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Multi-Component Balanced Scorecard for Perspectives Efficiency Measurement

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Abstract

Measuring efficiency of each cards of a balanced scored problem seems to be essential to be informed from organization performance about the defined strategy for further directing. Finding a method which can separately evaluate efficiency of cards with common data is a major point in which the main task is efficiency assessment of each perspectives with common inputs and outputs. In this paper Multi Component Efficiency assessment in Data Envelopment Analysis (DEA) technique has been used for efficiency evaluation of card performance in a balanced scored problem. The acquired efficiency scores from this method shows the performance of that organization only in one card while the common resources are being utilized among all of the cards.

Keywords: Balanced Scorecard, Data Envelopment Analysis, Efficiency, multi component

1 Introduction

Data envelopment analysis (DEA) which is introduced by Charnes et al. [2], has been presented a constant return to scale (CRS) model for assessing the

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performance of a set of resemble decision making units (DMUs). In the usual setting, each DMU is assessed in terms of a set of outputs that represent its achievements, and a set of inputs that represent the available resources. As described in literature, DEA has been applied to variety of problems. The variable returns to scale version of the model has been introduced by ,Banker et al. [1]. In 2000, Cook et al. [3] proposed a method to determine a multi- component efficiency measurement with shared inputs. In many circumstances however, the DMUs involved may perform several various functions, or can be separated into different components. In such situations, inputs are often shared among those components and all components are involved in producing some outputs. This sharing phenomenon will commonly present the technical difficulty of how to decompose an overall measure into component parts. In such conditions, we have to determine the performance of DMUs in each component.

Balanced scorecards are having a fundamental influence on executives strategic decision making by promoting their use of future-oriented, non-monetary success indicators. In his article Rickards [6] has explained how to create a balanced scorecard with a reasonable number of indicators, set appropriate benchmarks for them, and evaluate overall management performance against those benchmarks. Garcia-Valderrama et al. [4] in their article proposed a framework for analysis of the relationships between the four perspectives of the balanced scorecard (BSC) of Kaplan and Norton [5] . Therefore, several different models of efficiency have been developed while DEA technique is used. Each of the variables has been extracted from a model of the BSC for research and development (R&D) activities. Banker et al.[1] mentioned that many organizations have invested substantial resources in recent years to implement a balanced scorecard of performance metrics thus in their paper they investigated the best practice frontier relationship between a financial performance metric and three non financial performance metrics reported and used in the UStelecommunications industry.

In this paper the problem in question is to efficiency assessment for of each perspective of balanced scorecard problem in a way that in these perspectives or cards there exist common inputs and outputs and it is not possible to evaluate each card separately. Considering multi component efficiency assessment while DEA technique is used the problem is mooted.

The paper unfolds as follows: in section 2, background of DEA and BSC will be briefly reviewed. Through section 3, the proposed method will be presented. An empirical illustration is documented in section 4, and section 5 concludes the paper.

2 Background

2.1 Data Envelopment analysis

Data envelopment analysis (DEA) is a method for determining the relative efficiency of a set of organizational units such as schools or bank branches when there are multiple inputs and outputs. The DEA method has been introduce in 1987 by Charnes et al, [2] and later extended to one of the scientific managerial methods in Performance evaluation. Efficiency measurement using tools such as DEA, as proposed by Charnes et al. [2], has tended to concentrate on achieving a single measure of efficiency for each member of a set of DMUs. One of the significant feature of this method would be determining the production function by DEA. Considering this function it is possible to judge how a DMU is utilizing inputs to produce outputs. DEA models verify rational efficiency of a DMU which the weighted sum of outputs to that of inputs. Actually rational effects which affected by each DMU, show its efficiency on the frontier.

2.2 Balanced Scorecard

As the methodology for solving internal and external problems of the organizations and their improvement BSC was suggested by Kaplan & Norton [5]. Moreover it helps considering their total targets and criteria which identify the strategy and target of the organization for units of the organization from top to down. Traditional Performance Evaluation system, are mainly based upon financial scale which overweight the company's short term Profit deficit and importance effective parameter to company profit, however respectively decreasing all major parameter regarding to expenses such as employee training plans and R & D activities suspension may increase the company's profit, but will cause company to lose its competitive situation in the market & endanger it's long term profit. Therefore in order to perform a complete evaluation of organization Performance, it must be evaluated in 4 perspectives as follows which is one of the aims of comprising method discussed in this session.

- Financial Perspective.
- Customer Perspective.
- Internal Process Perspective.
- Learning and Growth Perspective.

In fact BSC method shows, how Learning and Growth of employee conclude to modification of internal processes and well rectification of them. Consequently, it will cause to establish and improve particular value to the customer and market; finally will conduct to increasing the company's portfolio or its financial improvement.

2.3 Multi component efficiency

Consider the CRS model which was first introduced for relative efficiency evaluation, by Charnes et al. (1978) as follows:

$$\begin{array}{ll} \max & \frac{U^t Y_o}{V^t X_O} \\ s.t. & \frac{U^t Y_j}{V^t X_j} \leq 1, \quad j = 1, ..., n, \\ & U \geq 0 \quad V \geq 0. \end{array} \tag{1}$$

In which input vector X_k is used to produce output vector Y_k for each DMU_k, $k = 1, ..., n$. The structure in (1) pays no attention for the performance of subunits that may exist within the DMU. Under such condition assumes that one desires to measure the overall efficiency of each DMU. Thus it is needed to provide a performance measurement tool with component-based information as part of the aggregate efficiency score, while the components of a DMU is being emphasized. Now, let $Y_1^k, Y_2^k, ..., Y_n^k$ be the set of each component transactions of DMU_k in which

$$Y_k^i = (Y_{k1}^i, Y_{k2}^i, ..., Y_{kJ_i}^i), i = 1, ..., b.$$

Moreover, let $X_1^k, X_2^k, ..., X_n^k$ be $I_1, I_2, ..., I_b$-dimensional vectors of dedicated inputs to each components and X_k^c be a I_c-dimensional vector of shared inputs. All components are involved in producing the J_c-dimensional vector of output Y_k^c. Some portion α_i of the shared input X_k^c is allocated to the *ith* component. Also, *ith* component is involved in producing some portion β_i of the shared output Y_k^c. It should be noted that $\alpha_i \geq 0$, $\beta_i \geq 0$ and $\sum_{i=1}^b \alpha_i = 1, \sum_{i=1}^b \beta_i = 1$. In this model α_i and β_i are decision variables which must be determined. Thus a measure of aggregate performance e_k^a has been represented as the following in which the operation * for two vectors like $K \in R^n$ and $L \in R^n$ is defined as $(k_1 L_1, ..., K_n L_n) \in R^n$.

$$e_k^a = \frac{U^{1t} Y_k^1 + ... + U^{bt} Y_k^b + U^{S_1 t} * \beta_1 Y_k^c + ... + U^{S_b t} * \beta_b Y_k^c}{V^{1t} X_k^1 + ... + V^{bt} X_k^b + V^{S_1 t} * \alpha_1 X_k^c + ... + V^{S_b t} * \alpha_b X_k^c}$$

such that $\sum_{i=1}^b \alpha_i = 1, \sum_{i=1}^b \beta_i = 1$. In this representation, the vectors U and V would be determined in a DEA manner as discussed below. Now, while e_k^a is being considered, performance measures for each components of DMU_k can be represented from the following expression.

$$e_k^i = \frac{U^{it} Y_k^i + U^{S_i t} * \beta_i Y_k^c}{V^{it} X_k^i + V^{S_i t} * \alpha_i X_k^c}, i = 1, ..., b.$$

Moreover, it has been proven that the aggregate performance measure e_k^a is a convex combination of e_k^i s. To derive $e_k^a, e_k^1, e_k^2, ..., e_k^b$ the following mathematical program has been introduced. where ε is a nonarchimedean constant.

By applying Charnes and Cooper (1978), the following model will be derived which in the multiplier form. Moreover, Since α_i and β_i are decision variables, the problem is clearly nonlinear. By making the change of variables $\bar{U}^{s_i} = U^{si}\beta_i$ and $\bar{V}^{s_i} = V^{si}\alpha_i, i = 1, ..., b$ this problem reduces to the following form:

$$\begin{aligned}
\max \quad & \sum_{i=1}^{b} U^{it} Y_k^i + \sum_{i=1}^{b} \bar{U}^{s_i t} Y_k^c \\
s.t. \quad & \sum_{i=1}^{b} V^{it} X_k^i + \sum_{i=1}^{b} \bar{V}^{s_i t} X_k^c = 1 \\
& \sum_{i=1}^{b} U^{it} Y_j^i + \sum_{i=1}^{b} \bar{U}^{s_i t} Y_j^c - \sum_{i=1}^{b} V^{it} X_j^i + \sum_{i=1}^{b} \bar{V}^{s_i t} X_j^c \leq 1, j = 1, ..., n, \\
& U^{it} Y_j^i + \bar{U}^{s_i t} Y_j^c - \bar{V}^{it} X_j^i - \bar{V}^{s_i t} X_j^c, \quad i = 1, ..., b, \quad j = 1, ..., n, \\
& U^i \geq \varepsilon \quad V^i \geq \varepsilon, \quad i = 1, ..., b, \\
& U^{s_i} \geq \beta_i \varepsilon \quad V^{s_i} \geq \alpha_i \varepsilon, \quad i = 1, ..., b, \\
& 1\alpha = 1, 1\beta = 1, \alpha_i \geq 0, \beta_i \geq 0, \quad i = 1, ..., b.
\end{aligned} \tag{2}$$

3 Perspective Efficiency and Application

In balanced evaluation it seems essential to assess efficiency of each cards solely for performance monitoring of organizations. Having a thorough knowledge from card performance with common inputs and outputs for re-directing organization about the defined strategy for managers is of fundamental importance and it is needed to examine each of the performances with a suitable method. In this paper the problem in question is to evaluate efficiency of each perspective of balanced scorecard problem in a way that in these perspectives or cards there exist common inputs and outputs and it is not possible to evaluate each card separately. The indexes used in this project are listed in the following tables (Table 1). Moreover in these tables the importance of weights of each indexes have also been indicated.

Table.1 *Inputs indexes*

index	*Input*	*Importance Weights*	*index*	*Output*	*Importance Weights*
$I1$	*Motivational Expense*	7	$O1$	*Advance Service*	6
$I2$	*Competitive Pricing*	6	$O2$	*High Speed Service*	4
$I3$	*rate of Overdue*	8	$O3$	*High Quality Service*	6
$I4$	*Loans Expense/ Income Ratio*	10	$O4$	*Return of the Capital*	10
$I5$	*Increasing Personal Proficiency*	8	$O5$	*Increasing Personal Skills*	6
$I6$	*Electronic Service*	4	$O6$	*Online Service*	5
$I7$	*Speeding up the Service*	4	$O7$	*interest Margin*	8
			$O8$	*Customer Satisfaction*	7
			$O9$	*Customer Attraction Rate*	5
			$O10$	*Capital Growth rate*	5

The input-output data are gathered in Table 2 and 3. These data are obtained through performing balanced scorecard method in a commercial bank in 2010.

Table.2 *Inputs*

No.	*I*1	*I*2	*I*3	*I*4	*I*5	*I*6	*I*7
1	0.2924	0.31570	0.45926	0.01962	12.1664	1691	907
2	0.2090	0.52668	0.33944	0.06422	11.9852	2173	842
3	0.1901	0.69747	0.46077	0.13235	12.0883	2161	824
4	0.0630	0.83851	0.52933	0.06398	12.1312	1550	755
5	0.2596	0.36806	0.56144	0.06952	12.0703	806	820
6	0.4286	0.23710	0.96000	0.08723	13.6636	627	577

Table.3 *Outputs*

No.	*O*1	*O*2	*O*3	*O*4	*O*5	*O*6	*O*7	*O*8	*O*9	*O*10
1	108	0.031	0.031	0.20	74.52	1410	0.03	0.032	0.24	0.46
2	68	0.034	0.036	0.15	78.12	2236	0.03	0.032	0.53	0.34
3	60	0.032	0.033	0.13	55.50	2138	0.12	0.034	0.49	0.46
4	42	0.033	0.034	0.04	55.66	1574	0.04	0.031	0.45	0.53
5	39	0.032	0.033	0.03	59.71	836	0.04	0.034	0.36	0.56
6	14	0.034	0.035	0.18	69.00	570	0.05	0.038	0.34	0.96

In his model for balanced evaluation, the common inputs and outputs are as follows which are specified after investigating experts opinions. In this paper using the above-mentioned indexes, a method for balanced evaluation has been defined as follows. In this model the cards are characterized on basis of defied strategy and connected to each other. Figure 1 shows a balance scorecard network. The above-mentioned figure shows the presented model for balanced

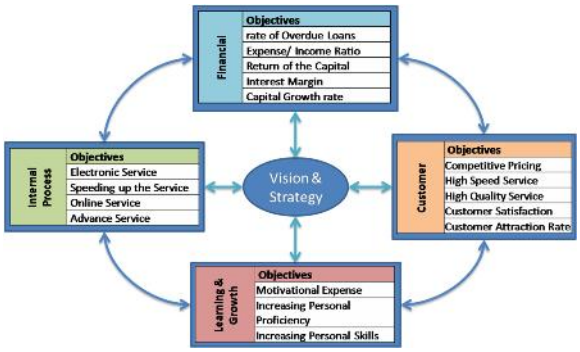

Figure 1: *Balanced Scorecard diagram.*

evaluation in this paper in which inputs and outputs of each cards are classified as follows. Here what gains the major importance is that some of the items for these cards are held in common. That means although motivational expenses index is defied for learning and growth, it uses from financial resources thus it has influenced financial card. This partnership prevents from evaluating each of the indexes solely. Also, it is not possible to evaluate these indexes without considering their partnership with others. Therefore, it reveals the importance of using multi component efficiency evaluation for efficiency assessment of these cards with common resources. The provided model for balanced evaluation is schematically portrayed in Figure 2.

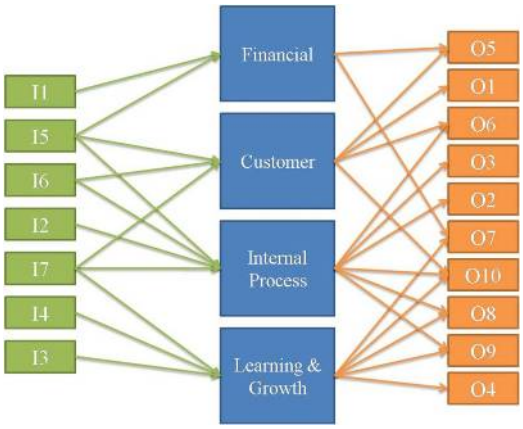

Figure 2: *Multi Component Input and Output diagram.*

4 Results

The acquired results from performing this model is interesting. With calculating the component efficiency of balanced scorecard, performance of each card will be specified solely. It should be noted that under such circumstances just for some cards it is possible to introduce new targets while considering compensation of inefficiency in this new period. Which means that in this new period the mentioned unit should both compensate its inefficiency and reach the target. But, the important thing is that disposability must be considered in this new target. Since the task of a unit, which could be efficient in last period, in this period will be more hard and it requires a new survey in its process to have the ability of reaching new target within compensating the previous inefficiency. According to the obtained results which are listed in Table 4 unit 3 has the highest aggregate efficiency but in the customer perspective it has the efficiency of 0.78 and this shows that this unit is inefficient in customer perspective. Meanwhile units 1 and 6 has the efficiency score of 1 in customer perspective thus these units can be targets for unit 3. In this manner unit 1, which is the second unit due to the aggregate efficiency, has the efficiency score of 0.21 in inter process perspective and it has efficiency score of 0.96 in financial perspective. As a result, units 3 and 4 in financial perspective and units 3, 5 and 6 in internal perspective, can be targets for unit 1 and also they can make improvements in their performances for future periods.

Table.4 *Results*

No.	*Aggregate Efficiency*	*Financial*	*Customer*	*Internal Process*	*Learning & Growth*
1	0.998590558	0.21533685	1	0.96925635	1
2	0.982929585	0.43236725	0.63914878	0.99980505	0.9840398
3	0.999357917	1	0.78746492	1	1
4	0.990602679	1	0.77807824	0.83486654	0.99128152
5	0.995868459	0.24086588	0.84130594	1	0.73827446
6	0.997991773	0.28396877	1	1	1

5 Conclusion

In this paper the efficiency of each perspectives of balanced evaluation model have been calculated via multi component efficiency assessment in DEA technique and the aggregate and component efficiencies have been obtained. Considering the obtained efficiency scores from this method performance of organization for reaching the defined goals of balanced evaluation on basis of organization strategy, can be measured. The important task is to find the weakness of each perspective under the condition that each of them uses the common resources. Considering the obtained efficiency for each of the cards, a suitable target can be found for compensating inefficiency. Also target of the new period can be obtained by removing the inefficiency of the last period. The significant feature of this method is evaluating efficiency for each perspective with common inputs and outputs and moreover is to find a suitable target for inefficient cards. For further investigation relevant to this issue is to better forecasting for the new periods by compensating the inefficiency of the last periods.

References

[1] R.D. Banker, H. Chang, S.N. Janakiraman, C. Konstans, A balanced scorecard analysis of performance metrics, *European Journal of Operational Research,* **154** (2004), 423436.

[2] A. Charnes, W.W. Cooper, E. Rhodes, Measureing the efficiency of decision making units, *European journal of operational reaserch,* **2** (1978),429-444.

[3] W.D. Cook, M. Hababou, H.J.H. Tuenter, Multicomponent efficiency measurement and shared inputs in DEA: an application to sales and service performance in bank branches, *Journal of Productivity Analysis,* **14** (2000), 209-224.

[4] T. Garcia-Valderrama, E. Mulero-Mendigorri, D. Revuelta-Bordoy, Relating the perspectives of the balanced scorecard for R & D by means of DEA, *European Journal of Operational Research.* **196** (2009), 11771189.

[5] R.S. Kaplan, D.P. Norton, "The balanced scorecard measures that drive performance", *Harvard Business Review,* (1992), 71-9.

[6] R.C. Rickards, Setting benchmarks and evaluating balanced scorecards with data envelopment analysis, *Benchmarking: An International Journal,* **10** (2003), 226-245.

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