MEASURING TECHNICAL AND SCALE EFFICIENCY OF PUBLIC HOSPITALS IN THE UAE USING THE DEA METHOD: A PILOT STUDY

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ABSTRACT

In order to get a handle on rising health care costs, governments need to improve the productivity and efficiency of hospitals and health care centers. The United Arab Emirates (UAE) spends a lot of money to provide healthcare to its citizens through a system of district hospitals and healthcare centers. One crucial element of this review process is efficiency assessment. However, to date no attempt has been made to assess the technical efficiency of hospitals. A main problem for policy makers and hospital administrators is how to measure the efficiency of individual hospitals and whether the set of efficiency measures produced can be used as an incentive for improved performance. In this paper we will present the results of the use of a mathematical modeling method, namely the DEA, in a pilot study to evaluate the technical and scale efficiency of a sample of 18 hospitals[1]*. The results of this important research will provide hospital administrators as well as health care policy makers with a wealth of precise information that can be used by them to streamline the operations and improve the performance of their respective organization. The study found that 44.5% of the hospitals were inefficient. The information provided includes technical and scale efficiency levels, a measure of possible input reductions and output improvements, identification of appropriate benchmarks and target inputs and outputs for the inefficient hospitals*

[1] The names of the hospitals have been concealed for confidentiality reasons

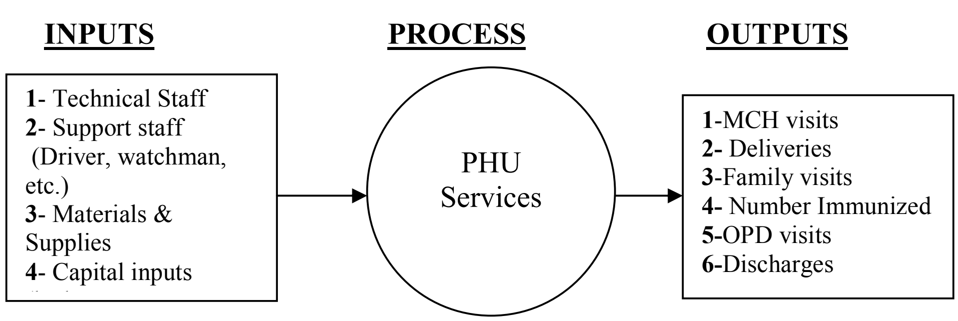
INTRODUCTION

Governments in most developing countries are beleaguered by the problem of increasing health care spending. Inefficient utilization of health resources has been found to be a major cause (*Sriratanaban, 2001*). This growing trend is forcing governments to focus on the issue of assessment and improvement of hospital efficiency. However, to date no attempt has been made to assess the technical efficiency of hospitals. A major problem for policy makers and hospital administrators is how to measure the efficiency of individual hospitals and health care centers and, whether the set of measures produced can be used as an incentive for enhanced performance. In this paper we will present the results of the use of a mathematical modeling method, in a pilot study to evaluate the technical and scale efficiency of public hospitals in the UAE. The table below provides demographic indicators for the United Arab Emirates.

Table 1. UAE Demographic Indicators (Source: World Health Organization report 2006)

Area (square kilometers)	83600
Total Population	4,210,000
% Urban Population	79
Birth Rate per 1000	15.5
Death Rate per 1000	1.6
% population growth	5.9
% population below 15 years	25.5
% 65 years and over	1.0
Total fertility rate	2.5

The results of this important research will provide hospital administrators as well as health care policy makers with a wealth of precise information that can be used by them to streamline the operations and improve the performance of their respective organization. The information provided includes technical and scale efficiency levels, a measure of possible input reductions and output improvements, identification of appropriate benchmarks and the target inputs and outputs for the inefficient hospitals. Turnock [9] developed a conceptual framework that binds together the mission and functions of public health to the inputs, processes, outputs and outcomes of the system.



Public health systems are intricate nonprofit organizations, which employ multiple inputs to produce multiple outputs. The outputs are intended to ultimately yield health or quality of life outcomes. The outputs identified in the model will act as proxy measures for the desired outcomes. The objectives of the study are twofold:

1- The primary objectives are:

i- To measure technical and scale efficiency of a sample of public hospitals

ii- To identify the inefficient hospitals as well as the relatively efficient ones and to provide a measure of possible input reductions and output improvements

iii- To identify for each inefficient hospital, a reference set of appropriate benchmarks

iv- To demonstrate policy implications for health care sector policy makers

2- And the secondary objectives are:

i- To meet the *objectivity* criterion by basing performance audits on scientific methods

ii- To encourage the use of models and techniques developed in the field of Operations Research and other Quantitative Methods

The UAE healthcare system

The UAE is divided into 9 medical districts, namely, Abu Dhabi, Western, Al-Ain, Dubai, Sharjah, Ajman, Um Al Quwain, Ras Al Khaima and Fujaira. The public sector consists of 23 hospitals, 106 primary health care centers (PHC) and 116 clinics all under the jurisdiction of the Federal Ministry of Health and 8 other government hospitals. The private sector comprises 21 hospitals. The UAE spends a lot of money to provide healthcare to its citizens through a system of district hospitals and healthcare centers as shown in the table below on healthcare expenditure indicators. In fact the UAE spends more that most countries its size. The World Health Organization (WHO) commission for macroeconomics and health recommends a per capita total expenditure of $34.

Table 2. UAE Health Expenditure Indicators (Source: WHO Report 2006)

GDP	$104 billions
GDP per capita	$24121
Total expenditure on health per capita	$661
General government expenditure on health (per capita)	$493
Total expenditure on health as % of GDP	3.3
General government expenditure on health as % of total health expenditure	74.7
Out-of-pocket expenditure as % of total health expenditure	17.8
General government expenditure on health as % of total general government expenditure	8.0
Ministry of Health budget as % of government budget	7.7
Number of physicians per 100000 (2004)	202

METHODOLOGY AND DATA COLLECTION

Methodology

The methodology uses a special linear programming model (DEA) to compute efficiency of each hospital in the sample. The original DEA mathematical model proposed by Charnes et al. is formulated as follows

$$\text{Maximize } E_0 = \frac{\sum_{i=1}^{k} u_i y_{i0}}{\sum_{j=1}^{m} v_j x_{j0}} \qquad (1)$$

Subject to:

$$\frac{\sum_{i=1}^{k} u_i y_{ir}}{\sum_{j=1}^{m} v_j x_{jr}} \leq 1 \quad \text{for } r=1,\ldots,n \qquad (2)$$

$$u_i, v_j > 0 \quad \text{for } i=1,\ldots,k \text{ and } j=1,\ldots,m \qquad (3)$$

Where:

E_0= Efficiency index of the DMU being assessed from the set of r =1,…,n
k = The number of outputs at the DMUs
m = the number of inputs at the DMUs
y_{ir} = Observed output i at DMU r
x_{jr} = Observed input j at DMU r

The solution sought is the set of (u_i, v_j) values that maximize the efficiency ratio E_0 of the DMU being assessed without resulting in an output/input ratio exceeding 1 (100% efficiency) when applied to each one of the other DMUs in the data set. Consequently, if a relative efficiency rating of 100% is not attained under this set of weights, it cannot be attained under any other set (for the same sample of DMUs). The model is a fractional programming formulation of the performance evaluation problem. It is difficult to solve the model as stated because the objective function is non-linear and fractional. This fractional programming model is replaced with an equivalent linear programming formulation through a series of transformations (Cooper, 1978). Efficiency can either be characterized with an input orientation or an output orientation. In this study we will consider the input orientation.

Input orientation model

A decision-making unit (DMU) is not efficient in utilizing its inputs to produce given amounts of output if it can be shown that some other DMU or a combination of DMUs can produce. The same amount of output with less of some resource (input) and no more of any other resource. Conversely, a DMU is efficient if this is not possible. The linear programming model is be formulated as:

[VRS]: Minimize E (4)
Subject to:
$WX \leq EX_0$ (5)
$WY \geq Y_0$ (6)
$WI = 1$ (7)
$W \geq 0$ (8)

Where X and Y are the input and output matrices, respectively; X_0 and Y_0 are the input and output vectors, respectively for the DMU being assessed (the test DMU); W is a vector representing the weights (%) of inputs and outputs of DMUs used in constructing a composite DMU; and E is the efficiency index. If the optimal solution of the above linear program has an objective function value of E=1, then we conclude that the test DMU is relatively efficient and if the value of the objective function is less than 1 (E<1), then we can conclude that the test DMU is not efficient. The [VRS] model above assumes variable returns to scale (VRS). This model assumes that changes in inputs would lead to disproportionate changes in outputs A percentage increase in input can yield less than the same percentage of outputs signifying diseconomies of scale (DRS) or more than the same percentage increase of output implying existence of economies of scale (IRS). Constant returns to scale (CRS) assumes that the same percentage change in outputs occur for a percentage of change in inputs. The [CRS] model is obtained from the [VRS] model by dropping constraint (4). The [VRS] model is solved for each of the hospitals in the sample. The minimal value of E, the efficiency index, called TE-(VRS) provides initial performance evaluation for each hospital. Then the [CRS] model is solved for each hospital, and the minimal value of E, called the TE-(CRS) is calculated. Then a scale efficiency index SE is calculated as the ration TE-(CRS) to TE-(VRS). TE-(VRS) scores can be decomposed into two components: One due to pure technical inefficiency and another due to scale inefficiency.

Data collection

a- Input and input variables

The choice of inputs and outputs was guided by suggestions from hospital administrators, the availability of data and by previous performance studies. For this study we used a total of 7 variables, including 4 inputs and 3 outputs.

The inputs used are**:**

- i- The number of doctors
- ii- The number of technical staff (paramedics, nurses, medical assistants)
- iii- The number of support staff (cleaners, drivers, watchmen, and others)
- iv- The number of hospital beds

The outputs for each individual hospital are:

- i- The number of patients
- ii- The number of child deliveries
- iii- The number of surgeries performed

b- Inputs and outputs measures

A form requesting the required data was developed and delivered to the secretary of the federal health minister. Thirty hospitals representing all the 9 medical districts were selected and the forms were sent to the hospital administrators. Twenty-one forms were returned of which, three were incomplete.

For this study, data from 18 hospitals were used. Moreover, data were collected between September and December 2006. The summary of the data used is presented in the following table:

Table 3. Mean and standard deviation of inputs and outputs

	Mean	Standard Deviation	Minimum	Maximum
Inputs				
-Beds	145	91.26	23	362
-Doctors	60	37.5	10	178
-Technical Staff	220	140.7	22	599
-Support Staff	124	84.66	12	346
Outputs				
-Patients	10650	18827.3	1129	84000
-Deliveries	1244	1153.02	107	3600
-Surgeries	2241	2057.3	510	9490

FINDINGS OF THE STUDY

The [VRS] linear programming model was developed and solved for each of the 18 hospitals. The technical efficiency scores TE-(VRS) obtained are given in the table below:

Table 4. Technical efficiency of public hospitals (%)

Hospital Number	Technical Efficiency	Hospital Number	Technical Efficiency
PH-01	100	PH-10	100
PH-02	100	PH-11	100
PH-03	49.80	PH-12	100
PH-04	56.47	PH-13	100
PH-05	87.88	PH-14	60.55
PH-06	100	PH-15	100
PH-07	53.40	PH-16	100
PH-08	46.20	PH-17	100
PH-09	42.40	PH-18	99.00

The results of the above table indicate that 55.5% were technically efficient with a TE score of 100%. However, 44.5% of the hospitals had TE scores less than 100%, which means that they were technically inefficient, and 37.5% of the inefficient hospitals units have a TE score less than or equal to 50%. Moreover, the TE scores among the inefficient facilities ranges from 42.4 % in hospital # PH-09 to 99% in hospital # PH-18. This finding implies that hospital PH-18 and hospital PH-09 could potentially reduce their current input levels by 1% and 57.6 % respectively, while leaving their output levels unchanged.

Table 5. Maximum uniform input reduction

Inefficient hospital number	Maximum uniform reduction (%) in input usage
PH-03	50.20
PH-04	43.53
PH-05	12.12
PH-07	46.6
PH-08	53.8
PH-09	57.6
PH-14	39.45
PH-18	1.00

The average TE score among the inefficient hospitals is 62% with a standard deviation of 20%. These hospitals could, on average, produce their current levels of output with 38% less inputs than they are currently using.

Next, the [CRS] linear programming model was developed and solved for each of the 18 hospitals. The technical efficiency scores TE-(CRS) were obtained. Then a scale efficiency index SE for each hospital is calculated as the ration TE-(CRS) to TE-(VRS). The results are given in the table below

Table 6. Scale efficiency of public hospitals (%)

Hospital Number	Scale Efficiency	Hospital Number	Scale Efficiency
PH-01	1	PH-10	1
PH-02	1	PH-11	1
PH-03	0.706883	PH-12	1
PH-04	0.801867	PH-13	1
PH-05	0.951261	PH-14	0.807194
PH-06	1	PH-15	1
PH-07	0.813171	PH-16	1
PH-08	0.969847	PH-17	1
PH-09	0.928927	PH-18	0.997273

The results in table 6 above show that 55.55% of the hospitals in the sample had a scale efficiency of 100%. This means they have the most productive size for that particular input-output mix. Also, 44.45% of the hospitals had SE scores less than 100%, which means that they were found to be scale inefficient. These hospitals suffer from inefficiencies originating from unsuitable size; that is being too small or too large. The average SE among the inefficient hospitals is 87% with a standard deviation of 10%. This means that, on average, the scale inefficient hospitals could reduce their size by 13% without affecting their current output levels. In addition, all ten scale efficient hospitals exhibited constant returns to scale (CRS), implying thereby that they are operating at their most productive scale sizes. Six scale inefficient hospitals have decreasing returns to scale (DRS) and two hospitals revealed increasing return to scale (IRS). A hospital showing decreasing returns to scale should cut down both inputs and outputs. However, a hospital showing increasing returns to scale should increase both its inputs and outputs. Then, we identified, for each

inefficient hospital, a reference set of efficient hospitals that can be used as benchmarks when trying to improve efficiency. Table 7 below gives, for each inefficient hospital, the reference set together with the corresponding optimal weights (in parentheses).
These reference sets are the benchmarks for the inefficient hospitals to use if they want to streamline and improve their operations in order to increase their efficiency.

Table 7. Benchmarks for the inefficient hospitals

Inefficient Hospital	**Reference set**
PH-03	**PH-02** (0.029); **PH-06** (0.008); **PH-12** (0.150); **PH-15** (0.678) and **PH-17** (0.136)
PH-04	**PH-02** (0.19); **PH-06** (0.024); **PH-15** (0.786)
PH-05	**PH-01** (0.092); **PH-11** (0.176); **PH-15** (0.732)
PH-07	**PH-06** (0.032); **PH-12** (0.270); **PH-13** (0.287); **PH-15** (0.445)
PH-08	**PH-06** (0.056); **PH-11** (0.125); **PH-12** (0.277); **PH-15** (0.445); **PH-16** (0.097)
PH-09	**PH-02** (0.143); **PH-06** (0.043); **PH-11** (0.01); **PH-15** (0.772); **PH-16** (0.032)
PH-14	**PH-02** (0.091); **PH-06** (0.003); **PH-12** (0.397); **PH-15** (0.420); **PH-17** (0.089)
PH-18	**PH-01** (0.302); **PH-11** (0.269); **PH-15** (0.429)

Furthermore the weights (uj and vj) computed by the model for the benchmark hospitals, are used to compute, for the inefficient hospital, the target inputs and outputs levels to achieve in order to improve its efficiency. These are shown in the table below.

Table 8. Efficient input targets

Hospital No.	**Beds**	**Doctors**	**Technical Staff**	**Support Staff**
PH-01	148	46	182	132
PH-02	199	55	170	136
PH-03	35	23	46	40
HP-04	65	23	64	52
PH-05	72	31	103	66
PH-06	362	178	599	346
PH-07	54	31	76	32
PH-08	90	45	137	69
PH-09	72	27	79	57
PH-10	203	70	290	200
PH-11	232	109	395	210
PH-12	23	41	74	18
PH-13	50	24	55	12

PH-14	43	31	63	40
PH-15	23	10	22	23
PH-16	250	61	243	83
PH-17	50	48	79	110
PH-18	117	48	171	106

Table 9. Efficient output targets

Hospital No.	Patients	Deliveries	Surgeries
PH-01	19519	776	1359
PH-02	5986	2560	1900
PH-03	2800	330	1433
HP-04	4043	657	1212
PH-05	4733	720	2523
PH-06	84000	3600	3000
PH-07	4798	457	1799
PH-08	8252	980	2904
PH-09	5654	726	1308
PH-10	10157	2670	3000
PH-11	11974	3237	9490
PH-12	3500	200	3500
PH-13	1440	363	1151
PH-14	3100	450	2092
PH-15	1129	107	992
PH-16	6009	2790	1383
PH-17	5008	927	1173
PH-18	9598	1152	3392

Each hospital using the corresponding inputs levels shown in table 8 and producing the outputs levels shown in table 9 will be running efficiently. If they are not, they should make every effort to reduce their inputs to these levels and increase their outputs to the target levels.

CONCLUSION

In this study we have demonstrated how a mathematical programming approach can be applied to measure the efficiency of hospitals. The method provides a wealth of information that can be used by hospital administrators and health care policy makers in making important and strategic decisions. The study has revealed that about 45% of the 18 hospitals evaluated are not efficient, and among these inefficient hospitals 37.5% are running at less than 50% efficiency levels. This should be a great concern for the administrators of these units. Furthermore, reference sets were identified and target input and outputs levels were calculated for each inefficient hospital. This provides guidance to the administrators of these hospitals on how to improve their efficiency. Moreover, the mathematical model results can help policy-makers focus on the operating aspects of the hospitals as distinct from the liquidity based profitability measures already in use. What is important from a managerial perspective is how inefficient hospitals (poor performers) should orient strategies to become better performers. The results of the analysis can be used by health care policy makers to provide prescriptive guidance to hospital administrators to achieve this goal. As a result of this study, health care policy makers at the ministry may opt to close down those hospitals with efficiency scores below a certain threshold (for instance 50%), and in this case hospitals PH-03, PH-04 and PH-09 would be good candidates. Or, they can opt for the conversion of low performers, especially the ones exhibiting decreasing returns to scale, into primary health care centers.

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