n DMUs to be evaluated, where each DMU contains s different outputs and m different inputs. We denote the i th input and r th output

for $DMU_j (j = 1, 2, \dots, n)$ as $x_{ij} (i = 1, 2, \dots, m)$ and $y_{rj} (r = 1, 2, \dots, s)$ respectively. We assume that $x_{ij} \geq 0$, $y_{rj} \geq 0$ and each DMU must has at least one

positive input and one positive output value.

The CCR model, proposed by Charnes et al in 1978 [1], for measuring the technical efficiency of the j_0^{th} DMU (DMU_0) was first stated as follows.

$$\begin{aligned}
 e^{CCR} &= \max \sum_{r=1}^s u_r y_{rj_0} / \sum_{i=1}^m v_i x_{ij_0} \\
 \text{s.t.} \quad &\sum_{r=1}^s u_r y_{rj} - \sum_{i=1}^m v_i x_{ij} \leq 0, j = 1, 2, \dots, n \\
 &u_r, v_i \geq 0, r = 1, 2, \dots, s, i = 1, 2, \dots, m. \quad (1)
 \end{aligned}$$

Through the Charnes and Cooper transformation [9] for linear fractional programming yielded the equivalent programming problem as follows.

$$\begin{aligned}
 e^{CCR} &= \max \sum_{r=1}^s \mu_r y_{rj_0} \\
 \text{s.t.} \quad &\sum_{r=1}^s \mu_r y_{rj} - \sum_{i=1}^m \omega_i x_{ij} \leq 0, j = 1, 2, \dots, n \\
 &\sum_{i=1}^m \omega_i x_{ij_0} = 1 \\
 &\mu_r, \omega_i \geq 0, r = 1, 2, \dots, s, i = 1, 2, \dots, m. \quad (2)
 \end{aligned}$$

for which the LP dual problem is

$$\begin{aligned}
 e^{CCR} &= \min \theta \\
 \text{s.t.} \quad &\sum_{j=1}^n \lambda_j x_{ij} + s_i^- = \theta x_{i0}, i = 1, 2, \dots, m \\
 &\sum_{j=1}^n \lambda_j y_{rj} - s_r^+ = y_{r0}, r = 1, 2, \dots, s \\
 &\lambda_j \geq 0, j = 1, 2, \dots, n. \quad (3)
 \end{aligned}$$

Model (3) is sometimes referred to as the ‘‘Farrell model’’ because it is the one used in Farrell [10]. In the economics portion of the DEA literature, it is said to conform to the assumption of ‘‘strong disposal’’, because it ignores the presence of non-zero slacks. Besides, it is also under the assumption of constant returns to scale (CRS).

Then, based on CCR model, Banker, Charnes and Cooper built the BCC model as follows [2].

$$\begin{aligned}
 e^{BCC} &= \min \theta \\
 \text{s.t.} \quad &\sum_{j=1}^n \lambda_j x_{ij} + s_i^- = \theta x_{i0}, i = 1, 2, \dots, m \\
 &\sum_{j=1}^n \lambda_j y_{rj} - s_r^+ = y_{r0}, r = 1, 2, \dots, s \\
 &\sum_{j=1}^n \lambda_j = 1 \\
 &\lambda_j \geq 0, j = 1, 2, \dots, n. \quad (4)
 \end{aligned}$$

In the economics portion of the DEA literature, the BCC model, that is (4), are under the assumption of variable returns to scale (VRS). BCC model could be used to determine the returns to scale, including decreasing, constant and increasing.

For model (3) and (4), DMU_0 is efficient if and only if $\theta^* = 1$ and $s_i^- = s_r^+ = 0$ for all i and r . DMU_0 is weakly efficient if $\theta^* = 1$ and $s_i^- \neq 0$ and (or) $s_r^+ = 0$ for some i and r in some alternate optima.

DMU_0 is inefficient if $\theta^* < 1$ [11]. Assume the CCR and BCC scores of a DMU are e^{CCR} and e^{BCC} respectively. The scale efficiency is defined by $e^{scale} = e^{CCR^*} / e^{BCC^*}$ [12].

The following conditions identify the situation for returns to scale (RTS) for the CCR model given in (3).

- (i) Increasing RTS prevail at $(\hat{x}_0 : \hat{y}_0)$ if and only if $\sum_{j=1}^n \lambda_j^* < 1$ for all optimal solutions.
- (ii) Decreasing RTS prevail at $(\hat{x}_0 : \hat{y}_0)$ if and only if $\sum_{j=1}^n \lambda_j^* > 1$ for all optimal solutions.
- (iii) Constant RTS prevail at $(\hat{x}_0 : \hat{y}_0)$ if and only if $\sum_{j=1}^n \lambda_j^* = 1$ for at least one optimal solution [13].

III. BASIC FUNCTION OF EFFICIENCY EVALUATION INFORMATION SYSTEM

We thought that the efficiency evaluation sub-system should contain at least three parts. One is evaluation among it and its homogeneous DMUs, another is evaluation among its performance in different time, and the last is benchmarking.

The first evaluation aims to determine the efficiency of DMU_0 when it compares with other DMUs from

cross-sectional data. The DMU_0 can be aware of its location exactly among the same kind of DMUs by the results above. It is very useful for the DMU to understand the gap between itself and other DMUs.

The second evaluation aims to determine the efficiency of DMU_0 in series times. Through the results, we can know whether the DMU’s performance has been improved. Here, we assume the DMU is a company. Through specifically understanding the developments and trends of the company, we can do better preparation for its future development, in order to avoid irreparable loss caused by the company management’s delaying.

An important part of organizational planning and control is the selection of proper performance benchmarks [14]. Benchmarking is a means to evaluate their own businesses and study other organizations. It takes the internal or external best practices in business enterprises as its own internal development goals, and then applies the goal to their business practice. Through the results, we can determine the practical and scientific path for efficiency improvement.

IV. REAL COMPANY A'S EFFICIENCY EVALUATION INFORMATION SYSTEM

Before introducing the efficiency evaluation sub-system, we should introduce the management information system briefly which developed by ourselves. It contained five parts: system management, basic information management, sale data analysis, efficiency evaluation, data inquiry. The interface was designed as Fig.1.



FIG.1 COMPANY A MANAGEMENT INFORMATION SYSTEM INTERFACE

Now, we began to introduce the efficiency evaluation sub-system in details. This sub-system contains three parts. The first part was evaluation among Company A and its homogeneous companies, the second part was evaluation among its performance in different time, and

the last was benchmarking. The system's interfaces were shown as Fig.2, 3, 4 respectively when they were running based on CCR model.

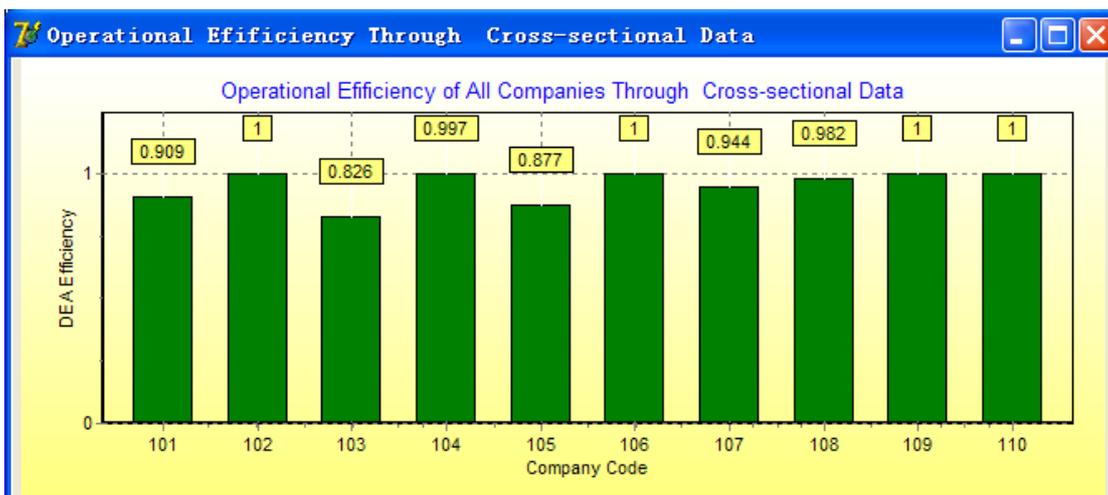


FIGURE.2 EVALUATION OF OPERATIONAL EFFICIENCY THROUGH CROSS-SECTIONAL DATA

From Figure.2, we could gain the companies' efficiency value and their sizes intuitively.

From Figure.3, we could gain the company's efficiency value and their trend in time series intuitively.

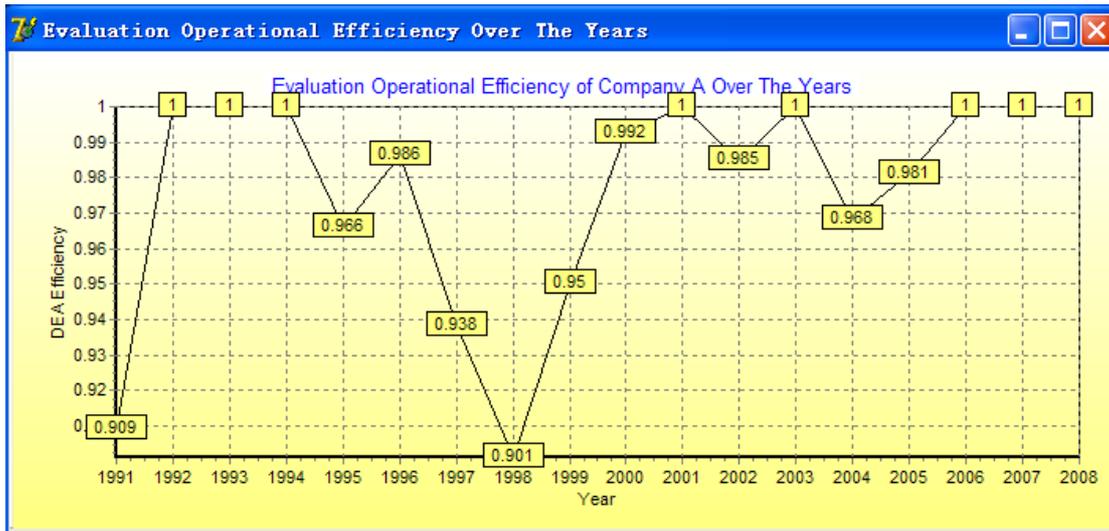


FIGURE.3 EVALUATION OF OPERATIONAL EFFICIENCY OF COMPANY A OVER THE YEARS

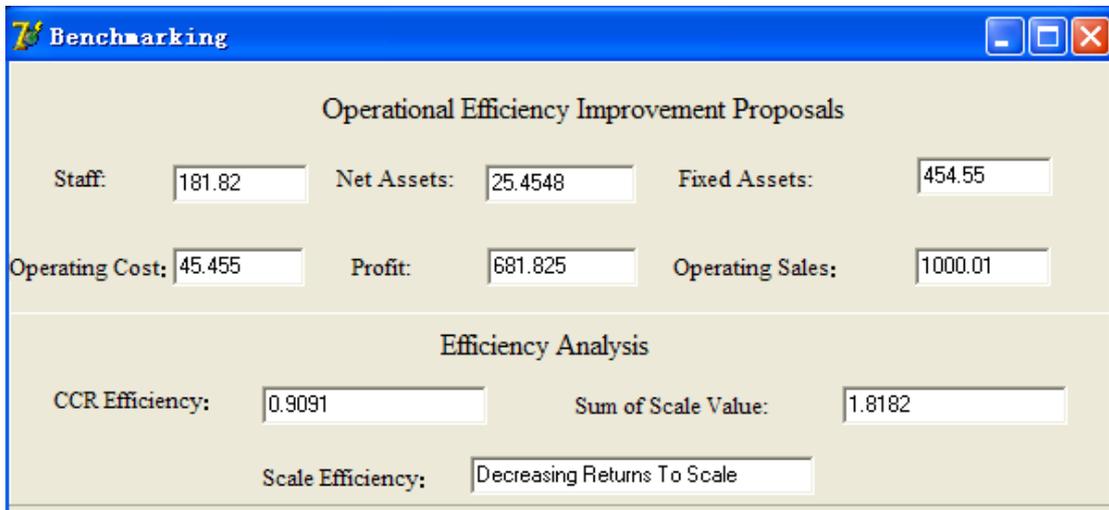


FIGURE.4 BENCHMARKING BASED ON CCR

From Figure.3, we could gain the company's efficiency improvement proposals for efficient and its returns to scale intuitively.

Part of the data used for DMUs' evaluation was generated automatically by the information system. The others were inputted by an interface from outside.

The calculations of the DEA models were operated at computer background. The results were stored in database. When we need the related data, we could call them by programming directly. This approach could reduce the running time apparently. For example, if we should evaluation the Company A's efficiency among all DMUs, we just called the evaluation results in database by using SQL language instead of calculating the DEA models, that was, linear programming. If operations are frequent, the former's advantages, which had low time and space complexity, would show out.

V. CONCLUSION

DEA has been used in many fields popularly. Nowadays, DEA has been used widely in many fields. There are several software tools for dealing with DEA

model, including professional and universal tools. All these tools can deal with some DEA models. However, they can not become part of enterprise management information system perfectly, which is popularly used for management in our firms now. To build efficiency evaluation information system is very useful. This paper briefly introduces the DEA model and the parts which the system should contain. At last, for illustrating our idea, we take an efficiency evaluation information system of a real company A as an example.

As one of the solutions, our proposed approach is only one way to integrate DEA into management information system. This will help managers grasp the state of their company among the same kind companies better. It is also useful to gain the company development trend during the time series. Last but by no means least, the system can make benchmarking and propose some useful suggestions for company too. However, our system is based on personal platform. This may limit its usage in some degree. Therefore some extensions can be studied in the future. The next work we will do is to build an efficiency evaluation information system based on Web.

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