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Network DEA Approach to Organizing and Job Evaluation Process Assessment: Real Case of Iranian Oil and Gas Industry

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Abstract All organizations have structure. Researchers emphasized the importance of the organizational structure to achieve the goals and mission of an organization. Thus Performance assessment of organizing is essential for managers and decision makers to find weaknesses and eliminate them. Organizations are designed by different methods and process, based on same principles and theories. In this study, process of organization designing in five organizations in field of oil and gas in Iran is examined. Main criteria and parameters that affect the efficiency of this process are identified and applied in an operational research framework. This research utilizes two stages Network Data Envelopment Analysis to construct a model to analyses the efficiency and effectiveness of mentioned process. the strength of this approach relation to traditional DEA and the need for extraction of efficiency of sub-processes (design of organization and job classification and evaluation) has caused to we develop a network related to considered process and utilize an additive efficiency decomposition approach to evaluate the relationships between efficiency of stages and overall efficiency. Finally, based on the results, we recommend ways of enhancing the overall performance of this process.

Keywords: Data Envelopment Analysis (DEA), two- stage Network, Organizational structure, job classification and evaluation.

1 Introduction

Organizational structure may be considered the anatomy of the organization, providing a foundation within which the organization functions. Organization structure is believed to affect the behavior of organization members. The specific structure of a building is a major determinant of the activities of the people within it [1].

As Hall noted, all organizations have structure. Designed to minimize or at least regulate the influence of individual variations on the organization, "and "structure is the setting in which power is exercised..., decisions are made ..., and ... the organization's activities are carried out" [1].

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Organizational structure analysis and design is a process by which primary and secondary processes of organization, with respect to concerns including vision statement, goals and strategies of organization, environmental conditions and competitors, are decomposed into jobs, group of duties which can be done by employees. *Process- element hierarchy* is presented in Fig.1. Organization analyzers and designers use this hierarchy to design jobs and define tasks of a job. Concept of this hierarchy first proposed by H. Paul [2], from process to activity, that we develop and complete it. After design of jobs, process of job classification and evaluation begins to work.

Job classification and evaluation is a process of analyzing the job content, responsibilities, concerns, restrictions, demands, authorities and duties to classify jobs, based on similarities and differences, into job families and assessing the worth of job categories on a number of dimensions or compensable factors. Results of this process are used in modules of human recourses management including compensation, Training planning and career planning [3,4].

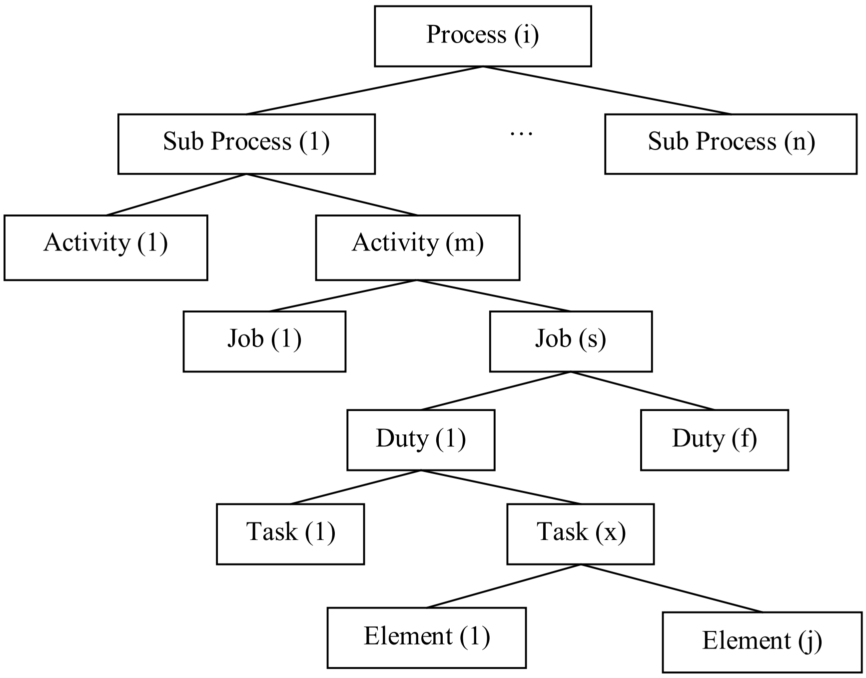

Fig.1 Hierarchical analysis of design of Organizational structure and job evaluation process

In the literature organizational structure studied from different aspects, Penning [5] applied multiple instruments for measuring structural characteristics of complex organizations. R. Dalton et al. [1] presented various models of organizational structure and summarize the literature dealing with the relationships between structural dimensions and performance. K. Inkson et al. [6] studied relationships between context and structure. Lawler et al. [7] examined the relation between structure and process and organizational climate which in turn is related to organization performance and employee job satisfaction.

Other researchers in this field studied relation between strategies, processes and Structure [8-10]. They suggested organizational structure must be matched with strategies and environmental changes to ensure good performance under challenging conditions. In mentioned studies, evaluation of organizational structure is established based on some criteria that extracted from related theories. In this study, mathematical linear programming is used to evaluate the efficiency of the organizational structure.

Researchers in the field of job evaluation studied evaluating of job analysis methods [11], effect of job classification and evaluation on the compensation system and decisions involving pay equity [12,13]. V. Sliedregt et al. [14] examined the assumption that job value scores match with pay grade structures, and allow adequate predictions of basic wages or salaries in practice. The main concern in this field is showing impact of job classification and evaluation system on the other human resource subsystems and Employee's performance. In this study, job classification and evaluation briefly is named *job evaluation.*

Efficient and effective organizing and job evaluation are essential for achieving the goals and mission of organizations. Aim of this study is to evaluate the efficiency of organizing and job evaluation process. For this purpose data of five governmental organizations are working in the field of oil and gas industry, is gathered and analyzed by using Network Data Envelopment Analysis (NDEA) technique. In addition, it is the first research attempt to construct a performance evaluation model for the organizing and evaluation process that considers both the efficiency of the respective functional departments as well as their relative contributions to the overall performance of the process.

2 Network Data Envelopment Analysis

Performance evaluation is a critical part of the management process. It provides information necessary for decision-making, and also delivers a competitive advantage for continued operations.

Data Envelopment Analysis (DEA) is a non-parametric tool for assessing the relative efficiency of homogeneous Decision Making Units (DMU).This approach first establishes an ‘‘efficient frontier’’ formed by a set of decision making units (DMUs) that exhibit best practices and then assigns the efficiency level to other non-frontier units according to their distances to the efficient frontier [15].

This operational research methodology has two main models have been developed according to the nature of returns to scale: the CCR model and the BCC model. The CCR model, named for Charnes et al. [16], was developed under the assumption of constant returns to scale (CRS). The second model, the BCC model, introduced by Banker et al. [17] as an extension of the CCR model, was developed under the assumption of variable returns to scale (VRS).

Today, over 3000 papers published on or using various DEA efficiency models, such as the additive model, the slacks-based measures, combined models (DEA-AHP, PCA-DEA…),DEA with undesirable inputs or outputs, etc. are available, for over 30 industrial or non-industrial applications health care, banking, hotel management and locating facilities, etc.

Traditional DEA models consider the process of a DMU as a black box; they ignore to measure the efforts of different processes and sub-processes within the organization [18], Thus to measure the efficiency of a network system (systems with more than one process connected with each other) a Network DEA (NDEA) model is needed. Fare and Grosskopf [18-20] developed several network models that can be used to discuss variations of the standard DEA model. Kao [21] presented relational NDEA model and in addition to parallel and series systems, he modeled an equivalent tandem system where each stage has a parallel structure.

NDEA has been widely applied in industries such as banking [22-24], tourism [3], major league baseball [25], and airport [26].S. Lozano et al. [27] applied NDEA approach to airports performance assessment considering undesirable outputs, M. M. Yu and Erwin T.J. Lin [28] developed a multi-activity network DEA model to assess Efficiency and effectiveness in railway performance.

The network DEA model does not have a standard form; it depends on the structure of the network in question. Fig.2 presented a two-stage network structure studied by Y. Li et al. [29]. They assume that the output from the first stage ***all*** become the inputs to the second stage. These measures in-between the two stages are called *intermediate* measures. Specifically, a two-stage network DEA conducted and illustrated in Fig. 3. This structure relaxes above assumption by introducing ***outputs*** from first stage in addition to the intermediate measures.

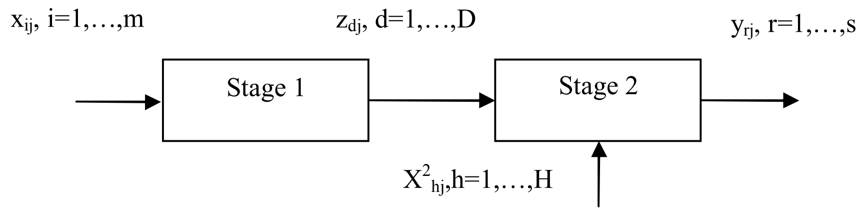

Fig.2 Two-stage process of DMU j (Y. Li et al., 2012)

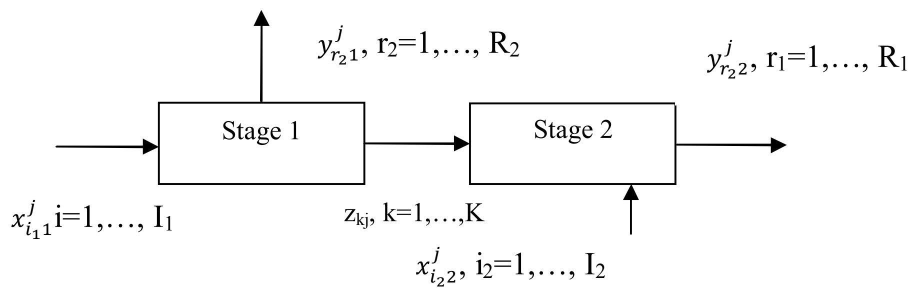

Fig.3 Two-stage process with additional output from first stage

We assume that each DMU $_j$ (j=1,…, n), has inputs and outputs (in 2 stage),as follows:

- **Stage 1**: I_1 inputs to the first stage,$x^j_{i_1 1}$, (i_1=1,…,I_1) with multipliers (weights) $v_{i_1 1}$, k output (intermediate measures) from the first stage, z^j_k, (k=1, 2,..,K) with multipliers η_k. These K outputs become part of the inputs to the second stage. Another part of outputs are $y^j_{r_1 1}$, (r_1=1, 2,…, R_1) with multipliers $u_{r_1 1}$.
- *Stage 2:* I_2 inputs to the second stage,$x^j_{i_2 2}$, (i_2=1,…,I_2) with multipliers (weights) $v_{i_2 2}$, R_2 outputs $y^j_{r_2 2}$, (r_1=1,2,…,R_2), with multipliers $u_{r_2 2}$.

Y. Li et al. [29] defined Overall efficiency of the two-stage process as the product of two stages' efficiencies to analyze the performance of two-stage network structure described in Fig. 3. D. Cook et al. [30] developed a multi stage network model that overall efficiency of process be represented *as a convex linear combination of the P (stage) measures*. Approach of Y.Chen et al. [31] and D. Cook et al. [30] is closer to our purpose thus based upon their model and the CCR model [16], we can establish NDEA model for Fig. 4.

The efficiency ratio of first and second stage for DMU j (with defined multipliers) would be expressed as (1) and (2):

$$\theta_1 = \frac{\sum_{r_1}^{R_1} u_{r_1 1} y_{r_1 1}^{j} + \sum_{k=1}^{K} \eta_k z_k^{j}}{\sum_{i_1=1}^{I_1} v_{i_1 1} x_{i_1 1}^{j}}, \tag{1}$$

$$\theta_2 = \frac{\sum_{r_2=1}^{R_2} u_{r_2} y_{r_2 2}^{j}}{\sum_{i_2=1}^{I_2} v_{i_2 2} x_{i_2 2}^{j} + \sum_{k=1}^{K} \eta_k z_k^{j}}, \tag{2}$$

Overall efficiency ratio of DMU $_j$ is as follows:

$$\theta = w_1 \theta_1 + w_2 \theta_2 \; where \; w_1 + w_2 = 1, \tag{3}$$

Weights of stages in the relation present the relative importance of the performances of individual stages to the Overall performance of the entire process. Depending on the type of process, we can choose reasonable relation for weights. In this study, weights are the proportion of the total inputs for the process that are used at the each stage, reflecting the relative size of that stage. Weights of first and second stage respectively are as (4) and (5):

$$w_1 = \frac{\sum_{i_1=1}^{I_1} v_{i_1 1} x_{i_1 1}^{j}}{\sum_{i_1=1}^{I_1} v_{i_1 1} x_{i_1 1}^{j} + \sum_{i_2=1}^{I_2} v_{i_2 2} x_{i_2 2}^{j} + \sum_{k=1}^{K} \eta_k z_k^{j}}, \tag{4}$$

$$w_2 = \frac{\sum_{i_2=1}^{I_2} v_{i_2 2} x_{i_2 2}^{j} + \sum_{k=1}^{K} \eta_k z_k^{j}}{\sum_{i_1=1}^{I_1} v_{i_1 1} x_{i_1 1}^{j} + \sum_{i_2=1}^{I_2} v_{i_2 2} x_{i_2 2}^{j} + \sum_{k=1}^{K} \eta_k z_k^{j}}, \tag{5}$$

Thus, overall efficiency will be in the form equation (6):

$$\theta = \frac{\sum_{r_1=1}^{R_1} u_{r_1 1} y_{r_1 1}^{j} + \sum_{k=1}^{K} \eta_k z_k^{j} + \sum_{r_2=1}^{R_2} u_{r_2 2} y_{r_2 2}^{j}}{\sum_{i_1=1}^{I_1} v_{i_1 1} x_{i_1 1}^{j} + \sum_{i_2=1}^{I_2} v_{i_2 2} x_{i_2 2}^{j} + \sum_{k=1}^{K} \eta_k z_k^{j}}, \tag{6}$$

The aim is to maximize the overall efficiency θ of the two stage process, subject to the restrictions that θ_1 and θ_2 mustnot exceed unity, therefore the ratio of outputs to inputs of each stage is set smaller than one

$$
\begin{aligned}
& Max \quad \frac{\sum_{r_1=1}^{R_1} u_{r_1 1} y_{r_1 1}^{o} + \sum_{k=1}^{K} \eta_k z_k^{o} + \sum_{r_2=1}^{R_2} u_{r_2 2} y_{r_2 2}^{o}}{\sum_{i_1=1}^{I_1} v_{i_1 1} x_{i_1 1}^{o} + \sum_{i_2=1}^{I_2} v_{i_2 2} x_{i_2 2}^{o} + \sum_{k=1}^{K} \eta_k z_k^{o}}, \\
& s.t. \\
& \qquad \frac{\sum_{r_1=1}^{R_1} u_{r_1 1} y_{r_1 1}^{j} + \sum_{k=1}^{K} \eta_k z_k^{j}}{\sum_{i_1=1}^{I_1} v_{i_1 1} x_{i_1 1}^{j}} \le 1 \ \forall \text{ j for stage 1}, \\
& \qquad \frac{\sum_{r_2=1}^{R_2} u_{r_2 2} y_{r_2 2}^{j}}{\sum_{k=1}^{K} \eta_k z_k^{j} + \sum_{i_2=1}^{I_2} v_{i_2 2} x_{i_2 2}^{j}} \le 1 \ \forall \text{ j for stage 2}, \\
& \qquad v_{i_1 1}, u_{r_1 1}, v_{i_2 2}, u_{r_2 2}, \eta_k \ge \varepsilon,
\end{aligned}
\tag{7}
$$

Or in the linear programming format, after making the usual Charnes and Cooper transformation, model (7) can be transformed as model (8)

$$
\begin{aligned}
& Max \quad \sum_{r_1=1}^{R_1} u_{r_1 1} y_{r_1 1}^{o} + \sum_{k=1}^{K} \eta_k z_k^{o} + \sum_{r_2=1}^{R_2} u_{r_2 2} y_{r_2 2}^{o} \\
& s.t. \\
& \quad \sum_{i_1=1}^{I_1} v_{i_1 1} x_{i_1 1}^{o} + \sum_{i_2=1}^{I_2} v_{i_2 2} x_{i_2 2}^{o} + \sum_{k=1}^{K} \eta_k z_k^{o} = 1, \\
& \quad \sum_{r_1=1}^{R_1} u_{r_1 1} y_{r_1 1}^{j} + \sum_{k=1}^{K} \eta_k z_k^{j} - \sum_{i_1=1}^{I_1} v_{i_1 1} x_{i_1 1}^{j} \le 0 \ \forall \text{ j}, \\
& \quad \sum_{r_2=1}^{R_2} u_{r_2 2} y_{r_2 2}^{j} - \sum_{k=1}^{K} \eta_k z_k^{j} - \sum_{i_2=1}^{I_2} v_{i_2 2} x_{i_2 2}^{j} \le 0 \ \forall \text{ j}, \\
& \quad v_{i_1 1}, u_{r_1 1}, v_{i_2 2}, u_{r_2 2}, \eta_k \ge \varepsilon,
\end{aligned}
\tag{8}
$$

In the base CCR model, variables are non-negative but Charnes et al.,[16] one year after first paper, proposed variables be equal or greater than ε. We use ε for lower bound of variables to ensure w_1 and w_2 not be zero and all of inputs and outputs are considered in efficiency evaluation. Note that the optimal value of θ_1 obtained by solving model (9)

$$
\begin{aligned}
& Max \quad \sum_{r_1=1}^{R_1} u_{r_1 1} y_{r_1 1}^{o} + \sum_{k=1}^{K} \eta_k z_k^{o} \\
& s.t. \\
& \quad \sum_{i_1=1}^{I_1} v_{i_1 1} x_{i_1 1}^{o} = 1, \\
& \quad \sum_{r_1=1}^{R_1} u_{r_1 1} y_{r_1 1}^{j} + \sum_{k=1}^{K} \eta_k z_k^{j} - \sum_{i_1=1}^{I_1} v_{i_1 1} x_{i_1 1}^{j} \le 0 \ \forall \text{ j}, \\
& \quad \sum_{r_2=1}^{R_2} u_{r_2 2} y_{r_2 2}^{j} - \sum_{k=1}^{K} \eta_k z_k^{j} - \sum_{i_2=1}^{I_2} v_{i_2 2} x_{i_2 2}^{j} \le 0 \ \forall \text{ j}, \\
& \quad \sum_{r_1=1}^{R_1} u_{r_1 1} y_{r_1 1}^{o} + \sum_{r_2=1}^{R_2} u_{r_2 2} y_{r_2 2}^{o} + (1-\theta^*) \sum_{k=1}^{K} \eta_k z_k^{o} - \theta^* \sum_{i_1=1}^{I_1} v_{i_1 1} x_{i_1 1}^{o} - \theta^* \sum_{i_2=1}^{I_2} v_{i_2 2} x_{i_2 2}^{o} = 0, \\
& \quad v_{i_1 1}, u_{r_1 1}, v_{i_2 2}, u_{r_2 2}, \eta_k \ge \varepsilon,
\end{aligned}
\tag{9}
$$

In model (9), the overall efficiency, θ^* , remains unchanged and obtained from solving of model (2) for considered DMU. θ_2 is then calculated, from convex linear relation with overall efficiency and θ_1, as $\theta_2 = \frac{\theta - w_1.\theta_1}{w_2}$.

3 An illustrative application

The aim of this study is to apply a network DEA model for measuring the efficiency of *organizing and job evaluation* process in five governmental company of oil and gas industry in Iran. For conducting a network DEA approach to this process, two main sub processes could be distinguished. Fig. 4 presents stages, inputs and outputs of organizing and job evaluation process.

This network, inputs and outputs is determined based on working process in these companies. So this process is described briefly.

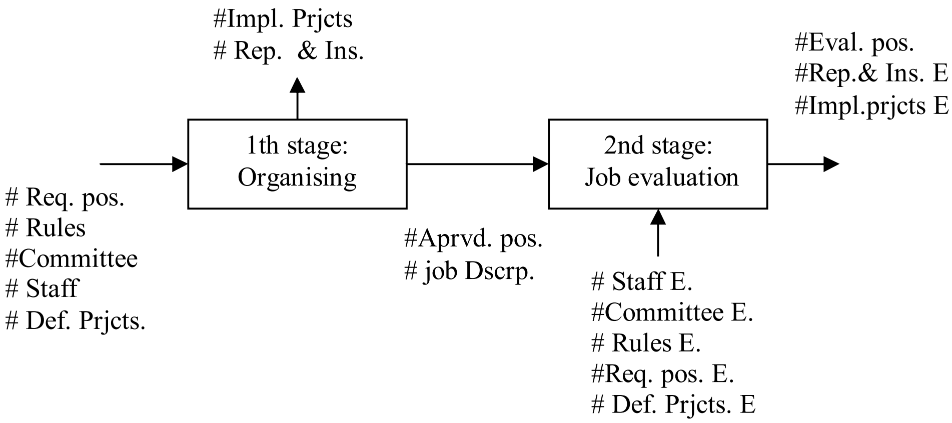

Fig. 4 organizing and job evaluation process as a two–stage network

Stage 1-organising: the main goal of organizing department is design, improve and bring up to date the structure and positions of organization. Improvement of structure performs in defined periods or when a request of organization review be received from other department. The number of these requests is first input. Policies and decisions issued by government and board of directors, External and internal rules and regulation affect the size, centralization and the other dimensions of design of structure. This parameter is defined as second input. The number of employees and the number of official working groups and committees for relevant decisions, in this department are other inputs. Projects and studies in order to continuous improvement and solving problems, in this field, are defined that intended as the last input. Notations and description of inputs and outputs of process are presented in table 1. Main documents that produced in this stage are intended as outputs.

Stage 2- job evaluation: In this stage, the worth of particular job is assessed on a number of dimensions or compensable factors usually including knowledge and skill, effort, responsibility and working conditions. A numerical score is assigned for each factor and a total score (job grade) for the job is computed [3]. This assessment is done on approved positions (Z_1) and positions that other departments requested only a review of job factors and grade (X_{42}). Other inputs and outputs are described in table 1.

Table 1 Notations and description

	notation	parameters	description
Inputs of first stage	X_{11}	# Req. pos.	The number of positions that was requested for review and design
	X_{21}	# Rules	The number of rules, regulations and directives on the design of organizational structure
	X_{31}	#Committee	The number of formal working groups and committees in the organizing department
	X_{41}	# Staff	The number of employees in the organizing department
	X_{51}	# Def. Prjcts.	The number of defined projects in this stage
outputs of first stage	Y_{11}	# Impl. prjcts	The number of implemented and completed projects in this stage
	Y_{21}	# Rep. & Ins.	The number of prepared reports and guidelines in this department
Intermediate measures	Z_1	# Aprvd. pos.	The number of created and approved positions
	Z_2	# job Dscrp.	The number of provided job description
Inputs of second stage	X_{12}	# Staff E.	The number of employees in the job evaluation department
	X_{22}	#Committee E.	The number of formal working groups and committees in the job evaluation department
	X_{32}	# RulesE.	The number of rules, regulations and directives on the job evaluation process
	X_{42}	# Req. pos. E.	The number of positions that was requested for review and change of job grade
	X_{52}	# Def. Prjcts. E	The number of defined projects in this stage
outputs of second stage	Y_{12}	# Eval. pos.	The number of evaluated positions
	Y_{22}	# Rep. & Ins. E	The number of prepared reports and guidelines in this department
	Y_{32}	# Impl.prjcts E	The number of implemented and completed projects in this stage

Table 2 provides the real data set related to this process. Table 3 report results of model 8 and 9. DMUs in table 2 are companies of oil, gas, Refining and Distribution and petrochemical industries that are shown briefly with CO_j.

Table 2 data set

	Inputs of first stage					**outputs of first stage**		**Intermediate measures**		**Inputs of second stage**					**outputs of second stage**		
	X11	X21	X31	X41	X51	Y11	Y21	Z1	Z2	X12	X22	X32	X42	X52	Y12	Y22	Y32
co_1	655	8	4	13	7	4	4	516	510	8	4	6	179	5	686	6	4
co_2	10600	18	17	30	17	3	3	4300	4100	30	15	13	400	15	4400	3	2
co_3	4742	7	6	14	5	2	2	2034	1900	8	3	5	50	6	2036	2	1
co_4	1140	11	8	10	10	2	2	500	450	11	10	8	110	7	530	3	1
co_5	490	6	3	4	3	1	1	213	200	3	1	5	5	2	217	2	0

The results based upon model (2), with $\varepsilon = 0.00001, \varepsilon = 0.000001$, are shown in columns 2 and 3,overall efficiencies are very close to each other so results are shown in columns 4–7just for $\varepsilon = 0.00001$. Results show organising and job evaluation process in first and third companies are efficient also overall efficiency of CO_5approximatelyis 1 but considered process of CO2 and CO4 clearly are not efficient Because of inefficiency in the second stage ($\boldsymbol{\theta_2^* < 1}$).

Table 3 Result

	$\varepsilon = 0.00001$	$\varepsilon = 0.000001$	$\varepsilon = 0.00001$			
	Overall efficiency (θ^*)	**Overall efficiency (θ^*)**	θ_1^*	w_1	θ_2^*	w_2
co_1	1	1	1	0.998	1	0.002
co_2	0.9893	0.9951	1	0.485	0.979	0.516
co_3	1	1	1	0.496	1	0.505
co_4	0.8352	0.8355	1	0.503	0.668	0.497
co_5	0.9985	0.9998	1	0.008	0.998	0.993

Value of $v_{i_1 1}$ shows the relative increase in the first stage efficiency of DMU if $x_{i_1 1}$ is reduced by 1 and $u_{i_1 1}$ presents the relative decrease in the first stage efficiency of DMU if $y_{i_1 1}$ is increased by 1 and so for second stage. The number of staff (X_{41}) of first stage affects the efficiency of this stage more than other parameters also the number of requested positions(X_{11}) affects efficiency of CO_4. Changes of the number of prepared reports and guidelines (Y_{21}) on first stage efficiency of $CO_1$and the number of created and approved positions (z_1) on first stage efficiency of CO3 and CO4 have greater impact. Thus managers should focus on these parameters to improve the efficiency of design of organization.

The number of rules (X_{32}), the number of requested positions (X_{42}) and the number of evaluated positions (Y_{12}) are more affect the θ_2.Thus its necessary to increase the number of evaluated positions relation to the number of requested positions, also managers of CO3 and CO4 should reduce the number of rules to improve second stage efficiency and overall efficiency in their organizations.

4 Conclusion

The importance of the organizational structure in achievement of organization's goals and impact of job classification and evaluation system on the other human resource subsystems and Employee's performance has caused efficiency assessment of this process becomes an important managerial issue for managers and decision makers.

This paper is the first to apply the network DEA proposed by Y.Chen et al. [31] and D. Cook et al. [30] to construct a network performance evaluation model for the organizing and job classification and evaluation process. The model evaluates the performance of two departments and of the overall process, as well as the strategic and managerial issues of efficiency and effectiveness, resulting in a comprehensive performance measure.

This empirical study considers 5 organization of oil and gas industry in Iran and provides detailed results on the overall effectiveness and efficiency of the individual stages and analysis of inputs and outputs which are more effective.

For future work, this model can be applied under variable returns to scale (VRS) assumptions. The development of an integrated model of DEA and multivariate statistical techniques for increasing the strength of discrimination of DMUs can be done. Finally, we hope that organizations improve their overall performance through comprehensive performance evaluation, and that this leads to an increase in the competitiveness of them in this industry.

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