Applied Mathematical Sciences, Vol. 3, 2009, no. 26, 1249 - 1264

Efficiency and Effectiviencess Rating of Organization with Combined DEA and BSC

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Abstract

Measuring the performance of a production system has been an important task in management for purposes of control, planning, etc. Traditional studies in data envelopment analysis (DEA) view systems as a whole when measuring the efficiency, ignoring the operation of individual processes within a system. Our approach integrates the balanced scorecard (BSC) and data envelopment analysis (DEA) for builds a relational network dea model ,taking into account the interrelationship of the bsc within the system . The input and output measures for the integrated DEA-BSC model are grouped in cards which are associated with BSC . With efficiency decomposition, the process which causes the inefficient operation of the system can be identified for future improvement. finally we illustrate the proposed approach with a case study involving six banking branches.

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Keywords: Balanced scorecard, Data envelopment analysis, Network flows

1 Introduction

Measuring the performance of a production system has been considered in management for purposes of control, planning, etc. One technique widely applied to measure the relative efficiency of a set of production systems, or decision making units (DMUs), which utilize the same inputs to produce the same outputs, is data envelopment analysis (DEA). Conventionally, the system is treated as a black box, in which only inputs and outputs of the black box are considered in measuring the efficiency. The performance of the component processes interacting with each other in the system are not considered. DEA is a mathematical programming technique that elaborates the relative efficiency of multiple decision-making units (DMUs) on the basis of observed inputs and outputs, which may be expressed with different types of metrics. The BSC is a management tool composed of a collection of measures, arranged in groups, and denoted as cards. The measures are related to four major managerial perspectives, and are aimed at providing top managers with a comprehensive view of their business.The cards offer balanced evaluation of the organizational performance along financial, marketing, operational and strategic dimensions. BSC combines financial and operational measures, and focuses both on the short- and long-term objectives of the organization. It was motivated by the realization that traditional financial measures by themselves are inadequate in providing a complete and useful overview of organizational performance. Network models dealing with complex and interrelated technologies within the linear activity analysis model introduced by Koopmans (1951) and Dorfman et al. (1958) were initiated by Shephard and Fare (1975) and have been mainly applied to efficiency measurement by Fare and Primont (1984), Fare and Whittaker (1995), Fare et al. (1992) and Lothgren and Tambour (1999). The network model, which accounts for both vertically and horizontally integrated production structures, yields a multi-stage representation of the technology that can be used by researchers to undertake comparisons among independent and competing firms a good illustrating example is given by Fare and Grosskopf (1996).[9] The method that we propose in this paper uses an extended DEA model, which quantifies some of the qualitative concepts embedded in the BSC approach. The integrated DEA-BSC model addresses four common goals that firms are trying to accomplish: (1) achieving strategic objectives (effectiveness goal); (2) optimizing the usage of resources in generating desired outputs (efficiency goal); (3) obtaining balance (balance goal); and (4) obtaining Cause and Effect in Perspectives . The model is applicable for every organizations for-profit. The contribution of the model that is presented in this paper is both conceptual, and excutive for any given DMUthat are devoted to specific output/input measures.[2] The rest of the paper is organized as follows: Section 2 provides dea models and balanced scoredcard . The integrated DEA-BSC simulation model is presented in Section 3,. Section 4discusses a case study that applies the DEA-BSC model. Finally, Section 5 presents concluding remarks.

2 LITERATURE REVIEW

2.1 DEA models

Let X_{ij}, $i = 1...m$ and Y_{rj}, $r = 1...s$, be the ith input and rth output, respectively, of the jth DMU, $j = 1...n$. The DEA model for measuring the relative efficiency of DMU_k under an assumption of constant returns to scale is the CCR model (Charnes et al. 1978):

$$
\begin{aligned}
\max \quad & E_k^{CCR} = \frac{\sum_{r=1}^{s} u_r Y_{rp}}{\sum_{i=1}^{m} v_i X_{ip}} & \\
\text{s.t.} \quad & \frac{\sum_{r=1}^{s} u_r Y_{rj}}{\sum_{i=1}^{m} v_i X_{ij}} \leq 1 & j = 1...n \\
& v_i \geq \varepsilon & i = 1...m \\
& u_r \geq \varepsilon & r = 1...s
\end{aligned}
\tag{1}
$$

where E_k^{CCR} is the efficiency of DMU_k, u_r and v_i are the multipliers associated with the rth output and ith input, respectively, to be determined by this mathematical program, and e is a small non-Archimedean number (Charnes et al., 1979; Charnes and Cooper, 1984) which is imposed to prohibit each

DMU to assign zero weights to unfavorable input/output factors. This model is a fractional linear program which can be transformed into the following linear program:

$$
\begin{aligned}
\max \quad & E_p^{CCR} = \sum_{r=1}^{s} u_r Y_{rp} & \\
\text{s.t.} \quad & \sum_{r=1}^{s} u_r Y_{rj} - \sum_{i=1}^{m} v_i X_{ij} \leq 0, & j = 1...n \\
& \sum_{i=1}^{m} v_i X_{ip} = 1 & \\
& v_i \geq \varepsilon & i = 1...m \\
& u_r \geq \varepsilon & r = 1...s
\end{aligned} \tag{2}
$$

For systems composed of several processes interrelated with each other, this model ignores the performance of individual processes. Consequently, the efficiency does not properly represent the aggregate performance of the component processes. Certainly, Model (2) can be applied to measure the efficiency of each process independently; however, the relationship between the system efficiency and process efficiencies is not revealed.[10] Systems with more than one process connected with each other are networks. To measure the efficiency of a network system a network DEA model is needed. Different from the conventional DEA model, the network DEA model does not have a standard form. It depends on the structure of the network in question. Fare and Grosskopf (1996a, 2000) and Fare et al. (2007) developed several network models that can be used to discuss variations of the standard DEA model.[10]

2.2 Series structure

For a system consisting of two processes connected in series, Seiford and Zhu (1999) applied the conventional DEA model to calculate the efficiency of each process independently. Kao and Hwang (2008) developed a relational model to calculate the efficiency of the system taking into account the series relationship of the two processes. The major difference between the independent model and relational model lies in that the latter requires the same factor to have the same multiplier no matter how it is used while the former allows a factor to have different multipliers when it is used in different places. An interesting result of the relational model is that the system efficiency is the product of the two process efficiencies. Their conclusion can be extended to general series systems of more than two processes. Note that a series model may be solved using backward induction.[10] Consider a series system of h processes. As in the preceding section, letX_{ij} andy_{ij} be defined as the inputs and outputs of the system, respectively. Denote as the pth intermediate product, p = 1, . . . ,q, of process t, t = 1, . . . ,(h -1), for DMU_j. The intermediate products of process t are the outputs of process t as well as the inputs of process t + 1. Note that the intermediate products of the last process h are the outputs of the system. The number of intermediate products, q, can be different for each process. Here, it is assumed that they are the same for all processes just for simplification of notation. Fig. 1 is a pictorial expression of the series system. Denote as the multiplier, or the importance, associated with the pth intermediate product of process t. The system efficiency ofDMU_k is calculated by the following model generalized from the tandem system of Kao and Hwang (2008):

$$\max E_p^{CCR} = \sum_{r=1}^{s} u_r Y_{rp} \quad (3)$$

$$s.t. \sum_{i=1}^{m} v_i X_{ip} = 1 \quad (4)$$

$$\sum_{r=1}^{s} u_r Y_{rj} - \sum_{i=1}^{m} v_i X_{ij} \leq 0, j = 1...n \quad (5)$$

$$\sum_{p=1}^{q} w_p \; z_{pj}^1 - \sum_{i=1}^{m} v_i X_{ij} \leq 0, j = 1...n \quad (6)$$

$$\sum_{p=1}^{q} \; w_p^t \; z_{pj}^t - \sum_{p=1}^{q} \; w_p^{t-1} \; z_{pj}^{t-1} \leq 0, j = 1...n, t = 2...h-1 \quad (7)$$

$$\sum_{r=1}^{s} u_r Y_{rj} - \sum_{p=1}^{q} \; w_p^{h-t} \; z_{pj}^{h-t} \leq 0, j = 1...n \quad (8)$$

$$v_i \geq \varepsilon, i = 1, ..., m, \quad (9)$$

$$u_r \geq \varepsilon, r = 1, ..., s. \quad (10)$$

$$w_r^t \geq \varepsilon, p = 1...q, t = 1...(h-1) \quad (11)$$

(12)

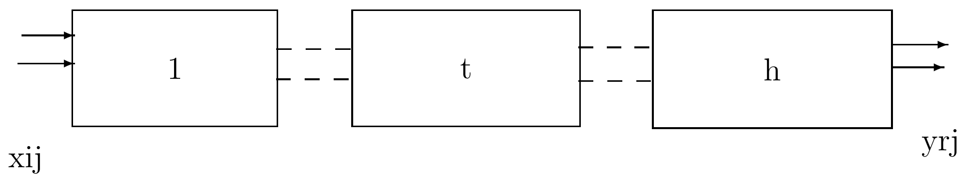

Fig1-serice system

where constraint set (5) corresponds to the system and constraint sets (6), (7), and (8) correspond to h processes. Note that the sum of the process constraints of a DMU, i.e. constraint sets (6), (7), and (8), is equal to its system constraint (5). Hence, the system constraint is redundant and can be omitted. Basically, the number of constraints required in this model is equal to the number of DMUs multiplied by the number of processes in the system. Let U_r^* andW_p^{*t} denote the optimal multipliers solved from Model (3)-(12). The efficiency of each process for DMU k is calculated as:

$$E_k^{(1)} = \frac{\sum_{p=1}^{q} w_p^1 z_{pk}^1}{\sum_{i=1}^{m} v_i X_{ik}} \tag{13}$$

$$E_k^{(t)} = \frac{\sum_{p=1}^{q} w_p^t z_{pk}^t}{\sum_{i=1}^{m} w_p^{t-1} z_{pk}^{t-1}} \tag{14}$$

$$E_k^{(h)} = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} w_p^{h-1} z_{pk}^{h-1}} \tag{15}$$

ADMU is efficient only if all its processes are efficient. Mathematically, the system efficiency will be low if there is a process which is very inefficient and will be high only when all processes have high efficiencies. In Model (3)-(12), when process constraints (6), (7), and (8) are removed, the conventional CCR model is obtained. [10]

3 The Balanced Scorecard (BSC) Approach

The balanced scorecard approach offered by previous studies addresses the issues of divergent stakeholder goals and gauging managers' effectiveness. Many authors argue that existing performance measures are basically too reliant on financial-accounting measures. It is thus necessary to develop a monitoring system that communicates both financial and nonfinancial measures using two combinations of lagging and leading indicators to address a firm's long-term and short term objectives (Yap, Siu, Baker & Brown, 2005; Edward & Thomas, 2005; Papalexamdris, Ioannou, & Prastacos, 2005; Braam & Nijssen, 2004). Kaplan and Nor- ton (1992) propose four balanced perspectives: financial, customer, internal business processes, and learning and growth perspective. They contend that the balanced scorecard retainsnot only an emphasis on achieving financial objectives but also includes the performance drivers of these financial objectives. It is argued that the scorecard enables companies to track financial results while simultaneously monitoring progress in building the capabilities and acquiring the intangible assets for future growth (Koplan & Nortion, 2005; Gumbus, 2005). In this section ,we will examine each of the four perspectives of the Balanced Scorecard.

1- Customer Perspective :When choosing measures for the Customer perspective of the Scorecard, organizations must answer two critical questions: Who are our target customers? and What is our value proposition in serving them?

2-Internal Process Perspective: In the Internal Process perspective of the Scorecard, we identify the key processes the firm must excel at in order to continue adding value for customers and, ultimately, shareholders.

3-Learning and Growth Perspective: If you want to achieve ambitious results for internal processes, customers, and ultimately shareholders, where are these gains found? The measures in the Learning and Growth perspective of the Balanced Scorecard are really the enablers of the other three perspectives. In essence, they are the foundation on which this entire house of a Balanced Scorecard is built.

4-Financial Measures :Financial measures are an important component of the Balanced Scorecard, especially in the for-profit world. The measures in this perspective tell us whether our strategy execution, which is detailed through measures chosen in the other perspectives, is leading to improved bottom-line results.

The balanced scorecard approach should be implemented at all levels of the organization and needs to focus on the key indicators for each of the four perspectives. Senior executives should decide to focus on the single most-important variable or multiple variables for each of the four perspectives. It seems that firms in different industries and different competitive positions tend to focus on different variables for each perspective of BSC. Fletcher and Smith (2004) suggest that, based on BSC, managers must evaluate their business from the four perspectives. They further argue that BSC is an excellent management framework to help managers track many factors that influence performance. The ability of BSC to provide this view depends upon "the construction of a set of performance measures that track how successfully a firm is carrying out its strategies, objectives, and overall mission".

4 Interrelationships among Four Perspectives of BSC

The BSC approach emphasizes that, in order to achieve objectives in the financial perspective, all objectives and measures in other perspectives should be linked (Gosselin, 2005; Laitnen, 2005; Kim & David, 2004). For most organizations, the financial themes of increasing revenues, improving productivity, enhancing assets utilization could provide the necessary linkages. To achieve a synergetic effect, firms should emphasize the cause and effect relationship among the BSC measures. Olve, Roy and Wetter (2000) argued that improved value in human resource and development capital should be the leading indicators of improvement in customer capital and profitability. These authors develop a cause and effect relationship among the BSC measures. Their cause and effect model indicates that the measures of human resource development would influence the internal business process of the firm These interrelationships are shown in Figure2.

A well-designed Balanced Scorecard should describe your strategy through the objectives and measures you have chosen. These measures should link together in a chain of cause-and-effect relationships from the performance drivers in the Learning and Growth perspective all the way through to improved financial performance as reflected in the Financial perspective. Based on the above literature review, it seems that the interrelationships among the four perspectives of BSC have drawn significant attention. However, scholars seem not to reach a consistent agreement on the interrelationships among the four perspective of the BSC. These interrelationships are as follows: (1) the learning and growth perspective of the balanced scorecard impacts on the internal business process perspective of the balanced scorecard; (2) the internal process perspective of the balanced scorecard has the influence on the customer perspective of the balanced scorecard; (3) the learning and growth, internal business process, and customer perspective of the balanced scorecard will significantly impact on the financial perspective of the balanced scorecard.

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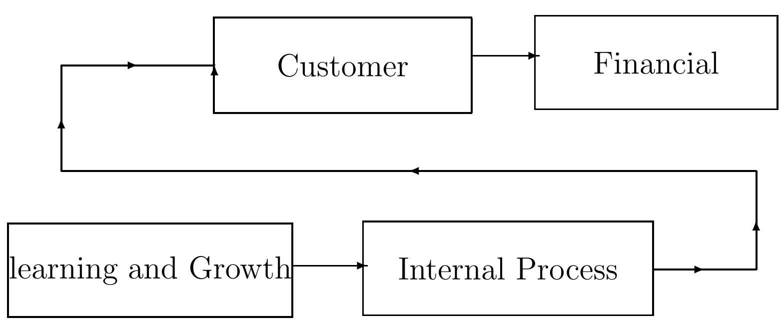

Fig2- cause and effect

5 Balance in the Balanced Scorecar

The concept of balance is central to this system, specifically relating to three areas:[1]. 1. Balance between financial and nonfinancial indicators of success. 2. Balance between internal and external constituents of the organization. 3. Balance betweenlag and lead indicators of performance.

6 The application of DEA into the BSC approach

The increasing use of BSC is changing the way in which top managers run their companies. According to Rickards (2003), BSC helps top managers realize their visions by assisting in developing appropriate strategies, setting new goals, establishing standards or benchmarks, measuring progress, and reporting results pertaining to both monetary and non-monetary vari- ables. However, due to the complexity of the management system of BSC and the interrelated nature of the BSC indicators, this approach clearly confronts managers with an extraordinarily complex optimization problem. DEA can be a helpful tool in dealing with this complexity. DEA, as developed by Charnes et al (1978) and further by Banker et al (1984), is designed to set benchmarking partners and is widely used in various kinds of industry; for example, there are some studies that have tried to measure the productivity and efficiency of container ports using DEA (Tongzon, 2001; Martinez-Budria et al , 1999; Roll and Hayuth, 1993). Thus, application of DEA to evaluate the BSC result may be a good solution to the implementation of the BSC. Richard (2003) argues that DEA is suitable for measuring the best practice of the BSC indicators. The efficiency frontier as measured by DEA can be used to specifically investigate the efficiency of decision-making units (DMUs). The slack could be used as the evaluation of a firm's efficiency on those BSC indicators. It is suggested that DEA can identify how to objectively determine BSC indicators (Rickards 2003). According to Rickards (2003), in order to adopt DEA to evaluate the BSC indicators the following requirements must be taken into consideration. First, all the inputs and outputs for the study must be present in and measurable for each DMU (i.e. there can be no missing data). Second, the relationship between the number of output and input variables to the number of DMUs studied should not exceed a certain upper limit in that practice is generally a ratio of 1:2. Third, the potential input savings or output increases identified in a DEA are not always attainable. Particularly in an operational setting, one simply may not be able to eliminate a DMU's inefficiencies when they involve absolutely small amounts of an indivisible input or output unit. Fourth, the source of the revealed savings or increased production potential is not always evident from the analysis.

7 The integrated DEA and BSC simulation model

The purpose of this study is to find out the relationships among four output perspectives. For such an objective, a structure equation model is employed to test the interrelationships of all the variables in the entire model. The proposed structural equation model is shown in Figure 3.

The techniques such as BSC and DEA are as instruments that can,t be stipulated as an alternative techniques , but the combined use of them in the performance evaluation system appears essential. in the other hand , it can be created a systematic links between two models. It is done so that one of them can be used as a complementary and improve of the weakpoints ,of the model, so using correct and accurate structure of them can be important issues of the performance rating in the organization

The processes of measurement and performance rating using of two techniques BSC and DEA can be setforth in the following issues:

1- the identification of organization : In the processes, the perposes and strategies of relevant organization identified and using from BSC techniques , the measurments that is designed in every view. The measurments are created in balance and with different views.

2- performance rating :The measurments created by BSC are in two groups, input and output, that is classified and using of DEA horizontal evaluation (during the time period)and ,or vertical evaluation (in comparison with similar units in the chronological period)used.

3- the design of path of modification and recovery : The path of modification and recovery are identified by DEA . the modification and recovery path increased for the output measurments and decreased input measurments . 4- the determination of goals of measurement for the next period: The measurments goals which is determind by DEA and placed as measurmentgoals for the next performance of BSC.

In this method , each time of BSC performance , that is in every time that the data of organization entiered into the BSC system and the results are presented the organization is evaluated by DEA and the goals ofmeasurments are recognized in the following period .If it achieved the determined goals, the organization will be efficient and expected conditions. In the next two periods of performance evaluation :the condition of organization compared with the expected conditions of the previouse period and the efficiency of new goals are determined.

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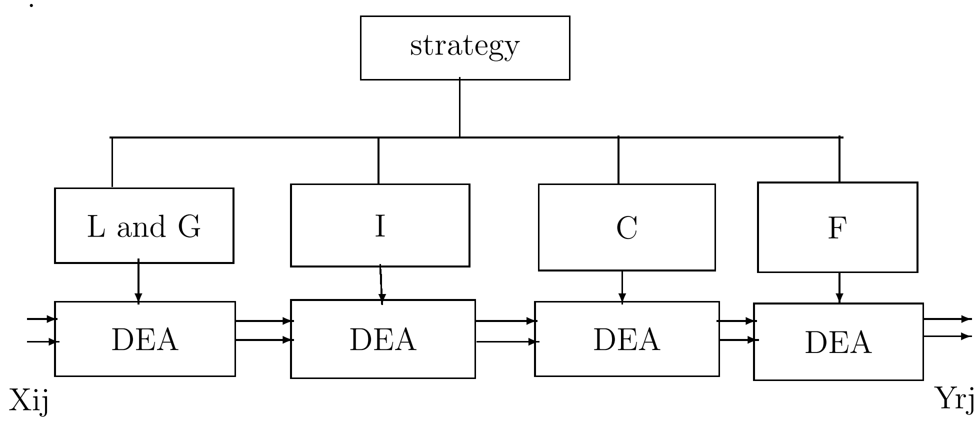

Fig3- The integrated DEA and BSC

8 Case study

We have applied our new approach to six bank branches in iran .The data for the case study are presented in Tables (1 and 2). We have four stages for production process .there are two inputs and two outputs to the first stage (learningand growth). The two inputs are motivation cost and Incrasing personnel major and the outputs are Incrasing personnel skill and Incrasing services rate.there are also three anather stages with nine intermediate measures between them . The evaluation of these units involves many performance aspects; therefore, using 3 finally output measures , two first input measures and 9 intermediate measures for this evaluation is quite reasonable.

DMU	X1	X2	Z1	Z2	T1	T2	T3	T4
1	0.2303	12.11	58.54	800	91	0.0313	1376	0.157
2	0.1872	11.96	30.80	692	57	0.0341	1896	0.189
3	0.185	12.08	46.25	718	8	0.0325	1842	0.34
4	0.053	12.07	18.55	682	37	0.0332	1315	0.335
5	0.17	11.96	39.10	643	34	0.0325	787	0.304
6	0.03	13.66	69	555	10	0.0335	510	0.12

Table 1. DEA-BSC data.

DMU	H1	H2	H3	Y1	Y2	Y3
1	0.0325	0.2291	0.0319	0.0148	0.1742	0.0481
2	0.0321	0.258	0.0361	0.0264	0.1298	0.0716
3	0.0341	0.29	0.0334	0.08	0.4752	0.07
4	0.0312	0.345	0.0341	0.027	0.189	0.014
5	0.0343	0.218	0.0393	0.03	0.2013	0.0123
6	0.0374	0.13	0.035	0.04	0.1028	0.01

Table 2. the case study data.

X1...Y3 measures define as you see in table 3:

X1	motivation cost.
X2	Incrasing personnel major.
Z1	Incrasing personnel skil.
Z2	Incrasing services rate.
T1	Forward service.
T2	High services rate.
T3	Online service.
T3	Competitional value.
H1	Customer satisfaction.
H2	Customer fit of rate.
H3	High quality service.
Y1	Profit margin.
Y2	Growth rate of resource .
Y3	Return of investment.

Table 3. efine of measures ,

Table(4) presents the results of the implementation .The first of column shows the results overall efficiency ,and in the anather columns show the each stages efficiency.

DMU	Overall efficiency	Stage 1	Stage 2	Stage 3	Stage 4)
1	0.26	1	0.63	0.56	0.74
2	0.4	0.85	1	0.47	1
3	0.38	0.89	0.91	0.5	0.89
4	0.07	0.82	0.71	0.85	0.15
5	0.06	0.8	0.44	1	0.19
6	0.049	0.64	0.3	0.94	0.26

Table 4. DEA-BSC results.

It will be unmistakable to get the satisfactory results which is subject to investment and try in the four prespective , that is a long as in this four Perspective , Learning and Growth, nternal Process, Customer and Financial ,don,t work well , getting the successful results undoubly won of be acquired.

9 Conclusion

Traditional studies in DEA view systems as a whole, ignoring the performance of their component processes in calculating the relative efficiency of a set of production systems. The deficiencies are, firstly, that the efficiency score may not properly represent the aggregate performance of the processes of a system. Secondly, it does not show which process causes the low efficiency of an inefficient system. The existing models in network DEA partially improve these deficiencies. Since, in terms of the multipliers used, each process is independent, a mathematical relationship between the process efficiencies and the system efficiency is not revealed. This paper builds a relational network DEA model to measure the efficiencies of the system and component processes at the same time, taking into account the operation of individual processes in the network structure. The DEA-BSC model advances the individual capabilities of DEA and BSC. From the viewpoint of DEA, the model generalizes the standard treatment of the data by splitting the inputs and outputs into subsets (cards), and adding constraints (balancing requirements) that reflect relationships among the cards. From the viewpoint of BSC, the model proposes a new approach to evaluate performance by applying quantitative analysis that combines the measures within each card into a single value. It also addresses some of the difficulties in existing BSC applications, namely, reliance on a known (sometimes arbitrarily chosen) baseline against which performance is evaluated and the fact that BSC does not produce a single, comprehensive measure of performance.

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Received: October, 2008