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The combination of data Envelopment analysis and Balance scorecard card to provide an evaluation and ranking model and its application in R&D projects.

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Abstract
The issue of assessing R&D projects is a kind of decision-making. This assessment includes multi-criteria indicators related to the organization's mission and purpose, the potential of strategy influence, the possibility of commercial and technical success, and so on. Therefore In this article, by combining two data coverage analysis techniques, data envelopment analysis DEA and balanced scorecard (BSC), a broad DEA model is developed, and the obtained model is used to evaluate R&D research and development projects. Efficient projects are identified, and Using the Anderson-Peterson model, efficient projects are ranked. At the end of the article, a brief comparison is made between DEA and DEA-BSC methods.
Keywords: Data envelopment analysis, Balance scorecard card, Efficiency, R&D projects.

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1. Introduction

This paper develops an analytical model with the aim of evaluating R&D projects. The issue of evaluating R&D projects is a kind of decision making. This assessment includes multi -criteria indicators related to the organization's mission and its purpose, the potential of strategy influence, the possibility of commercial and technical success, and so on. When evaluating, we have two categories of quantitative and qualitative scale. At qualitative scales, opinions and diagnoses are often replaced by data. While few scales such as return on capital are sometimes estimated. Quality indicators such as customer satisfaction are potentially important. In such organizations, qualitative indicators have a share in evaluation. Since projects compete with resources, they should be evaluated and prioritized despite these problems. The model we present in this paper is trying to respond to these challenges by combining two management methods called Data Card Analysis.

DEA is a linear programming technique that calculates the relative efficiency of multiple decision -making units based on the input and outputs observed. The basic concept of DEA is measuring the performance of a partial decision -making unit in front of the point designed on an efficiency boundary.

The importance of DEA in evaluating multi -criteria systems is evident. Specific DEA models have been proposed by Ural [1] and Koja [2] and Baker [3] in terms of technology selection or R&D project evaluation. BSC is a management tool that consists of indicators arranged in groups and appears as a score card. These indicators are related to four managerial aspects and their aim is to provide a comprehensive view for the senior manager in the business in question. These cards propose a Balance evaluation of the organization's performance in financial, commercial, operational and strategic dimensions. Most organizations today adapt the following goals to the BSC policy for managing processes:

1. Transparent vision and translation of strategy
2. Design of strategy initiatives
3. Dialogue and links strategic indicators and goals
4. Raise strategic learning and feedback

In the past decades, the issue of R&D project evaluation has attracted much attention and has led to diversity in evaluation methods. These methods try to develop quantitative indicators and evaluate the implementation of R&D projects by collecting mental and objective information. The overall review of these projects was first carried out by Freland and Baker [4], Pounds and Baker [5], Daniela [6], Smith and Freland [7] and Henriken and Tinor [8]. Recently, some researchers have suggested DEA as a tool for evaluating R&D projects [3,9] they categorized the appropriate evaluation indicators as the DEA model outputs and inputs Sang Chang [10] and Ural [1] of the Performance Rating Ranking of R&D projects used.

In this paper, we use the weighted restriction techniques that form the meaning of the meaningful size in the DEA, the model presented uses the wide -range DEA model, which quantitatively expresses some of the qualitative concepts in the BSC policy. BSC is a management tool that is made up of indicators located in groups of groups and appears as cards. Founded in year 1992 by professors at Harvard Robert Kaplan and David Norton [9].

The DEA-LBC model was introduced by Glani [11] and the following three common goals that most factories were trying to do are expressed.

1- To obtain strategic goals (executive goal)

2- Optimization of the use of resources in the production of required outputs (efficiency target)

3- Balance

2. Subject literature

2.1 Data cover analysis

In this section we briefly examine the DEA model. Suppose we have n up to DMU. With their help, we make up a set of PPS and determine the performance of each DMU according to PPS and Performance Border. Data domain to obtain n DMU performance as a set A consisting of n point $a_1, a_2, ..., a_n$ that we consider each point for a DMU. Each point of two types of components arrived. The first type M is input so that $0 \neq x_j \geq 0$ and the second type are composed of the output s is $0 \neq y_j \geq 0$, so we organize the data as follows:

$$A = [a^1, a^2, ..., a^n],$$

$$a^j = \begin{pmatrix} y_j \\ -x_j \end{pmatrix}; j = 1, 2, ..., n$$

This is a $M + S$ matrix in the next n. Used to estimate the technical performance of DEA for P-th DMU Model by Charles [12] This model is known as the CCR model:

$$\max e_p = \sum_{r=1}^{s} u_r y_{rp} \qquad (1)$$

$$s.t: \quad \sum_{r=1}^{s} v_i x_{ip} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{r=1}^{s} v_i x_{ij} \leq 0 \; ; j = 1, 2, ..., n$$

$$u_r \geq \varepsilon ; r = 1, 2, ..., s$$

$$v_i \geq \varepsilon ; i = 1, 2, ..., m$$

If the optimal model of model (1) is equal to one, we call DMU_p.

2.2 Balance Scorecard

Balance evaluation emerged in the late 1980s and early 1990s as a way to help organizations in complex and multidimensional environments at that time Professor Robert Kaplan and David Norton. Harvard University Accounting Professors, researching in four different companies, found the bugs of evaluation systems relying on these organizations. The main purpose of the BSC is to change the traditional evaluation system - which focused only on financial indexes - to provide a better and better performance assessment model. In the BSC, the financial aspect remains the main foundation of this assessment. But the other three aspects, such as customers, growth and learning and internal processes need to be more Balance. The aspects of the BSC are below:

Financial aspect: This aspect reflects the past performance of a company that includes the realization of financial goals and the implementation of strategy. He also examines how organizations grow and control the progress and registration of that organization's strategy. Evaluation indexes in this aspect usually include capital -to - capital costs, network interest rates, and so on.

Customer aspect: When choosing scales for the customer's view on the scorecard, the organization must answer two important questions: Who are the target customers? What is our proposed value to serve them? By focusing on these two organizations, it can distinguish itself from its competitors. Customer satisfaction is the main theme of most management systems because in these systems customers are at the beginning and end of the processes. On the one hand, systematic identification of customer requirements is a definite requirement, and on the other hand, customer satisfaction information is a variable that is examined in evaluation of management system performance. In this regard, the responsibility and accountability of the senior management of the organization has been emphasized on customer satisfaction.

Internal processes aspect: In this aspect we show that the internal operational process of organizations must follow an operational strategy map designed by themselves. Organizations should also do the best operations to achieve customer and shareholders' expectations. In this respect, key processes are identified where organizations need to be superior to continue to increase value for customers. Examples of indicators in this aspect are: proportionality of cooperation with other operations and team satisfaction index.

Learning and growth aspect: If organizations want to have proper operational development, they must rely on continuous growth and change. In the age of the workforce, organizations, unlike the predecessors who rely on the physical assets of the company, well realized that human resource knowledge is a decisive point in the business environment. Sharing a Balance evaluation system throughout the organization provides the opportunity for the organization's human resources to discuss assumptions that form the basis of strategy. Examples of the indicators of this aspect are: increasing employee skills, increasing the performance of information systems, and reducing employee authority.

3. DEA-SC assessment model

DEA consists of a model family with different assumptions on the output to input ratio. Initially, a model of DEA is selected that is best compatible with the details of the environment. For example, when evaluating a set of different projects with different needs and resources that compete for the same source, the variable -scale return model can be more appropriate than a fixed -scale return. On the contrary, when projects are homogeneous, a fixed-scale model is more appropriate. This paper chooses a fixed-scale propulsion model according to R&D projects. Below, suppose n is available in the R&D project, each using a different amount of m and generating different outputs. Matrix m at n is introduced with x and Matrix s in the out outputs with y. Corresponding to the input and output weights are displayed in order of $u=\{u_r\}$ & $v=\{v_i\}$. The DEA-LBC model develops the CCR model by combining the BSC structure. This structure is created by a set of Balance restrictions related to the aspects of the scorecard.

3.1 Single DEA-BSC model

To define the structure of BSC, a selection of inputs and outputs is considered. Focusing on the Balance limit of the output, let's assume that a subset of the set of outputs is K cards, in this way, the relation (3) is established.

$$\sum_{k=1}^{K}\Big(\sum_{r\in O_k} u_r y_{rj} \Big/ \sum_{r=1}^{s} u_r y_{rj}\Big)=1 \quad \forall j \qquad (3)$$

The value of the expression $S_k=(\sum_{r\in O_k} u_r y_{ro})/(\sum_{r=1}^{s} u_r y_{ro}) \quad k=1,2,...,K$ is a dimensionless quantity that represents the ratio of the final output of the project P_o to the card O_k. Most projects depend on outputs in O_k to determine their head-to-head score. In order to reflect the desired balance, a manager can impose limits on what may be appropriate upper and lower bounds for the relative importance of each card. The single DEA-BSC model adds the constraint set (4) as well as the corresponding input-dependent constraint set to the multiplicative form of the CCR model in the input state.

$$L_k \le \frac{\sum_{r\in O_k} u_r y_{ro}}{\sum_{r=1}^{s} u_r y_{ro}} \le U_k \quad ;k=1,2,...,K \qquad (4)$$

3.2 Multiple DEA-BSC model

We use graphical representation to combine a more general BSC structure with multiple hierarchical levels. Let $G_I(N_I, E_I)$ & $G_O(N_O, E_O)$ be the graphs corresponding to the set of output and input indicators respectively. Focusing on the outputs, suppose O_t represents the $t \in N_O$ node in the graph, which represents a card and contains a subset of the output indices. $(t, j) \in E_O$ indicates the capacity relationship that different cards have together, i.e. $O_j \subset O_t$. Therefore, the set of cards with the same number form an O_t collection, which means that they do not contain more than one single indicator sample and generally create the father card. This specification defines a hierarchical structure represented by a spanning tree. The model related to this structure is given below, which results from the combination of constraints (4) and the CCR model in multiple mode:

$$
\begin{aligned}
&\max e_o = \sum_{r=1}^{s} u_r y_{ro} \qquad (5)\\
&s.t: \quad \sum_{r=1}^{s} v_i x_{io} = 1\\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{r=1}^{s} v_i x_{ij} \le 0 \; ; j = 1,2,\dots,n\\
&L_{O_k} \sum_{r=1}^{s} u_r y_{ro} - \sum_{r \in O_k} u_r y_{ro} \le 0 \quad ; k = 1,2,\dots,K_o\\
&-U_{O_k} \sum_{r=1}^{s} u_r y_{ro} + \sum_{r \in O_k} u_r y_{ro} \le 0 \quad ; k = 1,2,\dots,K_o\\
&L_{I_k} \sum_{i=1}^{m} v_i x_{io} - \sum_{i \in I_k} v_i x_{io} \le 0 \quad ; k = 1,2,\dots,K_I\\
&-U_{I_k} \sum_{i=1}^{m} v_i x_{io} + \sum_{i \in I_k} v_i x_{io} \le 0 \quad ; k = 1,2,\dots,K_I\\
&u_r \ge \varepsilon ; r = 1,2,\dots,s\\
&v_i \ge \varepsilon ; i = 1,2,\dots,m
\end{aligned}
$$

4. Rating model

As mentioned, to find the efficiency, the distance of the points under evaluation is obtained from the PPS and the efficient DMUs are determined. In this part of the paper, the DMUs are ranked by the model that is presented. For this purpose, the DMU is constructed under the evaluation of the elimination observations and the new PPS. Then the distance of the removed DMU from the new PPS is used as the ranking criterion. The longer this distance, the lower the efficiency rating of the DMU.

$$
\begin{aligned}
&\max A_o = \sum_{r=1}^{s} u_r y_{ro} \qquad (6)\\
&s.t: \quad \sum_{r=1}^{s} v_i x_{io} = 1\\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{r=1}^{s} v_i x_{ij} \le 0 ; j = 1,2,\dots,n \; , \; j \ne o\\
&L_{O_k} \sum_{r=1}^{s} u_r y_{ro} - \sum_{r \in O_k} u_r y_{ro} \le 0 \quad ; k = 1,2,\dots,K_o\\
&-U_{O_k} \sum_{r=1}^{s} u_r y_{ro} + \sum_{r \in O_k} u_r y_{ro} \le 0 \quad ; k = 1,2,\dots,K_o\\
&L_{I_k} \sum_{i=1}^{m} v_i x_{io} - \sum_{i \in I_k} v_i x_{io} \le 0 \quad ; k = 1,2,\dots,K_I\\
&-U_{I_k} \sum_{i=1}^{m} v_i x_{io} + \sum_{i \in I_k} v_i x_{io} \le 0 \quad ; k = 1,2,\dots,K_I\\
&u_r \ge \varepsilon ; r = 1,2,\dots,s\\
&v_i \ge \varepsilon ; i = 1,2,\dots,m
\end{aligned}
$$

5- Numerical example

In this section, we present an example whose purpose is to study an R&D project in an industrial research laboratory. The data for this research is presented in the form of 50 units, the indicators used are collected based on the proposals of the political sector, such projects are included in the range of 30 to 60 units, so using 11 outputs and 2 inputs for this evaluation is completely wise. The goals of this project are in line with the long-term goals of the organization before the specific technical goals. The conventional DEA model may fail to correctly distinguish between these units. Therefore, DEA-BSC model is used for more accurate ranking of units. For this evaluation, we have two categories of limits, which create two policies. The limits related to these two policies are also given in table (1).

Table 1: Limit values in two management policies

Balance bounds used for the implementation of the DEA–BSC model in the case study

Card label	Card\measure	1st case		2nd case	
		Lower bound	Upper bound	Lower bound	Upper bound
O1	**Financial perspective**	**0**	**1**	**0.3**	**0.7**
	Discounter cash flow	–	–	–	–
O2	**Customer perspective**	**0**	**1**	**0.06**	**0.46**
	Customer focus group feedback	0.4	0.6	0.4	0.6
	Performance improvement metrics	0.4	0.6	0.4	0.6
O3	**Internal-business perspective**	**0**	**1**	**0.06**	**0.46**
	Congruence	0.32	0.52	0.32	0.52
	Importance	0.24	0.44	0.24	0.44
	Synergy with other operations	0.24	0.44	0.24	0.44
O4	**Learning and growth perspective**	**0**	**1**	**0.06**	**0.46**
	Propriety position	0.4	0.6	0.4	0.6
	Platform for growth	0.24	0.44	0.24	0.44
	Durability	0.16	0.36	0.16	0.36
O5	**Uncertainty perspective**	**0**	**1**	**0.12**	**0.52**
	Probability of tech & com success	–	–	–	–
I1	**Resources**	**0**	**1**	**0**	**1**
	Investments	–	–	–	–

Table 2: Ranking results of efficient units using the CCR model

Efficient unit on CCR model	DMU2	DMU20	DMU43	DMU10	DMU24	DMU34	DMU25	DMU31
score	1/23	1/19	1/14	1/11	1/1	1/09	1/08	1/01

Table 3: Ranking results of efficient units using the DEA-BSC model in the first policy

Efficient unit on DEA-BSC model	DMU2	DMU20	DMU43	DMU10	DMU25	DMU34	DMU24
score	1/19	1/17	1/11	1/06	1/05	1/04	1/01

Table 4: Ranking results of efficient units using DEA-BSC model in the second policy

Efficient unit on DEA-BSC model	DMU2	DMU20	DMU34
score	1/11	1/05	1/03

By using the model (6) and GAMS software, the efficiency of the units under evaluation has been obtained and the efficient units are ranked. The results of the comparison of different ranking methods are shown in Figure (1) and the ranking results are shown in Tables (2). (3) and (4) are given.

6-Conclusion

This paper presents a multi-criteria method for evaluating R&D projects based on the integration of two new management methods. At the beginning, explanations are given regarding R&D projects and how to evaluate them. Also, BSC is introduced as a management tool and DEA as a planning technique. Then the DEA-BSC model is stated and an example of R&D projects is evaluated with this model, in which 50 units under evaluation from this project are ranked with the help of this model, and a comparison between the efficiency rating using the CCR model and the model DEA-BSC takes place. One of the researches that is hoped to be done in the future is to determine the aspects that cause inefficiency in a DMU or to determine the efficiency of each aspect separately. Also, by obtaining efficiency on a variable scale, the relative inefficiency of each unit should be measured.

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