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Assessing the Relative Performance of Nurses using Data Envelopment Analysis Matrix (DEAM)

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Abstract

Assessing employee performance is one of the most important issue in healthcare management services. Because of their direct relationship with patients, nurses are also the most influential hospital staff who play a vital role in providing healthcare services. In this paper, a novel Data Envelopment Analysis Matrix (DEAM) approach is proposed for assessing the performance of nurses based on relative efficiency. The proposed model consists of five input variables (including type of employment, work experience, training hours, working hours and overtime hours) and eight output variables (the outputs are amount of hours each nurse spend on each of the eight activities including documentation, medical instructions, wound care and patient drainage, laboratory sampling, assessment and control care, follow-up and counseling and para-clinical measures, attendance during visiting and discharge suction) have been tested on 30 nurses from the heart department of a hospital in Iran. After determining the relative efficiency of each nurse based on the DEA model, the nurses' performance were evaluated in a DEAM format. As results the nurses were divided into four groups; superstars, potential stars, those who are needed to be trained effectively and question marks. Finally, based on the proposed approach, we have drawn some recommendations to policy makers in order to improve and maintain the performance of each of these groups. The proposed approach provides a practical framework for hospital managers so that they can assess the relative efficiency of nurses, plan and take steps to improve the quality of healthcare delivery.

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Introduction

Today, hospitals are considered as the most important consumers of resources in the healthcare and treatment sectors [1]. In such a situation, it is necessary to develop methods to assess performance for proper management of resources in order to improve the quality of healthcare. Efficiency is one of the most important and common mechanism for assessing and measuring the performance of an economic sector such as a hospital. The performance estimation through efficiency measurement has always been a matter of interest for researchers in different economic sectors [2].

The results of various studies indicate that the most important factor in determining the performance of hospitals and the quality of healthcare, from both the patients' and hospital managers' point of view, is the issue of human resources providing services [3, 4, 5]. This is important because of the direct interaction and communication between employees and the visitors [6, 7]. The performance appraisal and investment in the workforce are important parts for the management of healthcare resources, because the proportion of staff costs is high compared to the total cost of the treatment system. Also, the performance of such a system has a major influence on the welfare of the community [8]. However, in order to assess the performance of nurses, various approaches have been used such as self-appraisal, reflection, portfolio, multi-source feedback, standards and management by objectives, etc. [9], but efforts to improve the nurses' performance have been focused on effectiveness rather than efficiency [10, 11]. In summary, effectiveness is the capability of producing a desired result and efficiency is the ability to do things well, successfully, and without waste. So, comparing the nurses' performance with each other (relative performance) was not possible.

Data Envelopment Analysis (DEA) is one of the approaches widely used in assessing the relative efficiency of decision makers [12]. Although in the area of healthcare, this approach was initially used to assess the relative efficiency of homogeneous units [13, 14, 15, 16, 17, 18, 19, 20, 21, 22], but according to Masiye et al (2006) and Monika and Mariana (2015), DEA can also be used as a tool for controlling human resources [23, 24]. The DEA has the potential to be used for individual-level performance assessment. In this regard, Osman et al. (2011) and Johannessen et al. (2017) have used the DEA approach to assess the relative performance of human resources involved in healthcare [9, 25].

This paper proposes a DEA framework that can be used to measure the efficiency of nurses. Nurses, as one of the main providers of healthcare services, play an important role in providing high-quality, cost-effective healthcare services, and assessing their performance is an essential tool for improving the quality of healthcare services and advancing professional standards [26, 9]. Therefore, the DEA approach can be very useful as an appropriate tool for assessing nurses' performance based on relative efficiency. The proposed approach in this paper assesses the relative efficiency of nurses and ranks them accordingly. The relative concept is based on the fact that all nurses are evaluated by using the same input and output criteria. This paper focuses on the analysis of nurses' performance assessing based on Osman et al. (2011) developed approach taken from the analysis of the outputs of the DEA models, which we call it the DEA Matrix (DEAM) [9]. In the first part of the paper, an overview of the concept of DEA approach and the

relevant basic model have been discussed. In the second part, the research methodology is used to apply DEAM to assess the performance of hospital nurses as a case study. In the third section, we analyze the results of the implementation of the model. Finally, the conclusions and direction for future studies are given.

Background

Data Envelopment Analysis

DEA approach for the first time was introduced by Charnes et al. (1978) as a method for functional analysis for the performance of homogeneous decision-making units / organizations [27]. DEA has widely used to compare the performance of several competitive organizations within an industry. In fact, DEA has been added to the literature of economy by integrating Farrel's (1957) method [28], in such a way that the characteristics of the production process included several factors of production (input) and multiplicity (output) [27]. In DEA using a set of observations, an experimental production function is constructed based on observed data. It is called "frontier analysis" because this method offers a boundary function that includes all the data and in other words, envelops all the data. Since the DEA method is based on a set of optimizations and there is no parameter for estimation, it is a nonparametric method [29]. In other words, DEA tool is a non-parametric boundary evaluation model used for the relative measurement and the performance of a set of comparable entities (called decision-maker units: DMU) in converting inputs to outputs. In the literature of DEA, the basic assumption is the homogeneity of DMUs. This means that DMUs have the same inputs and outputs for measuring [30]. In fact, this approach measures the efficiency of a DMU compared to other DMUs within an organization or in a similar industry. For this reason, the performance score obtained by DEA is called a relative efficiency.

The advantage of DEA is that the performance boundary can be generalized and used as a template for similar organizations. DMUs which are on this boundary get the efficiency score of one and are technically more efficient than their counterparts. A score less than one and more than zero is assigned to all other DMUs. In fact, the efficiency of a DMU depends on the performance of that unit in transferring inputs to outputs compared to other units in a particular domain [31]. DEA has the ability to detect inefficient units and patterns for modeling [32]. The efficiency value is determined by comparing with a convex set of two or more DMUs that are located on an efficient boundary and use the same input level and produce the same or greater output level. This set is called the reference set which creates a hypothetical compound unit called virtual unit. It enables the management to understand its inefficiency and the optimal use of resources to increase productivity and performance. Therefore, DEA is an effective tool for multidimensional content that includes multiple inputs against multiple outputs which has been used in many applications [32, 33].

DEA formulation

Assume there are n DMUs (j= 1, …, n), each using m inputs (x_{ij}, i=1, .., m) and producing s outputs (y_{rj}, r=1,..s) According to the definition of efficiency, the basic model of DEA is formulated follows.

$$Max\ E_p = \frac{\sum_r y_{rp} u_r}{\sum_i x_{ip}\, v_i} \quad (1)$$

$Subject\ to$:

$$\frac{\sum_r y_{rj} u_r}{\sum_i x_{ij} v_i} \leq 1 \qquad \forall j = 1, \dots, n$$

$$u_r\ , v_i \geq 0 \qquad \forall r = 1, \dots s\ \&\ i = 1, \dots, m$$

Ep: efficiency index of decision maker's unit p

y_{rj}: the value of the output r for DMU j; r = 1,2, ..., s

x_{ij}: value of input i for decision-maker unit j; i = 1,2, ..., m

u_r: the specified weight for output r; r = 1,2, ..., s

v_i: the specified weight for input i; i = 1,2, ..., m

This model is based on multiple inputs and outputs, which is expressed in terms of a fractional programming model. The weights that maximize the efficiency of unit p (Ep) are determined in the form of the target function, thereby determining the relative efficiency of unit p. The first limitation shows that the efficiency of each unit cannot exceed one (there is a limitation for each decision maker unit p). The last limitation also states that all determined weights should be considered positive. Unit p is relatively efficient if its efficiency score is one (Ep = 1), otherwise it is inefficient.

In this study we use DEA to assess the relative performance of nurses in the form of relative efficiency by using DEAM approach. The nurses are chosen from the heart department of Imam Reza Hospital in Mashhad is located Iran.

Methodology: the proposed approach

Identification of inputs and outputs of the model

In order to identify the inputs and outputs for assessing the relative efficiency of nurses, expert opinions (experienced supervisors) based on Delphi method were used. We have identified five main issues to be considered: (1) type of employment that indicates the status of nurses' recruitment in the ministry of health includes Official , Temporary Official (that turns into Official after 3 years), Contractual (affiliated to organization), Contractual (non-affiliated to organization), Compulsory Service (that after training, they are committed to serving for 2 years); (2) work experience (experience level of the nurse in system); (3) training hours (the hours of ongoing training); (4) working hours (the hours of work time in one month); and (5) overtime hours (the hours of overtime work in one month). Since the education level of the nurses was similar, this variable has been omitted from the above list. The expected outputs include (1) documentation (the hours of documented records for patients in one month); (2) medical instructions (number of registered drug orders in one month); (3) wound care and patient drainage (the hours of care of the wounds and drains for patients in one month); (4) laboratory sampling (the hours of laboratory sampling in one month); (5) assessment and control care (the hours of assessments and care performed with the aim of controlling in one month); (6) follow-up and counseling and para-clinical measures (the hours of follow-up, counseling and para clinical

measures in one month); (7) attendance during visiting (the hours of attending a patient's visit by the doctor in one month); and (8) discharge suction. Details of inputs and outputs (the hours of attending at the time of discharge suction in one month) are given in Table 1.

Data on inputs and outputs for 30 nurses are taken from the hospital database in July 2016. In order to homogeneous the units of analysis (nurses), only the Nurses of the internal department of the hospital were considered. Also, in order to observe ethical considerations in preserving Nurses' information and information, the collected data were determined according to specific codes for Nurses.

Table 1 Inputs and outputs in DEA Model

Variables	Description	Scale
Inputs:		
I1: Type of employment	Official, Temporary Official, Contractual (affiliated to organization), Contractual (non-affiliated to organization), Compulsory Service	scores: 5, 4, 3, 2 and 1
I2: Work experience	the experience of the Nurse	years
I3: Training hours	given training during work	hours
I4: Working hours	work time in one month	hours
I5: Overtime hours	overtime work in one month	hours
Outputs:		
O1: Documentation	documentation done in one month	hours
O2: Medical instructions	registered drug orders in one month	hours
O3: Wound care and patient drainage	care of the wounds and drains of the patients in one month	hours
O4: Laboratory sampling	laboratory sampling in one month	hours
O5: Assessment and Control care	assessments and care performed with the aim of controlling in one month	hours
O6: Follow-up and counseling and para-clinical measures	follow-up, counseling and para clinical measures in one month	hours
O7: Attendance during visiting	attending a patient's visit by the doctor in one month	hours
O8: Discharge suction	attending at the time of discharge suction in one month	hours

In this research, two main DEA models have been used: the Constant Returns to Scale (CRS) model, sometimes called the CCR model, and the Variable Returns to Scale (VRS) model which is known as BCC model. In other words, the CCR model works under the assumption of CRS and it is used in situations where outputs increase proportionally for increase in inputs. For example, a doubling of working hours (input) will double documentation (output). The BCC model works under the assumption of VRS and this model fits situations where outputs do not increase proportionally for increase in inputs. For example, a doubling of work experience (input) will not double documentation (output).

Based on the CCR model, since the basic model (1) of DEA is a fractional programming model, after transformation it has been presented to a linear programming as follows [27].

$$Max\ E_p = \sum_r y_{rp} u_r \tag{2}$$

$$\sum_i x_{ij}\, v_i = 1$$

$$\sum_r y_{rj}\, u_r - \sum_i x_{ij}\, v_i \le 0 \quad \forall j = 1,2,\dots,30$$

$$u_r\,, v_i \ge 0 \qquad \forall r = 1,2,\dots,8\,, \qquad \forall i = 1,2,..,5$$

This is an input-oriented approach and the output- oriented model can be presented in the same way, too. The dual problem of model (2) can be written as follows:

$$Min\ E_p^{'} = \theta \tag{3}$$

$$\sum_j x_{ij}\, \lambda_j \le x_{ip}\theta \quad \forall i = 1,2,\dots,5$$

$$\sum_j y_{rj}\, \lambda_j \ge y_{rp} \quad \forall r = 1,2,\dots,8$$

$$\lambda_j \ge 0 \qquad \forall j = 1,2,\dots,30$$

It is assumed that in the CCR model the production functions have CRS. For example, the inputs are doubled, the outputs are proportionally changed with the sam ratio of inputs to double. However, in many organizations, a small decision maker unit with a large decision maker cannot be compared to the multiplication of inputs and outputs in a constant factor, which results from CCR. This issue has been addressed in the BCC model by adding the constraint ($\sum_j \lambda = 1$) to the dual problem, and thus, refer to VRS model that considers the form of IRS (increasing returns to scale) and DRS (decreasing returns to scale) [34]. The addition of this allows DMUs to be compared with each other in the same size. The BCC (VRS) model can be expressed as follows.

$$Min\ E_p^{'} = \theta \tag{4}$$

$$\sum_j x_{ij}\, \lambda_j \le x_{ip}\theta \quad \forall i = 1,2,\dots,5$$

$$\sum_j y_{rj}\, \lambda_j \ge y_{rp} \quad \forall r = 1,2,\dots,8$$

$$\sum_j \lambda_j = 1 \qquad \forall j = 1,2,\dots,30$$

$$\lambda_j \ge 0$$

Analysis based on the DEA matrix (DEAM)

In order to analyze the outputs taken from DEA models, we have developed a DEA Matrix (DEAM) based on the approach presented in Osman et al (2011) [9]. The basis for analysis in this matrix is similar to the Boston Consulting Group (BCG) matrix analysis [35]. This matrix gives a good insight using two-dimensional analysis and in this research, create a good discrimination between the nurses performance based on two oriented model for managers. Based on this matrix, in the analysis of relative efficiency based on DEA models, individuals (DMUs) are divided into

four groups: superstar, potential star, to be trained efficiency and question mark. The super star group consists of nurses with high relative efficiency in input-oriented DEA-CRS and output-oriented DEA-VRS. In this group, managers should improve the efficiency by providing motivation. Nurses in potential star group, although have high relative efficiency in output-oriented DEA-VRS, their input-oriented DEA-CRS is low. Therefore, in order to be able to join the superstar group, they must focus on the inputs of the model (work experience, working hours, etc.) and compensate the deficiency in the field. The group needs to be trained effectively, including nurses who, although having a relatively high performance in input-oriented DEA-CRS, have low relative efficiency in output-oriented DEA-VRS. The function of these groups can be improved through effective training courses in the fields of job knowledge, communication, and alike. The nurses in the question mark group also have low efficiency in both of input-oriented DEA-CRS and output-oriented DEA-VRS. In other words, their status indicates an inadequate performance. This requires careful studies to find the causes.

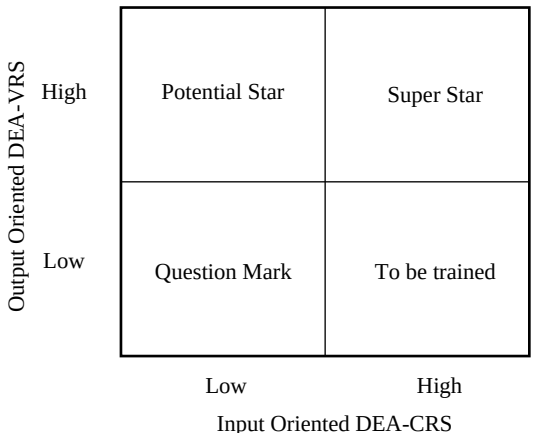

Fig. 1 DEA Matrix (Osman et al., 2011)

Results and discussions

Based on the inputs and outputs, the various DEA models including CRS and VRS were solved, results have been reported in Table 2. As can be seen, based on DEA-CRS, 14 out of 30 nurses (46%) are inefficient and the average score of performance is 0.77. According to the results of DEA-VRS in the input-oriented mode, 10 nurses (33%) are inefficient and the average efficiency score is 0.99 while in the output-oriented model with an average efficiency of o.83, 11 nurses are identified as inefficient. Details of the relative performance status of each nurse have been reported in Table 2. For example, as the Nurse 1 with efficiency score of 1 is an efficient service provider. The efficiency of Nurse 3 is 0.53 in DEA-CRS model is which is ranked eighth in terms of efficiency and its reference units are 18, 21 and 23. Also, this nurse has been ranked in the 9^{th} place with efficiency score of 0.93 in DEA-VRS (output-oriented), its reference units are 16, 21 and 25 while in the output oriented model its efficiency score equals to 0.55 (with the rank of 6^{th} and reference units of 18, 21 and 23).

Using the outputs taken from the DEA solution, we can determine the amount of deficit or surplus of the values of each of the inputs and outputs for each inefficient unit. For example, in Table 3 reports the shortage or surplus of

each input and output in respect to the target value means for the Nurse 3. As can be seen, Nurse 3 is an efficient person and he/she requires improving his/her Output 1 (documentation) from 22.5 hours to 56.15 hours of activity per month, Output 2 (medical instructions) from 24.27 Hour to 48.69 hours of activity per month, output 3 (wound care and patient drainage) from 13.48 to 25.78 hours per month, output 4 (laboratory sampling) from 10.93 hours to 54.19 hours of activity per month, Output 5 (assessment and control care) from 8 hours to 14.30 hours of activity per month, Output 6 (follow-up and counseling and para-clinical measures) from 24.2 hours to 73.74 hours of activity per month, Output 7 (attendance during visiting) from 15/12 hours to 13/41 Credit activity in the month, Output 8 (discharge suction) from 20.7 hours to 28.7 hours per month.

Table 2 Results of DEA-CRS and DEA-VRS for 30 nurses

Nurse	DEA-CRS (Input/ Output oriented)			DEA-VRS (Input oriented)			DEA-VRS (Output oriented)		
	E. Score	**Rank**	**Ref. set***	**E. Score**	**Rank**	**Ref. set**	**E. Score**	**Rank**	**Ref. set**
1	1.00	1	1	1.00	1	1	1.00	1	1
2	1.00	1	2	1.00	1	2	1.00	1	2
3	0.53	8	18,21,23	0.93	9	16,21,25	0.55	6	18,21,23
4	1.00	1	4	1.00	1	4	1.00	1	4
5	1.00	1	5	1.00	1	5	1.00	1	5
6	0.35	14	4,11,21	0.97	6	4,16,25	0.35	9	4,11,21
7	0.25	15	18,22	1.00	1	7	0.25	11	18,22
8	1.00	1	8	1.00	1	8	1.00	1	8
9	1.00	1	9	1.00	1	9	1.00	1	9
10	0.15	16	14,17,18	0.96	7	16,21,25	0.15	12	14,17,18
11	1.00	1	11	1.00	1	11	1.00	1	11
12	0.51	9	14,18,21,23	0.94	8	16,212,27	0.52	7	5,18,21,23
13	1.00	1	13	1.00	1	13	1.00	1	13
14	1.00	1	14	1.00	1	14	1.00	1	14
15	1.00	1	15	1.00	1	15	1.00	1	15
16	0.78	6	1,11,18	1.00	1	16	1.00	1	16
17	1.00	1	17	1.00	1	17	1.00	1	17
18	1.00	1	18	1.00	1	18	1.00	1	18
19	0.95	2	14,18,21,23	0.97	4	14,18,21,22,23	0.96	2	5,13,14,23
20	0.90	3	4,15,17,18,23	0.99	2	4,16,17,21,23	0.90	3	4,15,17,18,23
21	1.00	1	21	1.00	1	21	1.00	1	21
22	1.00	1	22	1.00	1	22	1.00	1	22
23	1.00	1	23	1.00	1	23	1.00	1	23
24	0.49	10	11,21,23	0.96	5	4,16,21,22	0.51	8	11,21,23
25	0.47	11	4,21,23	1.00	1	25	1.00	1	25
26	0.81	4	14,18,23	1.00	1	26	1.00	1	26
27	0.28	12	11,14,18,22	1.00	1	27	1.00	1	27
28	0.26	13	11,14,18,22	0.97	5	1,16,22	0.26	10	11,14,18,22
29	0.68	7	5,11,22	0.99	3	1,11,16,22	0.70	5	1,11,16,22
30	0.80	5	1,14,18	0.97	4	1,11,14,16,22	0.80	4	1,14,18
Average	**0.77**			**0.99**			**0.83**		

* Ref. set: Reference set is the set of efficient units from which an inefficient unit's inefficiency has been determined.

Table 3 Projection improvement for Nurse 3 (DEA-VRS Output oriented)

Inputs/ Outputs	Actual (Observed)	Projection (Target)	Difference (Target-Observed)
I1	4	2.87	1.13
I2	12	12	0.00
I3	42	18.71	23.28
I4	163.33	154.31	9.01
I5	103.67	100.50	3.17
O1	22.50	56.15	33.65
O2	24.17	48.69	24.52
O3	13.48	25.78	12.3
O4	10.93	19.54	8.61
O5	8.00	14.30	6.3
O6	24.02	64.73	40.71
O7	12.15	41.13	28.98
O8	7.20	28.07	20.87

After identifying the relative performance of each nurse, we grouped the nurses (DMUs) based on DEAM framework to determine their performance. According to this framework, DMUs were divided into four groups based on the relative efficiency scores: (1) Super Star group (CRS and VRS scores are higher than or equal the average efficiency scores (0.77 and 0.83 respectively)); (2) Potential Star group (CRS score is less than the average efficiency score (0.77) and VRS efficiency score is higher than or equal the average efficiency score (0.83)); (3) Question Mark group (CRS and VRS scores are less than the average efficiency score (0.77 and 0.83 respectively)); and (4) to be trained group(CRS score is higher than or equal the average efficiency score (0.77) and VRS efficiency score is less than the average efficiency score (0.83)). Based on the rule described, we grouped the nurses and the result are shows in the table 4. As can be seen, 19 nurses (63.3%) are in the Super Star group, 2 nurses (6.7%) in the Potential Star group, 8 nurses (26.7%) in the Question Mark group, and 1 nurse (3.3%) to be trained effectively. For example, Nurse 29 is located in the Question Mark group with relative efficiency 0.68 in input-oriented DEA-CRS and 0.7 in output-oriented DEA-VRS.

Table 4 The result of grouping the DMUs (nurses) based on DEAM framework

DMU (Nurse)	Efficiency		Type
	DEA-CRS (Input oriented)	DEA-VRS (Output oriented)	
1	1.00	1.00	Super Star
2	1.00	1.00	Super Star
3	0.53	0.55	Question Mark
4	1.00	1.00	Super Star
5	1.00	1.00	Super Star
6	0.35	0.35	Question Mark
7	0.25	0.25	Question Mark
8	1.00	1.00	Super Star
9	1.00	1.00	Super Star
10	0.15	0.15	Question Mark
11	1.00	1.00	Super Star
12	0.51	0.52	Question Mark
13	1.00	1.00	Super Star

14	1.00	1.00	Super Star
15	1.00	1.00	Super Star
16	0.78	1.00	Super Star
17	1.00	1.00	Super Star
18	1.00	1.00	Super Star
19	0.95	0.96	Super Star
20	0.90	0.90	Super Star
21	1.00	1.00	Super Star
22	1.00	1.00	Super Star
23	1.00	1.00	Super Star
24	0.49	0.51	Question Mark
25	0.47	1.00	Potential Star
26	0.81	1.00	Super Star
27	0.28	1.00	Potential Star
28	0.26	0.26	Question Mark
29	0.68	0.70	Question Mark
30	0.80	0.80	to be trained

Discussion

The DEAM results provide several insights for management to improve the nurses performance of nurses. The DEAM is a two-dimensional matrix whose one axis represents the relative efficiency score based on the input-oriented in CRS model and the other axis, which includes the relative efficiency score based on the output-oriented in VRS model. In each axis, the relative efficiency score is between zero and one. The score from zero to average efficiency scores represents a low efficiency and a score of average efficiency scores to one shows the high efficiency of nurses. As shown in Fig. 2, the status of each of the nurses studied in the DEA matrix (DEAM) is shown based on the results obtained from the DEA models. Accordingly, the nurses were divided into four types based on their performance scores: Super Star (63.3%), Potential Star (6.7%), Question Mark (26.7%), and to be trained (3.3%).

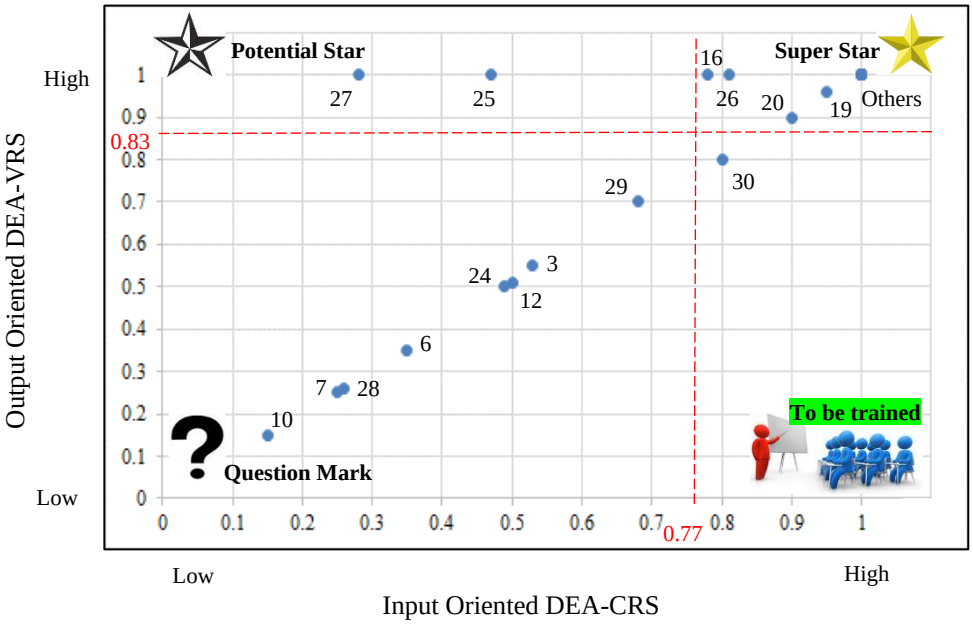

Fig. 2 allocating of the nurses according to their DEA Matrix (DEAM)

The Super Star group includes nurses with high relative efficiency in both input-oriented DEA-CRS and output-oriented DEA-VRS and according to Osman et al. (2011), Managers should provide motivation with various incentives to maintain and improve the relative efficiency of these nurses. In Potential Star group, nurses have high relative efficiency in output-oriented DEA-VRS and low score in input-oriented DEA-CRS. For this reason, this group is called the Potential Star, which makes it possible for them to become Super Star. To convert them into superstar groups, managers should focus on the inputs of these nurses (work experience, working hours, etc.) and compensate the deficiencies. Question Mark group includes the nurses who have low relative efficiency in both input-oriented DEA-CRS and output-oriented DEA-VRS and this status indicates an inappropriate performance. Manager should investigate the causes of poor efficiency in this group and find a way to improve the nurses in the Question Marks group. The nurses of forth group have low relative efficiency in input-oriented DEA-CRS and high score in output-oriented DEA-VRS. These nurses need to be trained and learn how to increase their outputs to inputs. Therefore, training courses can be greatly benefit for them in the field of job knowledge, communication, interpersonal skills, and so on.

Conclusions

Proper use of resources is one of the most important issues in the field of hospital management. In this regard, assessing the human resources performance, especially nurses, is of particular importance. This paper proposed a DAE framework for assessing the performance of nurses that helps hospital managers by (1) providing information about the performance of nurses based on efficiency and, consequently, the quantity of provision of services, (2) identifying nurses with low performance and (3) using DEA results makes it possible to give some suggestions for improving the efficiency of nurses which helps managers to know how to target their efforts or where to spend their limited resources in such a way that maximizes the managers' efforts. Using the proposed approach and analyzing the results, hospital managers are able to perform a proper analysis of the nurses' performance based on their relative performance evaluation. Careful programs should be planned to improve the performance of nurses as well as the matching of reward systems with the performance of individuals.

In future researches, the viewpoints of clients or patients about nurses' performance can be considered as part of the outputs in the model, so that it is possible to measure relative efficiency with a more comprehensive dimension. On the other hand, the present study was a cross-sectional study in a certain time for assessing the relative efficiency of nurses. It is recommended that researchers should evaluate the relative efficiency at different times in order to control and assess the progress of nurses' performance over time.

Compliance with Ethical Standards

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