Designing a new integrated model for performance evaluation of R&D centers (Case study: Energy Research Institute)

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Abstract

The necessity of design and implementation of performance evaluation systems for project-based research and development (R&D) centres is one of the crucial issues in all countries. The purpose of this paper is to provide an integrated performance evaluation method for research and development institutes. The proposed approach is a synthesis of BSC, AHP and network DEA appropriate for engineering departments and units of these organizations. Defining Indexes as input and output, regarding different features of BSC and prioritizing them based on expert judgment, to calculate unites and sub-unit's efficiency of these organizations, network DEA will be applied. Research and Development institutes, usually, are conglomeration of divergent administration unites and research sub-units, which could be considered as sub Decision Making Unites (sub-DMU) in this efficiency measurement model. Obtained results through this suggested integrated approach indicate its strength in the performance evaluation of R&D centres, moreover, its compatibility must be applied in all the research-oriented organizations.

Keywords: performance evaluation, development and research units, Analytical Hierarchy Process (AHP), Balanced Scorecard (BSC), Network Data Envelopment Analysis (DEA)

Introduction

Performance evaluation is one of the chief responsibilities of every corporation and the basis of performance management, which originally had been applied through financial indexes, in the past. In recent two decades issues including organizational learning, knowledge generation, and innovation capacity have been recognized as determining factors of competitive advantages. This focus is mainly owing to the advent of globalization, increased competition, and rapid technology development especially in communication and information fields. Therefore, organizations are required to equip themselves with apposite comprehensive indexes for their performance evaluation.

R&D institutes have also sophisticated nature affected by creative, unique and unstructured activities of this domain. Therefore, applying dynamic management is essential to improve their status quo. This management structure should be capable of conveying high-level decisions to operational layers and assessing acquired results aligned with defined objectives. Moreover, traditional performance evaluation systems are not appropriate to assess and evaluate research organizations and center's performance, due to the uncertainty of the result of their activities. This subject requires a new evaluation systems and specialized indexes.

Significance of this study

Obviously, evaluating different departments of a strategic R&D organization, especially when dealing with divergent departments, demands a systematical, and logical framework. In fact, the requirement of this type of performance evaluation system imposes the presence of an appropriate

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feedback system on organizational structure, which is essential for any learning organization that one of its main duties is to lead and guide other operational unites.

Effective performance evaluation system in research unites

To measure effective performance of the research unites, these unites should be studied as a system within the boundaries of a bigger system, according to figure 1. Subsequently, entering research unit's achievements into a receiver system or society will have some consequences, which should be studied as results.

An effective performance evaluation system of a research unit should (Brown G. Et al,1998):

• Focus on external measurement instead of internal measurement.

• Focus on results and output measurement instead of behaviors.

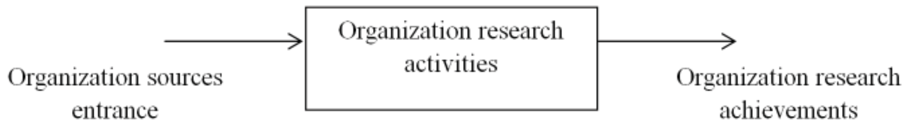

Figure 1 Research unites performance system

Performance evaluation system of research units in other countries

Reviewing applied performance evaluation systems in research centers at England, Poland, Australia and Hong Kong indicates that qualitative and external evaluation of research programs using expert assessor groups and adjusting these programs with organizational development strategies are emphasized and prominently organizational excellence models have been conducted in the performance evaluation.

Nevertheless, these models are not effective enough through following reasons:

Mentioned organizational excellence models are comprehensive and common models used for performance evaluation, aiming both self-assessment and external assessment; furthermore, they are designed to improve organization internal procedures, so that it ultimately leads to the augmentation of organizational excellence and its competitive capacity. While the intention of this study by providing an integrated and dynamic evaluation model considering the relation between departments, as well as different aspects of organization performance and finally conducting it to rank engineering departments in research centers is budget allocation. From the stakeholder's point of view, upgrading organization excellence and improving operational procedures is not at the scope of this work, rather the main focus is to propel these research unites from their project-oriented management (according to second generation of R&D management) to conduct a strategic perspective and a program-oriented management (third generation of R&D management). Moreover, these models are completely judgmental and in an effective evaluation system it is advised to use a combination of qualitative and quantitative measurements.

Methodology

As J.Monfared (2005) cites that performance evaluation system should monitor and control the strategy its suppositions and the performance of all organization units, continually, and should be conducted properly with organization characteristics and its strategy. Research institutes are one of the most influential and vital organizations at the present competitive world; in a way that such organization's performance evaluation consists of high complexity, while, evaluating such organization's performance is important for managers. Nowadays evaluating project-oriented research organizations has become one of the most challenging issues in decision making process of R&D department managers.

Proposed model through combining Balanced Scorecard (BSC), Analytical Hierarchy Process (AHP) and Network Data Envelopment Analysis (DEA)

The proposed model in this study for sequential years of performance evaluation of engineering departments in research centers is based on integrating and combining BSC, AHP and network DEA methods. Covering each other's weaknesses and boosting their strengths, as the result, this integration has made the proposed model a powerful tool for performance evaluation. Moreover, this model can be extended to all R&D departments, adaptable in any organization.

The very first step is to identify important indexes in performance evaluation of project-oriented research organizations based on different aspects of BSC. Afterward, expert judgments and their point of view concurrently with AHP will be applied to prioritize and weigh those indexes.

After determination of these indexes as input and outputs, and prioritizing them based on expert judgment, to evaluate the effectiveness of those departments Network DEA will be implemented. . Research institutes are usually composed of a set of smaller operational and research units, which can be considered as decision making unites in efficiency measurement models.

Balanced Scorecard method

Almost until 1975, conventionally, financial measures were applied to evaluate organization's performance (Kaplan, Norton, 2007). Though, due to limitations of these measures, the need for non-financial features was acknowledged by scholars (Chan, et al., 2006). Based on this requisition, different models were developed to measure the performance such as Sink and Tuttle model (Sink, Tuttle, 1989), performance matrix (Kanji, G.K 2001) and performance pyramid model (Neely, 1999). Although focused on financial and non-financial aspect, mentioned models failed to present these aspects in a balanced and consistent framework. As the ramification of this imbalanced framework, this model cannot display a precise and appropriate image of organizational performance (Keegan, et. al, 1989). Kaplan and Norton presented a balanced approach to measure performance called Balanced Scorecard. In this model, balance between financial and non-financial aspects, stimulus and performance features, local and foreign stakeholders, moreover between long term and short term objectives of an organization is performed (Lynch, 1991). Nowadays BSC is not only used as a performance evaluation tool, but also it is used as a tool for strategic management and converting policies and strategies into a set of clear and concise objectives. In general model presented by Kaplan and Norton (1996), organization performance was evaluated considering four areas of finance, customers, internal procedures, learning and development.

Analytical Hierarchy Process method (AHP)

Recently, Multiple-Attribute Decision Making (MADM) methods has been emerged in the context of decision making science, through which selecting a solution among other solutions or prioritizing them is considered. Of the mentioned methods, Analytical Hierarchy Process (AHP) method has been adopted more frequently than other methods in management science. AHP is one of the most prominent techniques of Multiple-Criteria Decision Making, which was invented by Tomas L. Saaty, in 1970s. AHP is a reflection of human thoughts and his natural behavior. This technique solves complex issues by exploring them based on their interactions, in order to make them more modest (L. Satty T., 1990).

Network Data Envelopment Analysis (DEA)

Classic data envelopment analysis (DEA) methods were first brought to inception by M.J. Farrell (1957) and then extended by Charnse, Cooper and Rhodes, (1978). In the classical approach, organizations were considered as black boxes in order to ignore any internal processes and limit any required calculations merely to initial inputs and final outputs. So to solve this problem, different models were presented under the title of Network Data Envelopment Analysis (DEA). Grasskopf and Fare presented an article entitled Network Data Envelopment Analysis. In this article the importance of network data envelopment analysis has been indicated (Fare and Grosskopf, 2000). In 2001, Castelli and, Pesnti and Ucovich presented the article of "DEA-like models for efficiency evaluation of specialized and interdependent units, in which they studied the evaluation of efficiency of the specified and interrelated decision making subunits which are making larger decision making units. In 2003, Lowis and Sexton offered a two-stage data analysis envelopment method to measure efficiency of units produced in two phases. Then, in 2004, they published "Network DEA: efficiency analysis of organizations with complex internal structure", in which they have proposed a model consists of units involving a network of related sub-units; each subunits provides resources for some other sub-units and also acquire its resources supplied by others. This model was proposed concerning mentioned inputs and outputs (Lewis, and Sexton, 2004). The very same year, Castelli, Pesnti and Ucovich submitted a new article to evaluate efficiency of hierarchal structured units (Castelli, et al, 2004). In 2007, Prietto and Zofio evaluated the efficiency of potential technic comparing different technologies in accordance with different economies; in their analytical framework input-output models are considered as a network, and this input-output network will be optimized using production efficiency criteria, then they applied this input-output model to OECD countries (Pireto, and Zofio, 2007).

Different types of Network DEA

Kao (2009) came up with a new approach of investigation of network decision making units by using two series and parallel structures which have been defined based on the multiplication of unit's efficiency.

Series structure

When units' activities are in along with each other, in a multi-section decision making unit, the system has a series structure. Under this condition, whole system's input enters into the first part, and final output of the system exits from the last section. The General form of series Network DEA has been shown in figure 2.

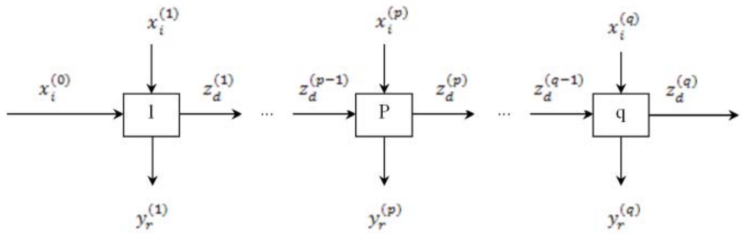

Figure 2. General form for the series model

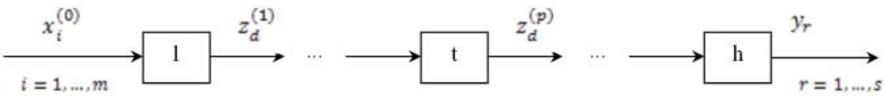

Figure 3 Series structure

Series network structure modelling

To introduce the first model, think of a decision making unit with h units whose sections are placed in series form all along a line. Figure 3 indicates a series model.

In this section, X_{ij} and Y_{rj} will be taken as the immediate inputs and outputs of the unit J, respectively. $Z_{pj}^{(t)}$ presents the pth vector of intermediate products, ($p=1,\ldots,q$) of process t, where t=1,..., h-1, for DMU j. Number intermediary products can differ from other units. For convenience, all intermediary products of each units will be considered as (p=1,......, q). So the linear input-oriented DEA model for network structures of figure 3 will be similar to model 1.

In case of u_r^*, v_i^* *and* $w_p^{(t)*}$ as optimized answers obtained by the model, the efficiency of each decision making units is achieved via model 2.

In a way that all decision making units will be efficient, if and only if their constituting sub units are efficient.

$$
\begin{aligned}
& E_k = \max \sum_{r=1}^{s} u_r Y_k \\
& s.t. \\
& \sum_{i=1}^{m} v_i X_k = 1 \\
& \sum_{r=1}^{s} u_r Y_{rj} - \sum_{i=1}^{m} v_i X_j \le 0, \quad j=1,\ldots,n \\
& \sum_{p=1}^{q} w_p^{(1)} Z_{pj}^{(1)} - \sum_{i=1}^{m} v_i X_j \le 0, \quad j=1,\ldots,n \\
& \sum_{p=1}^{q} w_p^{(t)} Z_{pj}^{(t)} - \sum_{p=1}^{q} w_p^{(t-1)} X_{pj}^{(t-1)} \le 0, \quad j=1,\ldots,n; t=2,\ldots,h-1 \\
& \sum_{r=1}^{s} u_r Y_{rj} - \sum_{p=1}^{q} w_p^{(h-1)} X_{pj}^{(h-1)} \le 0, \quad j=1,\ldots,n \\
& u_r, v_i, w_p^{(t)} \ge \varepsilon, \\
& r=1,\ldots,s;\ i=1,\ldots,m;\ p=1,\ldots,q;\ t=1,\ldots,h-1
\end{aligned} \tag{1}
$$

$$
\begin{aligned}
& E_k^{(1)} = \sum_{p=1}^{q} w_p^{(1)*} Z_{pk}^{(1)} \Big/ \sum_{i=1}^{m} v_i^* X_k \\
& E_k^{(t)} = \sum_{p=1}^{q} w_p^{(t)*} Z_{pk}^{(t)} \Big/ \sum_{p=1}^{q} w_p^{(t-1)*} X_{pk}^{(t-1)} \quad t=2,\ldots,h-1 \\
& E_h^{(t)} = \sum_{r=1}^{s} u_r^* Y_k \Big/ \sum_{p=1}^{q} w_p^{(h-1)*} X_{pk}^{(h-1)}
\end{aligned} \tag{2}
$$

Parallel structural

In these network DEA models, individual parts are operating in an individual and at the same time parallel to each other.

University is a good pattern of a parallel system. In this case individual parts are departments acting individually and in parallel, inside a university. The authors believe that parallel model is a special form of the series model having no intermediary products (Kao and Hwang, 2010)

In a multi-section decision making unit, whenever units' activities are alongside each other in paralleled form, the system has a parallel structure. Figure 4 indicates a parallel system.

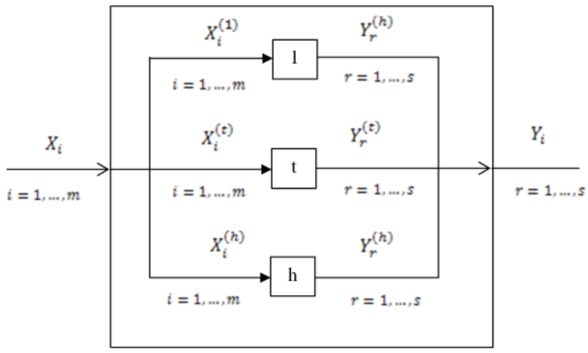

Figure 4 Parallel structure

$$
\begin{aligned}
& E_k = \max \sum_{r=1}^{s} u_r Y_k \\
& s.t. \\
& \sum_{i=1}^{m} v_i X_k = 1 \\
& \sum_{r=1}^{s} u_r Y_j - \sum_{i=1}^{m} v_i X_j \le 0, \quad j = 1,\dots,n \\
& \sum_{r=1}^{s} u_r Y_j^{(t)} - \sum_{i=1}^{m} v_i X_j^{(t)} \le 0, \quad j = 1,\dots,n;\ t = 1,\dots,h \\
& u_r, v_i \ge \varepsilon;\ \ r = 1,\dots,s;\ i = 1,\dots,m
\end{aligned}
\tag{3}
$$

In this structure, total entry is divided among all units and total output is obtained from all units' output. X_{ij} (i=1,...,m) is the total input of jth decision making units and $X_{ij}^{(t)}$ is input value allocated to the tth unit in jth decision making unit. Y_{rj} is the overall output of jth DMU, and $Y_{rj}^{(t)}$ is the output produced by tth unit jth DMU, while u_r^*, v_i^* are optimized answers obtained by the model. In this case, each decision making unit's efficiency will be as model 4.

$$
\begin{aligned}
& E_k = \sum_{r=1}^{s} u_r^* Y_k \Big/ \sum_{i=1}^{m} v_i^* X_k = 1 - s_k^* \\
& E_k^{(t)} = \sum_{r=1}^{s} u_r^* Y_j^{(t)} \Big/ \sum_{i=1}^{m} v_i^* X_j^{(t)} = 1 - s_k^{(p)^*} \Big/ \sum_{i=1}^{m} v_i^* X_j^{(t)} = 1 - \hat{s}_k^{(p)^*} \quad t = 2,\dots,h-1
\end{aligned}
\tag{4}
$$

Each decision making unit will be efficient, if and only if it constituting units are efficient.

1. Combining Balanced Scorecard Methods (BSC), Analysis of Hierarchal Procedure (AHP) and Network Data Envelopment Analysis (Network DEA)

As it was mentioned earlier, the first step is to identify important indexes of performance evaluation of research-oriented organizations based on BSC aspects. Then to prioritize and weigh these important indexes, based on AHP method, the judgment of experts and managers of these research centers will be used.

After determining indexes as inputs and outputs, furthermore prioritizing them based on experts' judgment, network DEA will be used to measure organization department efficiency. As was mentioned earlier, research institutes are usually made of some operation and research subunits which can be considered as Decision Making Units (DMU) in this efficiency measurement model.

Moreover, to conserve the organizations' benefits and to create and preserve an appropriate relationship between departments at the same time to prevent any unpropitious and destructive emulation between engineering departments, it is suggested that each department's performance be compared with its own performance of previous years, not other departments. In other words, each department should be compared with itself in different consequent years, not with other departments. In order to do so, the performance of a department in different years will be taken into the consideration and the year with the highest performance rate will be nominated as the base year, and then comparison will be made between the department performances at any year with the performance in this base year. Therefore, the performance of each department in every year, in this method, will be taken as one single decision making unit.

Considering suggested approach, the first step is to distinguish required indexes based on BSC. In what follows indexes introduced by the authors and indexes gathered from previous studies, will be presented. To investigate the suggested model of evaluating research institutes' performance, this model was conducted at the Iran Niroo (Energy) Research Center which will be demonstrated in next parts.

2. Number of decision making units (number of years through which each department is studied)

Decision making units studied in this section, are in the range of year 2000 to 2012, and the performance of each department in any year is evaluated and compared to its performance in other years.

3. Selecting appropriate indexes to evaluate performance of engineering departments in research centers

After gathering needed data through scrutinizing other scholars' books, articles and studies the mentioned criteria were explored during two expert sections and carried out studies. Among identified criteria, ten criteria were candidate for evaluation and index selections which were selected based on the investigation procedure for evaluation and index selection.

4. Introducing inputs and outputs

Inputs:

1-total costs

2-number of employees

3-number of running projects

4-number of customers

Outputs:

1-completed projects

2-progress percentage of running projects

3-number of satisfied customers

4- Employees' satisfaction rate in department 1 (score out of 100)

5-hours dedicated to personnel training and learning (man-hour)

6-profit obtained from each project

BSC aspects	performance evaluation indexes
Internal procedure	input: number of running projects
	output: number of completed projects
	output: running projects progress percent
learning and development	input: number of department employee
	input: hours dedicated to personal learning and Training
	output: unit personnel's satisfaction
financial	input: total costs of each department
	output: profit obtained from each department Completed projects
Costumer	input: number of costumers
	output: number of satisfied customers

Weighing selected indexes using Analysis of Hierarchal Procedure (AHP)

As it was mentioned before, AHP is used to weigh indexes of this study. Hence, a Pairwise Comparison Matrix based on experts' judgment is needed. Table 1 indicates this Paired Comparison Matrix.

After forming this matrix, the weights of each index were obtained based on procedure defined in AHP method using Super Decision software. Table 2 indicates indexes' weights.

Table 1. Paired Comparison Matrix related to performance evaluation indexes of central departments

	1	2	3	4	5	6	7	8	9	10
1	1	1.5	3	2.3	1.5	1.6	2	9	5	0.5
2	0.67	1	0.25	0.82	0.17	2.5	0.4	2	0.68	0.28
3	0.33	4	1	0.36	0.43	0.79	0.33	3.44	0.29	0.2
4	0.43	1.22	2.8	1	0.62	0.33	0.5	3.5	0.85	0.33
5	0.67	6.00	2.34	1.62	1	1.6	0.5	6	0.63	0.33
6	0.63	0.4	1.26	3	0.625	1	0.43	5	0.5	0.4
7	0.5	2.5	3	2	2	2.3	1	8	3	0.33
8	0.11	0.5	0.29	0.29	0.17	0.2	0.125	1	0.15	0.1
9	0.2	1.47	3.43	1.18	1.59	2	0.33	6.50	1	0.5
10	2	3.6	5	3	3	2.5	3	10	2	1

Table 2. Obtained weights using the AHP method in Super Decision software

1	2	3	4	5	6	7	8	9	10
0.1655	0.0577	0.0574	0.0658	0.1087	0.0724	0.1371	0.0165	0.0950	0.2238

Network design of the departments

To obtain department's efficiency using Network DEA, it is necessary to indicate organization engineering subgroups and its engineering departments in a network figure. Moreover, each department's inputs and outputs should be determined. Designed network along with defined indexes for the research-oriented organization is illustrated in figure 5:

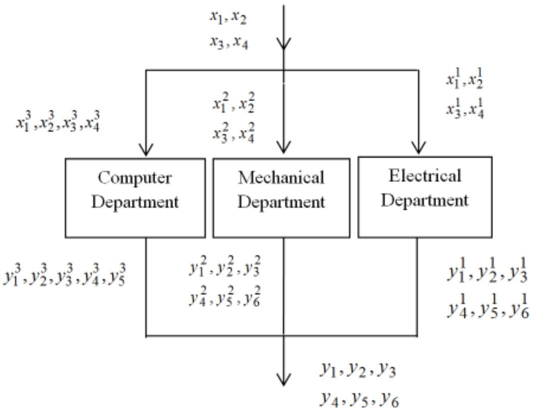

Figure 5. designed network of the organization's departments

X_{11}: total costs of department 1

X_{12}: number of employees in department 1

X_{13}: number of running projects in department 1

X_{14}: number of costumers of department1

Y_{11}: number of projects completed by department 1

Y_{12}: running projects' progress percentage in department 1

Y_{13}: number of satisfied customers of department 1

Y_{14}: satisfaction level of department 1 (score out of 100)

Y_{15}: hours of personnel's training and learning (man-hour)

Y_{16}: profit obtained from each project in department 1

Modelling designed network for the organization using NDEA method

As was suggested earlier, each year performance is considered as a decision making unit in this method. Figure 6 indicates a brief image of the used method for evaluating department's performance.

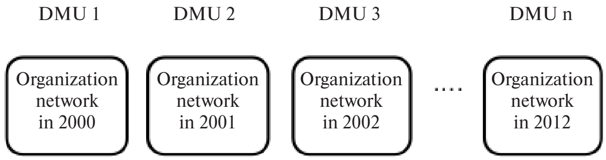

Figure 6. Organization network's performance evaluation method during different years

Considering that designed network for the organization has a parallel network structure, for modeling this structure, the application discussed in the literature introductory regarding parallel network structure is used. Following relation indicates modeling method of parallel networks.

$$
\begin{aligned}
& E_k = \max \sum_{r=1}^{s} u_r Y_k \\
& s.t. \\
& \sum_{i=1}^{m} v_i X_k = 1 \\
& \sum_{r=1}^{s} u_r Y_j - \sum_{i=1}^{m} v_i X_j \le 0, \quad j=1,\dots,n \\
& \sum_{r=1}^{s} u_r Y_j^{(t)} - \sum_{i=1}^{m} v_i X_j^{(t)} \le 0, \quad j=1,\dots,n;\ t=1,\dots,h \\
& u_r, v_i \ge \varepsilon; \quad r=1,\dots,s;\ i=1,\dots,m
\end{aligned} \tag{5}
$$

Considering that in the organization designed network (figure3) number of inputs equals 4 (i=1, ..., 4), number of outputs equals 6 (r=1, ..., 6), number of departments or sub-procedures equals 3 (t=1, 2, 3) and the number of decision making units (number of studied years) equals 13 (j=1, 2, ..., 13), so:

$$
\begin{aligned}
& E_k = \max \sum_{r=1}^{6} u_r Y_k \\
& s.t. \\
& \sum_{i=1}^{4} v_i X_k = 1 \\
& \sum_{r=1}^{6} u_r Y_j - \sum_{i=1}^{4} v_i X_j \le 0, \quad j=1,\dots,13 \\
& \sum_{r=1}^{6} u_r Y_j^{(t)} - \sum_{i=1}^{4} v_i X_j^{(t)} \le 0, \quad j=1,\dots,13;\ t=1,2,3 \\
& u_r, v_i \ge \varepsilon; \quad r=1,\dots,6;\ i=1,\dots,4
\end{aligned} \tag{6}
$$

For final modeling and evaluating department's efficiency, weighted data to conduct the model is needed. Through multiplying the organization original raw data by each index's weights (table2) weighted data will obtained as shown in table 3.

Table 3. Weighted data of the organization and its departments

I_4	I_3	I_2	I_1	O_6	O_5	O_4	O_3	O_2	O_1
2.83	1.15	3.64	262984058.47	468896210.64	45.61	2.87	4.25	0.08	2.17
0.53	0.23	1.15	132984327.96	209034201.31	9.12	0.92	0.69	0.02	0.65
0.99	0.40	0.92	62510343.17	122558558.04	15.96	1.21	1.64	0.03	0.87
1.32	0.52	1.56	67489387.30	137303451.27	20.52	0.74	1.92	0.03	0.65
2.63	1.03	3.64	331071072.52	451287442.30	215.48	3.29	3.56	0.13	1.63
0.33	0.34	1.21	89332821.71	200112680.31	71.83	0.84	0.41	0.03	0.33
1.38	0.23	1.10	103499050.97	78491216.63	64.99	1.21	2.19	0.05	0.43
0.92	0.46	1.33	138239199.83	172683545.27	78.67	1.24	0.96	0.05	0.87
2.24	1.89	3.35	382912540.54	473586463.54	264.51	3.47	3.43	0.15	2.17
0.72	0.69	1.10	161129365.09	220781348.73	86.65	0.96	1.10	0.04	0.54
0.59	0.46	1.21	113609198.13	119044454.11	95.77	1.14	0.82	0.06	0.65
0.92	0.75	1.04	108173977.35	133760660.77	82.09	1.37	1.51	0.05	0.98
2.57	2.24	4.33	345060489.07	476450338.71	748.21	3.96	2.88	0.15	1.52
0.86	0.92	1.39	117262147.41	82359121.52	239.43	1.29	0.82	0.05	0.43
0.72	0.69	1.44	103032265.59	193763387.76	249.40	1.30	0.55	0.05	0.76
0.99	0.63	1.50	124766076.13	200327829.52	259.38	1.37	1.51	0.04	0.33
2.11	1.84	4.33	323468128.67	476928448.17	862.22	4.15	3.43	0.20	2.17
0.59	0.69	1.39	72273937.54	171870759.34	275.91	1.26	0.82	0.07	0.43
0.72	0.63	1.44	124306363.26	183608344.57	287.41	1.47	1.10	0.06	0.87
0.79	0.52	1.50	126887827.90	121449344.29	298.90	1.42	1.51	0.07	0.87
1.51	1.84	4.33	266619326.42	534029051.21	890.73	3.98	2.06	0.15	2.61
0.40	0.69	1.44	94990826.41	217616264.64	296.91	1.42	0.82	0.04	1.20
0.66	0.63	1.39	95252509.13	191391965.25	285.03	1.30	0.41	0.05	0.98
0.46	0.52	1.50	76375990.95	125020821.34	308.79	1.26	0.82	0.06	0.43
0.92	1.61	4.33	253149739.11	448050641.73	1646.07	3.60	1.51	0.12	2.28
0.53	0.80	1.27	54716441.70	209851768.33	482.85	1.47	0.82	0.06	1.20
0.26	0.40	1.56	103693544.89	155825408.59	592.58	1.26	0.55	0.00	0.65
0.13	0.40	1.50	94739752.45	82373464.79	570.64	0.88	0.14	0.06	0.43
1.19	1.89	4.33	396413954.35	264566605.54	698.33	3.86	1.92	0.19	2.83
0.33	0.63	1.62	164336746.51	85825414.50	260.71	1.50	0.55	0.07	1.20
0.40	0.75	1.39	72942289.34	85414240.45	223.47	0.92	0.55	0.05	0.76
0.46	0.52	1.33	159134918.44	93326950.66	214.15	1.44	0.82	0.07	0.87
1.84	1.49	4.33	393758228.30	491228699.61	1510.67	4.61	3.02	0.21	2.50
0.53	0.34	1.44	155107126.33	171909008.07	503.56	1.54	0.82	0.07	0.54
0.53	0.40	1.50	112336147.07	123060572.89	523.70	1.63	0.69	0.07	0.76
0.79	0.75	1.39	126314954.92	196259118.71	483.42	1.44	1.51	0.07	1.20
4.35	3.38	4.33	303399893.23	424628063.18	2301.64	2.53	7.54	0.18	4.78
2.11	1.20	1.44	106600344.80	184913583.16	767.21	0.74	3.84	0.06	1.63
0.79	1.26	1.50	88307308.35	154367174.98	797.90	0.71	1.23	0.06	1.85
1.45	0.92	1.39	108492240.12	85347305.14	736.53	1.07	2.47	0.06	1.30
6.19	3.73	6.81	282256637.03	451746427.12	2746.77	3.12	10.01	0.18	5.87
2.30	1.38	2.60	74091571.55	119943299.75	1047.50	0.92	3.84	0.05	2.28
2.24	1.38	2.43	124543292.21	215254404.31	977.66	1.11	3.70	0.07	2.07
1.65	0.97	1.79	83621773.21	116548723.15	721.61	1.09	2.47	0.06	1.52
5.33	3.33	6.81	264239428.32	397131992.97	2645.87	2.89	8.77	0.16	4.67
1.91	1.20	2.60	81606109.03	149413961.81	1009.02	1.26	3.43	0.05	1.52
2.04	1.09	2.43	85510132.27	73399351.76	941.75	0.92	3.15	0.06	1.74
1.38	1.03	1.79	97123186.92	174318679.33	695.10	0.71	2.19	0.05	1.41
5.27	2.87	6.87	225075426.99	499447399.94	3866.76	3.98	8.64	0.16	3.80
1.38	1.15	2.31	53054402.83	210210350.38	1299.75	1.29	2.33	0.05	1.63
2.11	0.92	2.71	56597728.26	196828068.88	1527.21	1.44	3.43	0.06	1.20
1.78	0.80	1.85	115423295.88	92408980.64	1039.80	1.26	2.88	0.05	0.98

Next, the modeling will be carried out considering model 6 for each year; from 2000 to 2012. Solving these models in Lingo software, efficiency of the organization's network is achieved for each year. Furthermore, to obtain the organization engineering departments' efficiency for each year, following formula can be used:

$$E_k = \sum_{r=1}^{s} u_r^* Y_k \Big/ \sum_{i=1}^{m} v_i^* X_k = 1 - s_k^*$$
$$E_k^{(t)} = \sum_{r=1}^{s} u_r^* Y_j^{(t)} \Big/ \sum_{i=1}^{m} v_i^* X_j^{(t)} = 1 - s_k^{(p)^*} \Big/ \sum_{i=1}^{m} v_i^* X_j^{(t)} = 1 - \hat{s}_k^{(p)^*} \quad t = 2,\ldots,h-1 \qquad (7)$$

Results and discussion

Results obtained from solving model in software and related analyses have been presented in tables 4-16.

Table 4. Organization departments' efficiency results in 2000

DMUs	slack or surplus in 2000	Efficiency score in 2000
system	0.025723	0.974277
Computer department	0	1.000000
Mechanical department	0	1.000000
Electronic department	0.025678	0.974322

Organization departments' efficiency results in 2000 (tables 4) indicated that the whole organization system efficiency in this year equals 0.974277. Moreover organization departments' efficiency which is acting as sub-units is 1, 1, and 0.9743 for Department1, Department2 and Department3, respectively. In fact inefficiency of organization in this year was caused by Department 3 inefficiency. To increase system efficiency in this year, the organization has to decrease inputs of department 3 up to 2.5% (slack or surplus related to department 3) to achieve 100% efficiency.

Table 5. Results of organization departments' efficiency in 2001

DMUs	slack or surplus in 2001	Efficiency score in 2001
system	0.0457	0.9543
Computer department	0	1.0000
Mechanical department	0	1.0000
Electronic department	0.0457	0.9543

Efficiency results in obtaining for organization's departments in 2001 (tables 5) indicated that system efficiency (whole organization) in this year was 0.9543. Moreover organization department efficiency which is acting as sub-units is 1, 1, and 0.9543 for Department1, Department2 and Department3, respectively. In fact inefficiency of organization in this year was due to Department3 inefficiency. To increase system efficiency in this year, the organization had to decrease Department 3 inputs up to 4.57 % (slack or surplus related to department 3) to reach 100% of efficiency.

Table 6. Results obtained from organization departments in 2002

DMUs	slack or surplus in 2002	Efficiency score in 2002
system	0.04879	0.95121
Computer department	0	1.00000
Mechanical department	0.04943	0.95057
Electronic department	0	1.00000

Results of efficiency for organization departments in 2002 (tables 6) indicated that system efficiency (whole organization) in this year was 0.95121. Moreover organization departments' efficiency which is acting as sub-units is 1, 0.95057 and 1, for Department1, Department2 and Department3, respectively. In fact inefficiency of organization in this year was due to Department2 inefficiency. To increase system efficiency in this year, the organization had to reduce Department 2 inputs up to 4.943 % (slack or surplus related to department 2) to reach 100% of efficiency. Doing so, it can be considered as efficient system.

Table 7. Results obtained from organization departments in 2003

DMUs	slack or surplus in 2003	Efficiency score in 2003
system	0.23100	0.76900
Computer department	0.08485	0.91515
Mechanical department	0.06878	0.93122
Electronic department	0.07881	0.92119

Results of efficiency for organization departments in 2003 (tables 7) indicated that system efficiency (whole organization) in this year was 0.769. Moreover organization departments' efficiency which is acting as sub-units is 0.91515, 93122 and 0.92119 for Department1, Department2 and Department3, respectively. In fact inefficiency of organization in this year was due to all departments' inefficiency. In fact 91,515% of inefficiency is related to Department 1, 93,122% of inefficiency is related to Department 2 and 92,119% of the organizational inefficiency relates to Department 3. To increase system efficiency in this year, organization should reduce Department1 inputs up to 8.485%, (slack or surplus related to department 1), Department 2 inputs up to 6. 878% and department 3 inputs up to 7.881% to reach 100% of efficiency.

Table 8. Results obtained from organization departments 2004

DMUs	slack or surplus in 2004	Efficiency score in 2004
system	0.04190	0.95810
Computer department	0	1.00000
Mechanical department	0.04096	0.95904
Electronic department	0	1.00000

Results of efficiency for organization departments in 2004 (tables 8) indicated that system efficiency (whole organization) in this year was 0.95810. Moreover organization departments' efficiency which is acting as sub-units is 1, 0.95904 and 1, for Department1, Department2 and Department3, respectively. In fact inefficiency of organization in this year was due to Department2 inefficiency. To increase system efficiency in this year, the organization had to decrease Department 2 inputs up to 4.96 % (slack or surplus related to department 2) to reach 100% of efficiency. Doing so, it can be considered as efficient system.

Table 9. Results obtained for organization department efficiency in 2005

DMUs	slack or surplus in 2005	Efficiency score in 2005
system	0.09263	0.90737
Computer department	0	1.00000
Mechanical department	0.06081	0.93919
Electronic department	0.03330	0.96670

Results of efficiency for organization departments in 2005 (tables 9) indicated that system efficiency (whole organization) in this year was 0.90737 (the organization was inefficient in this year). Moreover organization departments' efficiency which is acting as sub-units is 1, 0.95904, and 1 for Department1, Department2 and Department3, respectively. In fact inefficiency of organization in this year was due to departments 1, 2 inefficiency. In fact 93,919% of inefficiency relates to Department 2, and 96,677 2% of inefficiency is related to Department3. To increase system efficiency in this year, organization should reduce Department2 inputs up to 6.801 %, (slack or surplus related to department 2), and Department 3 inputs up to 3.33% to reach 100% of efficiency.

Table10. Results obtained for organization department efficiency in 2006

DMUs	slack or surplus in 2006	Efficiency score in 2006
system	0	1
Computer department	0	1
Mechanical department	0	1
Electronic department	0	1

Results of efficiency for organization departments in 2006 (tables 10) indicated that system efficiency (whole organization) in this year was 100 % (the organization was efficient in this year). Moreover organization departments' efficiency which is acting as sub-units is 100% of all departments. Hence, the organization had desired performance in this year and it is at desired level.

Table 11. Results obtained from organization departments in 2007

DMUs	slack or surplus in 2007	Efficiency score in 2007
system	0.04563	0.95437
Computer department	0	1.00000
Mechanical department	0.04624	0.95376
Electronic department	0	1.00000

Results of efficiency for organization departments in 2007 (tables 11) indicated that system efficiency (whole organization) in this year was 0.954379. Moreover organization departments' efficiency which is acting as sub-units is 1, 0.95376 and 1 for Department1, Department2 and Department3, respectively. In fact inefficiency of organization in this year was due to department 2 inefficiency. To increase system efficiency in this year, organization should reduce Department 2 inputs up to 4.624 %, (slack or surplus related to department 2), to reach 100% of efficiency. Doing so, it will be identified as efficient system.

Table 12. Results obtained for organization department efficiency in 2008

DMUs	slack or surplus in 2008	Efficiency score in 2008
system	0	1.00000
Computer department	0	1.00000
Mechanical department	0	1.00000
Electronic department	0.00099	0.99901

Results of efficiency for organization departments in 2008 (tables 12) indicated that system efficiency (whole organization) in this year was 100%. Moreover organization departments' efficiency which is acting as sub-unites was 100% for both Department1, and Department2. This indicates that though the organization is in a desired level of efficiency aspect, department 3 is almost inefficient. So this department can reach system desired and considered efficiency in this year, through reducing its inputs up to 0.099%.

Table 13. Results obtained from organization departments in 2009

DMUs	slack or surplus in 2009	Efficiency score in 2009
system	0	1
Computer department	0	1
Mechanical department	0	1
Electronic department	0	1

Results of efficiency for organization departments in 2009 (tables 13) indicated that system efficiency (whole organization) in this year was 100 % (the organization was efficient in this year). Moreover organization departments' efficiency which is acting as sub-units is 100% of all departments. Hence, the organization had desired performance in this year and it is at desired level.

Table 14. Results obtained from organization departments in 2010

DMUs	slack or surplus in 2010	Efficiency score in 2010
system	0.01653	0.98347
Computer department	0	1.00000
Mechanical department	0.01673	0.98327
Electronic department	0.00031	0.99969

Results of efficiency for organization departments in 2010 (tables 14) indicated that system efficiency (whole organization) in this year was 0.98347 (the organization was inefficient in this year). Moreover organization departments' efficiency which is acting as sub-units is 1, 0.98327, and 0.99969 for Department1, Department2 and Department3, respectively. In fact inefficiency of organization in this year was due to departments 2 and 3 inefficiency. In fact 98.327% of inefficiency relates to Department 2, and 99.997 % of inefficiency is related to Department3. To increase system efficiency in this year, organization should reduce Department2 inputs up to 1.673 %, slack or surplus related to department 2), and Department 3 inputs up to 0.03% to reach 100% of efficiency.

Table 15. Results obtained from organization departments in 2011

DMUs	slack or surplus in 2011	Efficiency score in 2011
system	0.05566	0.94434
Computer department	0.00239	0.99761
Mechanical department	0.02194	0.97806
Electronic department	0.03044	0.96956

Results of efficiency for organization departments in 2011 (tables 15) indicated that system efficiency (whole organization) in this year was 0.94434 (the organization was inefficient in this year). Moreover organization departments' efficiency which is acting as sub-units is 0.99761, 0.97086 and 0.96956, Department1, Department2 and Department3, respectively. In fact inefficiency of organization in this year was due to all departments' inefficiency.

In other words 99.761% of inefficiency is related to Department 1, 97.806 % of inefficiency is related to Department2 and 96.956% of organizational inefficiency is related to Department 3. To increase system efficiency in this year, organization should reduce Department1 inputs up to 0.239 %, (slack or surplus related to department 1), Department 2 inputs up to 2.194% and Department 3 inputs up to 3.004% to reach 100% of efficiency.

Table 16: Results obtained from organization departments in 2012

DMUs	slack or surplus in 2012	Efficiency score in 2012
system	0	1
Computer department	0	1
Mechanical department	0	1
Electronic department	0	1

Results of efficiency for organization departments in 2012 (tables 16) indicated that system efficiency (whole organization) in this year was 100 % (the organization was efficient in this year). Moreover organization departments' efficiency which is acting as sub-unites was 100% of all departments. In fact organization efficiency in this year is due to all three departments' efficiency. Hence, the organization had desired performance in this year and it is at desired level.

Conclusions

In this study a new integrated approach was used to evaluate research and development organization's performance. This evaluation method for organization engineering method's performance differs for several years. In a way that, each department performance in a year is analyzed and studied with same engineering department performance in different years. In this proposed method a network of organization engineering departments was designed. Theme based on designing network performance evaluation indexes was defined based on balanced scorecard aspects and organization engineers. Next we used analysis of the Hierarchal Procedure method to determine the weights of each input and output. Finally to obtain department's efficiency we used network data envelopment analysis. Designed was administrated based on the NDEA method in Lingo software and results obtained from software were analyzed. It is worth mentioning that integrated BSC, AHP and Network DEA method is implemented and administrated for the first time in a research organization. More interestingly, this integrated method was administrated in a research-oriented unit which can be considered as a pattern to evaluate research unit's performance. This method covers weak points and supports strong points through combining three strong approaches of performance evaluation.

Results obtained from this investigation indicated the strength and capability of proposed performance evaluation methods in evaluating underlying organizational performance. Moreover the model obtained in this criterion can be generalized to all research and development organizations, being adaptable to all organizations.

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