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Surgical services efficiency by data envelopment analysis

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Abstract

Purpose – Different surgical services demand operating rooms (OR) to treat elective patients, each competing for a limited supply of OR time. The purpose of this paper is to obtain empirical measures of performance in the management of OR. The current research compares technical efficiency of 11 specialties in elective operating theatre of Alzahra Hospital in Isfahan, Iran in autumn of 2009.

Design/methodology/approach – Data envelopment analysis (DEA) can be used as tools in management control and planning. First, the input oriented and variable returns to scale model of DEA technique has been applied and separate benchmarks for possible reductions in resources used has been derive, and significant savings are possible on this account.

Findings – The efficiency scores of inefficient specialties are between 0.62 and 0.96. Neurosurgery and general surgery are the best and the worst units. DEA results determine by how much hospitals can increase elective inpatient surgeries for each specialty.

Originality/value – The originality of this study is to obtain empirical measures of performance in the management of OR. DEA has not been applied to measure the efficiency of different department in an organization. The measures are common in different units and have been collected in a similar way.

Keywords Performance measurement, Data envelopment analysis, Health services

Paper type Research paper

1. Introduction

In recent years providing health services to patients has becoming increasingly important and countries spend an average number of 8.4 per cent of their GDPs on health services (The World Health Report, 2007). In this environment application of managerial approaches will led to the more efficient use of resources. The health services efficiency is one of the most important issues in the

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current societies. It has been considered that big savings can be achieved by improving hospitals' efficiency. The evaluation of health care efficiency has lagged behind the measurement of health care quality. Providers, payers, purchasers, consumers and regulators all could benefit from more information on efficiency in health care. Hospitals absorb a large share of public health expenditures; therefore, considerable savings in health cost can be achieved through the improving their efficiency.

In Iran, the ratio of health expenditures to GDP has increased from 6.14 per cent in 2004 to 6.87 per cent in 2007 (The World Health Report, 2007). Within the social, political and economic environment in which hospitals operate, there is considerable public quest in Iran for improvements in productivity, reductions in operating costs and better quality of treatment. This requires the optimization based approaches to the evaluation of healthcare services and to the distribution of the limited resources among the hospitals according to their efficiency. The amount of equipment and particularly high-technology devices is usually insufficient in Iran, and public hospitals are often unable to respond independently to the needs of patients and have to outsource to the assistance of the private sector. This is why implementing systematic and exact techniques is vital in Iran.

Analytical approaches to assess the hospital performance are much more critical today with the interest in system reform and with recent changes in evaluation systems. This paper evaluates existing measures and develops new ones that, taken together, provide an analytic approach for assessing the surgical group's performance in order to achieve efficient care for the acute patients. Since operating theatre has the hospital's largest cost and revenue (Health Care Financial Management Association, 2003), it has significant role in the performance of the hospital as a whole. The most commonly used measures come from the data extracted from the hospital information system to assess hospital performance. The measures are chosen such that they are easily calculated and accessible.

The hospital in which this study was conducted in Isfahan started to operate as one of the largest health care centers in the Middle East in 1993. It contains 35 wards in six floors and 750 active beds. As affiliated to the Isfahan University of Medical Sciences, all surgeries, mostly complicated ones, are practiced in this hospital. There are 20 operating rooms (OR) for elective surgeries of ten groups, with approximately 65-75 surgeries per day. It is usual that two OR-days is assigned to each specialty and consequently distributed to the surgeons in the group. The elective inpatients are referred from the surgeons' clinics. It is a need for the OR supervisor to find out how efficient the specialties use their allocated block times for future planning. Indeed, Emergency cases are not taken into consideration because the emergency cases are treated in four OR in emergency department. The current research studies the efficiency of surgical services within this hospital. Data envelopment analysis (DEA) is a multi-criteria decision making technique that will be applied to understand the potential to grow different specialties of elective surgery.

In this study, the factors or attributes which affect on the surgical services' efficiency are determined by reviewing the literature on the OR and interviewing the experts. Then, the required data for the test example are collected from the hospital documentation and database. The efficiency of surgical groups are analyzed by DEA based on the recognized attributes. The target values for different attributes

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are determined for each inefficient group, proposing the possible improvements in the service performance. The efficiency scores for the individual surgeons within each service will also be reported.

2. Literature review

DEA has proven to be an effective method for health care efficiency measurement. In the last two decades DEA is used widely in evaluation of hospital technical efficiency all around the world at different levels of decision making units. Efficiency analysis has usually been allied to performance evaluation of decision-making units (DMUs). Farrell studied the measurement the efficiency of a production unit considered by a single input and a single output (Farrell, 1957). His study involved the evaluation of price and technical efficiencies and the derivation of the efficient production function. Farrell's model is unsuccessful in providing a way to recap all inputs and outputs into a single virtual input and single virtual output.

The efficiency of operational services has usually been measured by means of ratio analysis (cost per day, cost per patient, etc.) and econometric methods on the basis of which a production function or a cost function is predicted. Ratio analysis, regardless of providing direct information about performance, is limited by certain clear weaknesses. One of them is that each ratio being limited to one input and one output, the need to add in relative weights and the difficulty to explain the performance of individual hospitals when ranking efficiency across many hospitals. Econometric methods, on the other hand, are more reliable to the simple application of ratios, mainly because the model takes into account the relation between a number of hospital inputs and outputs. A number of studies have considered how hospitals use their resources and how they provide their services. The indicators of performance that are generally available provide assessments of individual hospitals in their intensity of care per case treated, their need for facilities and the efficiency of management (Ozcan, 2008). The usual way of forming the measurement of efficiency is through frontier estimation. The concept of "frontier" means the borderline for the set of units (or hospitals) with different efficiency scores; only those units which work on the frontier are efficient. The methods of frontier estimation for efficiency measurement try to approximate the frontier based on the observation of those units which perform the best practice.

Experimental measurement of efficiency varies from two main methodologies: stochastic parametric regression-based methods to non-stochastic non-parametric mathematical programming methods. DEA uses a series of linear programming models. The results of this mathematical modeling can be used to compare similar types of service providers. Like all mathematical models their results depend heavily on the precision of the data. Assume that there are n DMUs producing R output measures using M input measure s. Let the jth DMU produces rth output y_{rj} using mth x_{mj} input. Efficiency is measured by transforming observed data on multiple inputs and outputs into a single efficiency ratio for each operational unit performing similar services. Efficiency scores are calculated by the ratio of weighted sum of outputs to weighted sum of inputs as: $\sum_r u_r y_{rj} / \sum_m v_m x_{mj}$ in which u_r and w_m are the measures' weights. Each DMU is allowed to choose a set of weights that maximize its efficiency score, such that none of the DMUs' efficiency scores is larger than one. The optimal weights for the measures of each DMU are determined applying linear programming models (Charnes *et al.*, 1978) either by fixing the weighted sum of inputs at 1 and maximizing the weighted sum of outputs as in input oriented or vice versa, by fixing the weighted sum of outputs and minimizing the weighted sum of inputs as in output oriented models. The CCR[1] input-oriented model for jth DMU is as follows:

$$\max \quad z_j = \sum_r u_r y_{rj}$$

$$s.t. \begin{cases} \sum_m v_m x_{mj} = 1 \\ \sum_r u_r y_{ri} - \sum_m v_m x_{mi} \leqslant 0, & \forall i = 1, \ldots, N \\ u_r, v_m \geqslant 0, & \forall r, m \end{cases} \tag{1}$$

The efficiency analysis can be further described whether DMUs perform within regions of decreasing, constant or increasing returns to scale. Efficient DMUs are those for which it is possible to find a set of positive weights to make the efficiency ratio equal to one. Otherwise, the DMU's efficiency score will be less than 1 and it will be considered as inefficient. The DEA models aim to identify the efficient DMU that produces the largest amounts of outputs by consuming the least amounts of inputs. A DMU's efficiency score shows its current position (distance) relative to a "frontier" of best practice.

DEA, has received wide applications in efficiency evaluation for many public and private sectors, especially in health care. Areas of application consist of hospitals, physicians, nursing homes and health maintenance organizations (Ozcan, 2008). The first experience of DEA on hospitals was applied to a characteristics or types of hospitals group of teaching hospitals. O'Neill in 1998 applied DEA to a group of teaching hospitals to analyze their overall hospital productivity. Hospitals produce a wide range of heterogeneous outputs in differing proportions. Output dimensions have proved to be very difficult to measure. A way to ease this measurement problem in efficiency analysis is to use more homogenous and less aggregated units by considering specific services in the hospital, such as the surgical units. Finkler and Wirtschafter (1993) studied an application of DEA to a system of nine hospitals that offer obstetric services . Puig-Junoy proposes to apply DEA for measuring the technical efficiency at the patient level. DMUs are defined as the intencive care unit (ICU) taking resource allocation decisions in an individual production process, that is, a patient. Defining this level of study allows one to consider in detail patient characteristics which compose necessary dimensions of the input and output set (Puig-Junoy, 1998). Bahurmoz (1998) gets the point that the success of DEA in the developed countries be applied to Middle East countries significant that the practice of operations research techniques involves not only science; it also involves cultural, ethical, behavioral and bureaucratic structures that influence a country's and an individual's approach to decision making. Kontodimopoulos and Niakas (2005) have got encouraging results for efficiency evaluation of homo-dialysis units in Greece. Their data sample were classified as units working in the public and private sector, and also based on the location.

In 2004 O'Neill and Dexter examined an increase in OR block times using DEA. Later, Basson and Butler (2006) used DEA to evaluate the efficiency of 23 ORs. They proved that DEA analysis is more efficient than other ranking methods for measuring ORs efficiency according to the complex nature of efficiency evaluation in ORs. They also demonstrate the importance of selecting appropriate inputs and outputs on final result. O'Neill *et al.* (2008) in their study of taxonomy of DEA applications illustrate

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various inputs and outputs used by different researchers in service production process. These studies show that DEA is an efficient technique for evaluating the efficiency of surgical teams in ORs. O'Neill and Dexter applied DEA to 53 hospitals' perioperative services (Dexter and O'Neill, 2004). For inefficient hospitals, DEA provided information on the sources of inefficiency, as shown by the values of slack variables in the model. In addition to measures of hospital resources, their model includes market factors that are major predictors of surgical demand. Ketabi (2011) explores the ability of DEA to assess relative efficiency of CCU in Isfahan hospitals. Huang *et al.* Ozcan (2008) reviews the applications of DEA in different healthcare systems.

In general, these studies not only show that DEA is an effective technique for evaluating the efficiency of health care organizations, but also reflect the diversity of problems in health care management which can be handled by DEA. The need to put a lid on expenses and improve quality of services requires a superior model for measuring of efficiency. This study defenses DEA as a managerial tool.

The choice of inputs and outputs in a DEA study has very important implications for the results obtained. However, the aim here is not so much to assess but to exhibit the ability of DEA to evaluate relative efficiency of ORs. In order to decide which inputs and outputs can be selected to measure OR efficiency one has to develop a thorough understanding of what process a surgery generally performs and what resources are used. Clearly any resource used by a unit may be included as an input, where input factors are desired to be as low as possible. The outputs should include the amounts of services produced by the surgical group, and any other factor which need to be maximized. The outcome services may be produced at different levels of quality. Hence, the outputs may include a range of performance measures. In addition, environmental factors which may affect the production of these outputs must be identified and included in the evaluation model. But availability of data also must be considered, and for computational efficiency the multiplication of the number of inputs and outputs in total should not exceed the number of units being assessed. The most commonly used measures come from the ratios of data included in hospital information system. The advantages of some ratios, as input or output measures, are that they are easily calculated and accessible. Several researchers have studied different attributes affects the OR performance. Most of them aim at minimizing both over-utilization and under-utilization of ORs (O'Neill and Dexter, 2007; Guinet and Chaabane, 2003; Jebali *et al.*, 2006; Ozkarahan, 2000; Dexter and O'Neill, 2004). A summary of the literature on the OR performance attributes is given in Table I.

Table I. Literature on OR performance attributes

Reference to the research	Attribute
O'Neill and Dexter (2007), Guinet and Chaabane (2003), Jebali *et al.* (2006), Ozkarahan (2000), Dexter and O'Neill (2004)	Over-utilization
O'Neill and Dexter (2007), Guinet and Chaabane (2003), Jebali *et al.* (2006), Ozkarahan (2000), Dexter and O'Neill (2004)	Under-utilization
O'Neill and Dexter (2007), Dexter and O'Neill (2004)	Number of beds
O'Neill and Dexter (2007), Dexter and O'Neill (2004)	Number of surgeons
O'Neill and Dexter (2007), Dexter and O'Neill (2004), Testi *et al.* (2007)	Surgical demand
Tsai (2008)	Labor cost, and total cost
O'Neill and Dexter (2007)	Contribution margin
O'Neill and Dexter (2007)	Number of high technology services

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3. Research method

In this research the input oriented variable return to scale model of DEA has been used to determine the efficiency score for each service. The choice of the input oriented model is justified by the fact that managers in health care services tend to have greater control over inputs rather than outputs. Zhu has provided an easy-to-use and powerful DEA software, DEA Excel Solver, which is used in this study (Kontodimopoulos and Niakas, 2005). DEA Excel Solver is an Add-Ins tool for Microsoft Excel and provides a custom menu of DEA approaches.

The data for the test example hve been collected for each surgeon of each service at each month of the time period of autumn semester, 2009, and then has been added over the surgeons of each service and averaged over four months. The data for surgery infection and mortality has been documented for the whole service. The scheduling and educational planning remained unchanged during these four months.

3.1 Surgical services performance attributes

Many studies have demonstrated the impact of selecting appropriate inputs and outputs attributes on DEA final result. Nuti *et al.* (2013) reviews some of the verification tools for the performance measures effectiveness such as analyzing the degree of legitimacy, or the improvements which have been reached over time, or by comparing results of organizations adopting performance evaluation tools against "control" organizations, or by measuring performance effectiveness trough qualitative surveys. Without an integration of clinical and financial measures, it is almost impossible to effectively improve the processes in healthcare organizations for three purposes: strategic; to drive strategies into action and change the organizational culture, diagnostic; to evaluate the effectiveness of these actions and the extent of change and operational; to improve continuously (Mendez, 1999). The availability of data to construct measures, obtained either from service providers or from public databases, is the most important factor cited as either facilitating or impeding the use of measures (Damberg *et al.*, 2011).

This paper develops new measures that, taken together, provide an analytical approach for evaluating the surgical services performance. The selection has been based on the patient satisfaction and resource efficiency. In order to have reasonable selection, the input/output measures or variables were defined by interviewing the OR supervisor of the hospital and the experts in the care deputy of Isfahan University of Medical Science. Some of the attributes which reveals the service performance are: no. of surgeons in the group, average (marginal) revenue, no. of OR block allocated to the group, outcome of the surgeries (infection possibility and mortality), over or under utilization of the allocated OR block time and educational index such as no. of residents. Some qualitative factors have been integrated as type of surgeries that consists of: demand or waiting list, average of required (pre, peri, post-operative) resources such as surgery time, recovery time, ICU time and ward length of stay (LOS). Consuming the OR resources depends on the surgery time and the value of the OR facilities. Although the waiting time or equivalently the demand for the specialty surgery has been proposed as an effective factor on the OR time allocation in the literature, but in this research the waiting time or demand cannot be obtained. The reason is that the elective inpatients are referred from the surgeons' clinics and there is no access their data.

On the other hand, it is proved that in order to have a good measurement of efficiency, number of DMUs, input and output factors should have a logical relation. To reduce the number of factors, the effective attributes are aggregated by voting and

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priorities which are collected using pairwise comparison provided by OR supervisor and applying analytical hierarchy process (AHP). AHP is a multi-criteria decision making technique to find the relative importance of the factors. AHP algorithm is basically composed of two steps: determining the relative weights of the decision criteria and determining the relative rankings (priority) of alternatives (Saaty, 1982). Both qualitative and quantitative attributes can be compared using informed judgments to derive weights and priorities.

For all of three attributes: utilization, resource consumption and surgery outcome, the values have been calculated by the simple additive weighting of their sub-attributes' values. These values had been un-scaled by linear and fuzzy methods for un-scaling. Second, it is noted that four sub-attributes of resource consumption which are: OR time, recovery time, ICU time and ward LOS, depend on the nature of the surgery, and do not affect each other. Third, it is assumed that this research cannot make target value for resource consumption, because it depends on the medical concerns of the surgeries. Therefore, either this attribute is considered uncontrollable or as it is inherently input variable, has been considered as inversed output variable. The other note is that the utilization attributes, which shows the outcome of the group performance, has inverse concept; it is actually un-utilization, and therefore will be considered as an input attribute. The fifth note is that, the teaching index has been well measured by the number of residents and fellows at each service, but, unrealistic data had been reported, and therefore discarded at this stage of research; this attribute will be included in the model after reliable data will be obtained. Figure 1 shows the hierarchy of the attributes which affect on the surgical services' efficiency. Then, the efficiency score determined by DEA model based on the historical data, and can be used to the allocation of additional OR times.

4. DEA efficiency scores for surgical services

In this section the relative importance of the sub-attributes, efficiency and super-efficiency scores are reported, although the number of surgical services is not sufficient to discriminate their efficiency. It is actually the individual surgeons

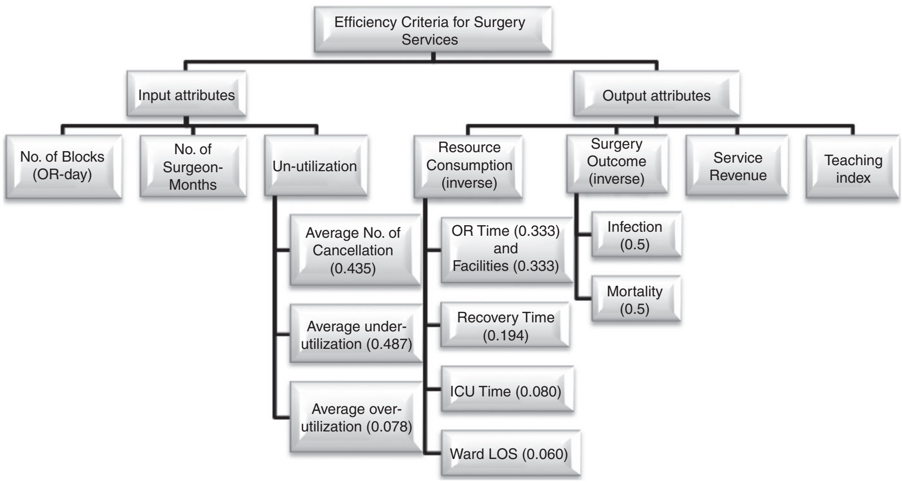

Figure 1.
The hierarchy of performance attributes for surgical services and relative importance of sub-attributes

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in different services to whom the OR blocks is allocated. Therefore, the efficiency of the surgeons in the operating theatre are also reported based on the same attributes.

4.1 The relative importance of attributes by AHP

In order to apply AHP, the commercial software expert choice is available which simplifies the implementation of the AHP's steps and automates many of its computations. The OR supervisor and head nurses agreed on the pairwise comparison between each set of sub-attributes. The relative importance of the resource consumptions, utilization and surgery outcome factors are shown beside the corresponding sub-attributes in Figure 1.

DEA can be performed to determine which surgical service has the potential for growth. DEA reveals whether a group is consuming more hospital resources than expected based on the producing output factors (education, utilization and revenue); then its efficiency must be increased by the proposed target values for the factors. Efficiency rating as related to performance assessment (that has been formulated in model 1) can be explained as the maximum proportion of the input measures which is necessary for the surgical service to perform at least the current outputs, in order to be classified as relatively efficient. The third column of Table II gives the efficiency scores for inefficient surgical services. For example, Urology is inefficient with an efficiency rating of 0.89, which means that it should be able to produce its current output level using 89 per cent less of each input.

4.2 The reference set or benchmark

The reference set or benchmark is a very useful indicator as it shows clearly how an inefficient surgical service performance is weak in comparison to its reference set. DEA identifies for each inefficient unit its reference set of efficient units which have shown better performance, as shown in Table III. The frequency of the efficient groups that appear in the reference set (reference set) of the inefficient groups, can be used to differentiate between them. Note that neurosurgery and transplantation appeared more than the others. This reflects that these groups can offer good practice examples to the others; while thoracic has been referred for only three other services and general surgery performance has not been adopted by the others.

DMU no.	DMU name	Efficiency	No. of blocks	Unutilization	Sergeon-month	Resource	Surgery outcome	Income
1	Plastic	1.00000	0.06213	1.26096	0.00000	0.00000	1.06280	0.01227
2	Oral and maxillofacial	1.00000	0.00000	0.00000	0.04762	1.31337	0.00000	0.00000
3	ENT	1.00000	0.00000	1.93295	0.00000	0.00000	2.00273	0.03977
4	Neurosurgery	1.00000	0.06764	0.22518	0.00000	0.00000	0.00000	0.01471
5	Orthopedics	0.95701	0.00000	1.93257	0.00000	0.00000	1.58227	0.03033
6	Gynecology	0.89241	0.00000	2.00608	0.00000	0.59250	0.00000	0.00000
7	Urology	0.89182	0.00000	2.02060	0.00000	0.00000	0.42980	0.00000
8	Transplantation	1.00000	0.05002	2.48264	0.00000	1.47912	0.00000	0.02480
9	General surgery	0.62373	0.08333	0.00000	0.00000	0.00000	0.00000	0.01732
10	Thoracic	1.00000	0.00000	2.06207	0.00034	0.00000	0.72472	0.01637
11	Pediatric	0.73113	0.00000	0.00000	0.04545	0.00000	1.42857	0.00000

Table II. Attributes' multipliers in input-oriented DEA

Table III.
Surgical services efficiency and benchmark

DMU no.	DMU name	Efficiency	Benchmarks					
1	Plastic	1.00000	1.000	Plastic				
2	Oral and maxillofacial	1.00000	1.000	Oral and maxillofacial				
3	ENT	1.00000	1.000	ENT				
4	Neurosurgery	1.00000	1.000	Neurosurgery				
5	Orthopedics	0.95701	0.151	Plastic	0.509	ENT	0.340	Thoracic
6	Gynecology	0.89241	0.592	Oral and maxillofacial	0.408	Transplantation		
7	Urology	0.89182	0.921	Plastic	0.079	Transplantation		
8	Transplantation	1.00000	1.000	Transplantation				
9	General surgery	0.62373	0.311	Neurosurgery	0.689	Thoracic		
10	Thoracic	1.00000	1.000	Thoracic				
11	Pediatric	0.73113	0.337	Plastic	0.154	ENT	0.509	Thoracic

DEA also provides performance targets that can be set by the head of group to improve its efficiency. As a by-product DEA yields a set of projected input/output levels that would render a surgical service relatively efficient, for every inefficient one. The percentage of reductions of input attribute for each inefficient DMU are given in Table IV. For example, general surgery group may perform efficiently, if its number of allocated block is reduced by 37 per cent, the overall utilization is increased by 41 per cent and number of surgeons-month is decreased by 52 per cent. Performance targets for the evaluation factors reveal the potential cost saving, or in other words, the excess resources that could have been saved in order to achieving an efficiency rating of 100 per cent.

4.3 Super-efficiency and full-ranking

Since half of the surgical groups have been determined as efficient DMUs, the super-efficiency model has been run to get the full ranking (and discriminating) of all DMUs. The Anderson and Peterson super-efficiency model 2 is identical to the CCR model (Charnes *et al.*, 1978), except that the self-referential constraint

Table IV.
Input attributes' target

	Target-percentage of input reduction		
DMU name	No. of blocks	Un-utilization	Surgeon-month
Plastic	0.00000	0.00000	0.00000
Oral and maxillofacial	0.00000	0.00000	0.00000
ENT	0.00000	0.00000	0.00000
Neurosurgery	0.00000	0.00000	0.00000
Orthopedics	55.45051	2.38722	28.83929
Gynaecology	20.42745	0.00000	38.36025
Urology	22.41110	0.00000	36.66667
Transplantation	0.00000	0.00000	0.00000
General surgery	36.63827	40.57401	51.62764
Thoracic	0.00000	0.00000	0.00000
Pediatric	31.84524	23.50089	26.88718

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(first constraint in model 1) is relaxed, allowing the efficiency score to exceed one (Andersen and Petersen, 1993).

$$\max \quad z_j = \sum_r u_r y_{rj}$$

$$s.t. \begin{cases} & \sum_m v_m x_{mj} = 1 \\ \sum_r u_r y_{ri} & -\sum_m v_m x_{mi} \leqslant 0, \quad \forall i = 1, \ldots, N, \;\; i \neq j \\ u_r, v_m \geqslant 0 & , \forall r, m \end{cases} \tag{2}$$

It provides the ability to make finer distinctions between efficient DMUs. Table V gives the full ranking of surgical groups in the hospital. As shown, neurosurgery and pediatric surgery have been detected as the most and the least efficient units.

5. DEA efficiency scores for the surgeons

In practice, the OR supervisor of the hospital allocates the OR block to the surgeons within a group. Almost all attributes' data had been collected for the surgeons separately, except for surgery outcome, over-utilization time and number of students (as teaching index). Removed these attributes, Figure 2 shows the input and output variables for the efficiency measurement of individual surgeons. There is no need to aggregate the attributes, because the number of surgeons as DMUs is sufficient to discernment between them. Table VI gives the efficiency scores for the surgeons.

6. Conclusion

Lessons from benchmarking activities in other sectors suggest that – when applied to health systems – benchmarking will be most effective if it focuses on practice as well as performance and carefully considers how performance is linked to resource allocation (Smith and Papanicolas, 2012).This paper considers the aspects of efficiency (based on the utilization and resource efficiency) beyond the traditional evaluation of check list for the hospitals. This study has evaluated the performance of the surgical services at

DMU No.	DMU name	Super efficiency
1	Plastic	1.12017
2	Oral and maxillofacial	1.23256
3	ENT	1.32789
4	Neurosurgery	2.80023
5	Orthopedics	0.95701
6	Gynaecology	0.89241
7	Urology	0.89182
8	Transplantation	2.50000
9	General surgery	0.62373
10	Thoracic	1.84202
11	Pediatric	0.73113

Table V. Super efficiency and full ranking

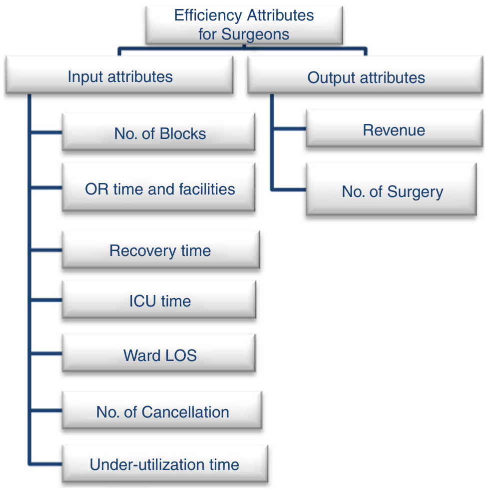

Figure 2. The hierarchy of performance attributes for surgeons

one large hospital in Isfahan, Iran using the input oriented and variable returns to scale (VRS) model of DEA. Previous studies have described how DEA can be employed to calculate the technical efficiency of similar departments in different hospitals. Driving separate benchmarks for possible reductions in resources is used. Considerable savings are possible on this account suggesting the potential and significant improvements. Results have been shown in Tables II-IV shows the optimal benchmarks for different attributes, especially for the number of allocated OR blocks, has been reported for each surgical service. Neurosurgery and pediatric surgery are the best and the worst services.

O'Neill and Dexter compared the operating theatres of several hospitals using DEA (Dexter and O'Neill, 2004), but in this research the efficiency of the operating theatre in one hospital has been determined by changing the OR blocks. Testi *et al.* (2007) found the optimal number of allocated OR blocks through Integer Programming with one criteria: waiting time. In this study several effective attributes have been considered . Chiu *et al.* (2012) also consider the elective case cancellation rate on the day of surgery as an indicator of operating theatre efficiency. They found out that the most common reason was no OR time due to overrun of previous surgery. In some specialties the schedule may be intentionally over-booked to increase the utilization rate, while carrying the risk that the cases could be cancelled. Overbooking can be minimized by taking surgeon, anesthesia, patient and facility factors into account and using statistical methods to estimate the amount of time allocated to each procedure (Chiu *et al.*, 2012).

DEA is a tool to measure efficiency of units with similar inputs and outputs. This method is confirmed as a suitable method in assessing efficiency in health care systems (Ozcan, 2008). Recently, the centralized models have been employed to treat the resource allocation and target setting problems. As this work has shown, DEA is a useful method in evaluating efficiency of surgical services in ORs. When a gap (or slack) is positive, there is potential for the hospital to increase the specialty's workload. That does not mean that increasing workload would benefit the hospital financially. In addition, there may not be efficient operational capacity to recruit

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DMU no.	Surgeon's name	Input-oriented CRS Efficiency
1	Thoraic and trans 1	0.85714
2	Thoraic and trans 2	0.85714
3	Thoraic 3	0.80548
4	Ortho 1	0.71429
5	Ortho 2	0.71429
6	Ortho 3	0.85714
7	Ortho 4	0.40612
8	Ortho 5	1.00000
9	Ortho 6	0.71429
10	Ortho 7	0.49022
11	ENT 1	0.85714
12	ENT 2	0.77860
13	ENT 3	1.00000
14	ENT 4	0.85714
15	ENT 5	1.00000
16	ENT 6	1.00000
17	Plastic 1	0.65187
18	Plastic 2	0.85714
19	Plastic 3	0.71429
20	Plastic 4	0.58672
21	Plastic 5	0.85714
22	Neuro 1	0.85714
23	Neuro 2	0.85714
24	Neuro 3	1.00000
25	Neuro 4	1.00000
26	Neuro 5	0.48116
27	Neuro 6	0.44268
28	Neuro 7	0.57143
29	Maxillo 1	0.23282
30	Maxillo 2	0.71429
31	Maxillo 3	0.71429
32	Maxillo 4	0.71429
33	Maxillo 5	0.57143
34	Maxillo 6	0.42644
35	Pedia 1	0.73195
36	Pedia 2	0.85714
37	Pedia 3	0.85714
38	Pedia 4	0.85714
39	Pedia 5	0.45169
40	Pedia 6	0.71429
41	Gyna 1	0.54052
42	Gyna 2	0.57143
43	Gyna 3	0.71429
44	Gyna 4	0.58427
45	Gyna 5	0.67601
46	Gyna 6	0.55967
47	Gyna 7	0.51318
48	Gyna 8	0.50002

(continued)

Table VI. Efficiency scores for the surgeons

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Table VI.

DMU no.	Surgeon's name	Input-oriented CRS Efficiency
49	General 1	0.85714
50	General 2	1.00000
51	General 3	0.35043
52	General 4	0.65252
53	General 5	0.53985
54	General 6	0.35220
55	General 7	1.00000
56	General 8	0.85714
57	General 9	0.57143
58	Urology 1	0.85714
59	Urology 2	0.66190
60	Urology 3	0.57143
61	Urology 4	0.85714
62	Urology 5	0.41347
63	Urology 6	0.71429
64	Urology 7	0.48565
65	Urology 8	0.57143
66	Urology 9	0.42857

another surgeon or increase the block time for a current surgeon. These issues should be considered when interpreting DEA results.

The DEA results should be interpreted with caution due to the limitation of available data, inaccuracy of the collected data and to the limitations inherited in DEA itself. As a minimum it offers initial perception and diagnoses of services' performance. A basic advantage of DEA is that the weights (multipliers) for the inputs and outputs are selected automatically on solving the model based on its data. This advantage could lead to misleading results where a unit might assign very low weights to certain inputs and outputs in order to get a larger efficiency score. After discussing on the result of efficiency ratings with the Care Deputy of the Medical University of Isfahan, a few facts which may interpret such performance have been revealed. These notes are summarized as follows:

(1) Although neurosurgery did perform its surgery with low utilization, but its revenue is very high and this made the service efficient. It is the same with general surgery. An improved DEA model may be applied to make the utilization factor have a pre-defined least importance, to prevent such false efficiency.

(2) It has been requested to find out how to increase the efficiency of the whole Operating theatre. It would be the future study to apply centralized DEA for centralized decision making.

(3) The efficiency score for the surgeons are more applicable, because the OR block is allocated to the individual surgeons. Therefore each surgeon can determine how to improve his or her efficiency in operating at the allocated blocks. The efficiency of the surgical services may be calculated from the efficiency scores of their surgeons. Indeed, the DEA efficiency analysis is more reliable for the surgeons, because there are more DMUs. The other

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advantage is that the potential improvement in different attributes for the surgeon are proposed separately, as the attributes are not required to be aggregated.

This paper focuses on evaluating the efficiency of ORs, considering surgical groups as decision making units. New measures have been developed that, taken together, provide an analytical approach for assessing the surgical services performance. One of the main impacts of this research is how efficiency measures of surgeries may be accounted, even in one governmental hospital. In other words, the cancelation rate, under or over utilization and the revenue have been considered as well as the quality of the care. One limitation of this research is that it has not provided operational evidence of the reliability. As the National Quality Forum mentions in its report, for many of the measures, the population is so small that are not usable, even at the group level. It may not make sense to endorse these (Smith and Papanicolas, 2012).

The reliability of the set of data that has been selected to measure efficiency has to be examined by comparing the efficiency scores for two or more consecutive years using the same factors. The results of the present study prove that DEA is a useful tool for performance evaluation and applicable to problems in developing countries. However, the need for a well-designed database is a prerequisite in order for the system to get benefit from Operations Research techniques; to calculate the performance measures the data infrastructure is key (Smith and Papanicolas, 2012).

Note

1. Charnes, Cooper and Rhodes.

References

Andersen, P. and Petersen, N.C. (1993), "A procedure for ranking efficient units in data envelopment analysis", *Management Science*, Vol. 39 No. 10, pp. 1261-1264.

Bahurmoz, A.M.A. (1998), "Measuring efficiency in primary health care centres in Saudi Arabia", *J. KAU: Econ. & Adm*, Vol. 12 No. 2, pp. 3-18.

Basson, M.D. and Butler, T. (2006), "Evaluation of operating room suite efficiency in the veterans health administration system by using DEA", *The American Journal of Surgery*, Vol. 192 No. 5, pp. 649-656.

Charnes, A., Cooper, W. and Rhodes, E. (1978), "Measuring the efficiency of decision making units", *European Journal of Operational Research*, Vol. 2 No. 6, pp. 429-444.

Chiu, C., Lee, A. and Chui, P.(2012), "Cancellation of elective operations on the day of intended surgery in a Hong Kong hospital: point prevalence and reasons", *Hong Kong Med J*, Vol. 18 No. 1, pp. 5-10.

Damberg, C.L., Sorbero, M.E., Lovejoy, S.L., Lauderdale, K., Wertheimer, S., Smith, A., Waxman, D. and Schnyer, C. (2011), *An Evaluation of the use of Performance Measures in Health Care*, RAND Corporation, Santa Monica, CA.

Dexter, F. and O'Neill, L. (2004), "Data envelopment analysis to determine by how much hospitals can increase elective inpatient surgical workload for each specialty", *Anesth Analg*, Vol. 99 No. 5, pp. 1492-1500.

Farrell, M.J. (1957), "The measurement of productive efficiency", *Journal of the Royal Statistical Society*, Vol. 120 No. 3, pp. 252-281.

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Finkler, M.D. and Wirtschafter, D.D. (1993), "Cost-effectiveness and data envelopment analysis", *Health Care Management Review*, Vol. 18 No. 3, pp. 81-88.

Guinet, A. and Chaabane, S. (2003), "Operating theatre planning", *International Journal of Production Economics*, Vol. 85 No. 1, pp. 69-81.

Health Care Financial Management Association (2003), "Achieving operating room efficiency through process integration", *Health Finance Manage*, Vol. 57 No. S3, pp. 1-7, 122.

Jebali, A., Hadj Alouane, A.B. and Ladet, P. (2006), "Operating room scheduling", *International Journal of Productions Economics*, Vol. 99 No. 1, pp. 52-62.

Ketabi, S. (2011), "Efficiency measurement of cardiac care units of isfahan hospitals in Iran", *J. of Medical Systems*, Vol. 35 No. 2, pp. 143-150.

Kontodimopoulos, N. and Niakas, D. (2005), "Efficiency measurement of hemodialysis units in Greece with data envelopment analysis", *Health Policy*, Vol. 71 No. 2, pp. 195-204.

Mendez, K. (1999), "Performance measurement in health Care", available at: www.qualitydigest.com/may99/html/body_health.html (accessed September 2013).

Nuti, S., Seghieri, C. and Vainieri, M. (2013), "Assessing the effectiveness of a performance evaluation system in the public health care sector: some novel evidence from the Tuscany region experience", *J. Manag Gov*, Vol. 17 No. 1, pp. 59-69.

O'Neill, L. and Dexter, F. (2007), "Tactical increases in operating room block time based on financial data and market growth estimates from DEA", *Anesth Analg*, Vol. 104 No. 2, pp. 355-368.

O'Neill, L. (1998), "Multifactor efficiency in data envelopment analysis with an application to urban hospitals", *Health Care Management Science*, Vol. 1 No. 1, pp. 19-27.

O'Neill, L. and Dexter, F. (2004), "Evaluating the efficiency of hospitals' perioperative services using DEA", in Brandeau, M.L., Sainfort, F. and Pierskalla, W.P. (Eds), *Operations Research and Health Care: A Handbook of Methods and Applications*, Kluwer's International Series, Boston, pp. 147-168.

O'Neill, L., Rauner, M., Heidenberger, K. and Kraus, M. (2008), "A cross-national comparison and taxonomy of DEA-based hospital efficiency studies", *Socio-Economic Planning Sciences*, Vol. 42 No. 3, pp. 158-189.

Ozcan, Y. (2008), *Health Care Benchmarking and Performance Evaluation: An Assessment using Data Envelopment Analysis (DEA)*, Springer, New York, NY.

Ozkarahan, I. (2000), "Allocation of surgeries to operating rooms using goal programming", *Journal of Medical Systems*, Vol. 24 No. 6, pp. 339-378.

Puig-Junoy, J. (1998), "Technical efficiency in the clinical management of critically ill patients", *Health Econ.*, Vol. 7 No. 3, pp. 263-277.

Saaty, T.L. (1982), *Decision Making for Leaders; The Analytical Hierarchy Process for Decisions in a Complex World*, Belmont, CA.

Smith, P. and Papanicolas, I. (2012), *Health System Performance Comparison: an Agenda Forpolicy, Information and Research*, World Health Organization, Copenhagen.

Testi, A., Tanfani, E. and Torre, G. (2007), "A three-phase approach for operating theatre schedules", *Health Care Manage Sci*, Vol. 10 No. 2, pp. 163-172.

The World Health Report (2007), *A Safer Future: Global Public Health Security in the 21st Century*, World Health Organization, Geneva, available at: www.who.int/whr/2007/whr07_en.pdf (accessed January 2013).

Tsai, M.H. (2008), "Ten tips in providing value in operating room management", *Anesthesiol Clin.*, Vol. 26 No. 4, pp. 765-783, viii.

Wachtel, R.E. and Dexter, F. (2008), "Tactical increases in operating room block time for capacity planning should not be based on utilization", *Anesthesiology*, Vol. 106 No. 1, pp. 215-226.

Zhu, Joe. (2002), *Quantitative Models for Performance Evaluation and Benchmarking: Data Envelopment Analysis with Spreadsheets*, Kluwer Academic Publishers, Boston, MA.

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