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Measuring Efficiency in Primary Health Care Centres in Saudi Arabia

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ABSTRACT. This paper addresses the applicability of Operations Research tools to Saudi Arabia. Data Envelopment Analysis has been applied to primary health care centres in Jeddah, Saudi Arabia to measure their relative efficiency. Results were found to be meaningful and confirm what previous studies have shown about the strength of DEA in measuring the relative efficiency of decision-making units. It will encourage the public authorities to make full use of DEA in order to rationalize resource allocations in addition to other Operations Research tools whose applications are well established in western countries and it should be equally applicable to the Saudi environment with minimum adjustments.

1. Introduction

There is growing feeling at all levels of government that public sector agencies should be held accountable for services they provide. Health sector agencies are not immune to such demand. Health sector units represented in hospitals and primary care centres must compete for resources in a period dominated by resource scarcity . The boom period of the seventies is over by all indications . Furthermore, the Kingdom being a signatory to Health For All (HFA) declaration necessitate the efficient allocation of health resources. Thus measuring efficiency in the public health sector becomes of prime concern.

Measuring efficiency has long been studied; at least since the time of Taylor and Fayol. It is not difficult to measure efficiency in goods producing industry where inputs and outputs can be determined by prices. In the service industry, however, the measurement yardstick is not clear. It is even worse in the public sector where profit is not a target. Measuring efficiency of units offering health services where human life is concerned complicates the question of how to measure the efficiency of such units (McGuire, 1987) and (Mensah and Li, 1992).

A rather new operations research technique (ORT), which is called Data Envelopment Analysis (DEA) has been put forward by Charnes *et al.* in 1978 to overcome the difficulty of measuring efficiency of public decision-making units having multiple inputs and outputs . They applied DEA to schools in Texas (1981). DEA received a lot of attention since its introduction by researchers and practitioners in the public and private sectors alike. It gained a lot of credibility in Europe and USA .

The question is: can the success of Data Envelopment Analysis in the developed countries be applied to Middle East countries? Knowing that the practice of ORTs 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.(Gass, 1990).

This study intends to test the applicability of an ORT in a different environment. It will measure the relative efficiency of Primary Health Care (PHC) centres in Saudi Arabia by implementing DEA. If it gives meaningful results, the authorities in the health sector will be getting a novel tool to help them improve their performance, reduce their costs and efficiently reallocate their resources. Other sectors can benefit as well from the experience.

Furthermore; what makes this study a valuable one is the fact that it is one of a few - if not the only one- that attempt to apply ORTs to the health sector in Saudi Arabia not to mention the addressing of efficiency in a quantitative manner.

The next section (Two) describes the method used. Section Three gives an overview of PHC services in the Kingdom of Saudi Arabia and the approach of selecting data needed to apply DEA. Section Four discusses the results. Section Five presents conclusion and recommendation for further research.

2. Methodology

2.1 Method

DEA is a technique to measure relative efficiency of a set of decision-making units (DMUs) having similar multiple inputs to produce similar multiple outputs.

The relative efficiency of a DMU is defined as the ratio of the sum of its weighted outputs to the sum of its weighted inputs. The objectives are to identify units that are relatively inefficient and setting targets for them based on examining the operational practices of the units classified as efficient. The underlying concept of DEA is based on Pareto optimality (Charnes *et. al.*,1985). A DMU is considered relatively efficient if there is no other DMU or a combination of DMUs which can produce at least the same amount of all outputs with less of one input and not more of any other input. Its relative efficiency ratio is equal to 1; otherwise, it is classified as relatively inefficient when its ratio is less than 1. An outline of the basic DEA model is given in appendix A. The reader who is not familiar with DEA is referred to Boussofiane *et al.* (1991), Ganley & Cubbin (1992) and Charnes *et al.* (1994).

This study used the input oriented model (Banker and Morey,1986b) to measure the relative efficiency of PHC centres in Jeddah, Saudi Arabia. The choice of the input model is justified on the fact that managers in health care services tend to have greater control over inputs rather than outputs.

2.2 Related Literature Survey

DEA received wide acceptance by researchers and practitioners in many public and private sectors. However, it has not been used extensively in health care. The first empirical test of DEA on hospitals was given by David Sherman (1984) who applied DEA to a group of teaching hospitals. DEA is found to provide meaningful insights into the location and nature of hospital inefficiencies as judged by a panel of hospital experts. Grosskopf and Valdmanis (1987) and Valdmanis (1992) employed DEA to find out the effect of ownership type on hospitals efficiency. Morey *et al.* (1990) compared the allocative efficiencies of 60 hospitals in the USA. Finkler and Wirtschafter (1993) presented an application of DEA to a system of nine hospitals that offer obstetric services. The study confirms its robustness which justifies its inclusion in the cost managers' tool kit. Efficiency and effectiveness in general practice was measured by DEA (Szczepura et al,1993) . The authors expected that DEA should prove a useful tool, offering not only a method for assessing efficiency but also the opportunity to identify practices where improvement in effectiveness may not be feasible without additional resources. Janet Lynch and Yasar Ozcan (1994) used DEA to construct an efficiency index to test a hypothesis that inefficient and under utilized hospitals in competitive markets are at greater risk for closure. Chilingerian and Sherman (1994) suggested the use of DEA as an evaluation method to classify physicians according to their efficiency rate.

Just before submitting this paper for publication, a recent issue of ANNALS OF OPERATIONS RESEARCH that addresses application of Operations Research in health care had four out of eleven studies addressing the application of DEA in health care. The first paper investigates the trends in labor efficiency in U.S. hospital markets for a five-year window using DEA (Ozcan et.al. 1996), the second one investigates physician practice pattern to identify benchmarks for practices and to reduce costs by applying a multistage DEA (Chilingerian and Sherman,1996). Morey and Dittman used DEA with non-discretionary factors and new hypothesis testing procedures to shed some light on reimbursement methods to hospitals by public insurers. The last paper used DEA to measure PHC quality in England (Salnas-Jimenez and Smith,1996).

In general, these studies not only demonstrate that DEA is an effective technique for evaluating the efficiency of Health Care organizations but also reflect the variety of problems in health care management which can be handled by DEA.

The previous studies were carried out in Britain and USA. There is no application to my knowledge of DEA in health sector in the Arab world where the need to measure efficiency and minimize expenses is acute. Saudi Arabia is no exception. Although Health services (public & private) expanded very fast in the last 20 years, services are not up to the standards expected. The need to put a lid on expenses and improve quality of services call for a good measure of efficiency. This study suggest DEA as a managerial tool. Its essence and strength will be demonstrated on primary health care centres in Jeddah.

3. Primary Health Care in Saudi Arabia

3.1 Over view of Primary Health Care in Saudi Arabia

Saudi Arabia occupies the largest part of the Arabian Peninsula .Its total population is estimated to be 16.9 million (1992), Density varies from 1 - 30 person/ sq.km. The highest concentration being in the metropolitan cities of Riyadh, Jeddah and Dammam.

PHC was introduced in Saudi Arabia in 1984 by establishing eleven "model" health centres in eleven health regions. Progress in the PHC operations in these health centres were reviewed by the end of 1984. Because results of the review were positive, PHC concept was extended to all the existing Health centres (Al Mazrou, 1990). By 1995, the number of PHC centres reached 1725 centres. Each PHC centre serve an average of 10.353 patients per annum (Annual Health Report, 1995). Jeddah district has 103 centres, 40 of them are in the city of Jeddah. These centres employ a staff of 1.100 employees. No information is available on the portion of the Ministry of Health's budget that is allocated to these centres.

3.2 Inputs and Outputs

The choice of inputs and outputs in a DEA assessment has very important implications for the results obtained. However, our aim here is not so much to assess but to exhibit the ability of DEA to assess relative efficiency of PHC centres.

In order to decide which inputs and outputs can be selected to measure PHC efficiency we have to develop thorough understanding of what functions PHC perform and what resources are used. Clearly any resource used by a centre should be included as an input. A centre will convert resources to produce outputs so that the outputs should include the amounts of services produced by the centre. These services may be produced at different levels of quality. Hence, the outputs may include a range of performance and activity measures. In addition, environmental factors which may affect the production of these outputs must be identified and included in the assessment model. But availability of data also must be considered, and for computational efficiency the number of inputs and outputs in total should not exceed one third of the PHC being evaluated. (Charnes et.al,1994).

PHC services in Saudi Arabia address the following functions (AL Mazrou 1990):

1- Provision of comprehensive maternal and child health care.
2- Immunization of children against major communicable diseases.
3- Prevention and control of locally endemic diseases.
4- Provision of adequate supply of safe water and basic sanitation.
5- Appropriate treatment of common diseases and injuries.
6- Provision of essential drugs.
7- Education concerning prevailing health problems & the methods of preventing and controlling them.
8- Promotion of food supply and proper nutrition.

Forty PHC centres grouped into five geographic locations in the city of Jeddah are selected for this study. Data was available for each centre on monthly basis through reports sent to the General Administration of PHC Office (GAPHCO) in Jeddah. These reports are then fed to a database at the computer centre of the GAPHCO. Reports

include details of different types of clinics and services offered, staff, patient demography, and various activity indicators. Note that these reports do not include any direct or indirect information on expenditures like medical supplies, net plant assets, total annual expenditures etc.

Centres vary in the facilities they have and consequently in the services they offer. Some have dentistry clinic(s) and some don't; some have pediatric clinics and some don't; some have laboratories and X-ray services while the others don't. Since not all activities are available in every centre we concentrate on the common activities which are available in all selected PHC centres; these are :

1- General Practice. (out patients).
2- Maternal care.
3- Child care: vaccination service.

These activities address the first 3 functions and to a certain extent the fifth function which are addressed by the PHC in Saudi Arabia. These activities are measured for the period June1995 to May 1996 by:

1- Total number of out patients visits.
2- Total number of pregnancy checkup.
3- Total number of children who completed the required immunizations for the first year of their age.
4- Other services such as first aid and different types of emergency services provided.

The relevant inputs are usually measured by capital assets utilized and total expenditures devoted for each centre which can be classified into three categories :

1- Net plant assets.
2- Medical supplies.
3- Staff expenses (Salaries, allowances etc.).

Unfortunately, such information was not available. The only information available is the number of staff classified into different categories. Therefore, the following related and available inputs are used as surrogates:

1) Full time equivalent-hours for physicians (includes specialist but excludes dentists).
2) Full time equivalent hours for nurses.
3) Full time equivalent hours for administrative staff.
4) Full time equivalent hours for technical staff such as statisticians, pharmacists, nutritionist etc.. this figure also includes care takers.

Although quality of service is a vital efficiency element in health care we chose to exclude this element in the absence of reliable data on quality indicators.

Examining the environment of different locations of PHC centres, it is noticeable that there is a disparity in their demographic characters. The centres can be classified into four categories in terms of population size. Thus, a categorical variable is

introduced to the set of inputs to represent population. Population category variable is given the values 1, 2, 3 and 4 as follows:

Category	Population
1	less than 10,000
2	10,000 - 19,999
3	20,000 - 29,999
4	30,000 - 39,999

Introducing a categorical variable ensures that only centres having similar situations or worse (less population) will be compared against each other. For example a centre in category (2) will be compared only with those in category 2 and 1. (Banker & Morey, 1986 b); so areas with less density are not penalized for their smaller scale of operations. Table (1) represents outputs and inputs during 1995/1996 of 40 PHC centres which are selected to measure their relative technical efficiency .

Table (1) : PHC centres data

CENTRES	OUT PATIENT	PREGNANT CHECK-UP	OTHERS	VACCINATED CHILDREN	PHYSICIANS	NURSES	ADMINISTRATORS	OTHERS	POPULATION
101	36219	1436	7760	755	12012	19391	4118	19048	4
102	24091	744	11141	178	6006	19391	5491	13556	2
103	54272	1647	11677	348	7894	19906	2917	22480	2
104	12212	428	9928	344	3947	16817	7036	18876	1
105	13831	134	5900	78	4118	15444	6178	14586	1
106	46370	971	24078	748	11232	24523	6552	16661	4
107	18062	529	3735	74	7036	15787	4976	12870	1
108	73930	2428	18028	322	10982	25397	8237	23166	4
109	29301	987	4296	289	7894	22994	7550	15616	3
110	11636	1381	4788	85	4805	13728	2059	8065	2
111	12795	630	5377	170	4633	16302	3947	24710	2
202	24425	1827	13810	121	8408	18190	3089	12355	2
203	35971	458	13114	103	10124	21107	7550	20764	2
204	9308	169	3377	158	4633	9438	5148	11326	2
205	31236	3129	16619	148	9610	17846	5320	16302	3
206	37332	116	6993	74	8752	19048	11840	4633	2
207	13501	139	1733	125	6864	17675	7894	8237	2
208	4266	67	2342	18	5491	11154	5491	1201	1
301	67322	3244	26785	257	14758	34148	3432	24710	4
302	38757	697	8929	192	8408	13728	5320	31574	2
303	54022	904	7886	225	10468	25054	2402	42557	3
304	48397	1431	23744	377	8065	25397	4290	36379	4
305	65478	1059	15713	671	9610	18704	6864	30716	3
306	27394	342	9273	125	4462	23166	8408	22651	2
307	15413	168	6242	162	4805	14929	6864	27799	2
308	55705	1245	5904	817	9781	20935	10296	31918	3
309	15284	63	3168	120	4633	10982	6349	14071	1
310	22383	305	1901	151	5663	15272	5491	4976	1
311	26280	584	5028	176	4290	11840	4805	14071	2
312	24522	248	4419	205	6006	15787	6521	9781	2
401	49203	2754	13699	191	8580	18533	3775	28486	3
402	23311	1117	5483	118	6692	20420	6178	14758	2
403	39638	1013	7028	220	6692	17332	2231	34835	3
404	22157	1013	8490	69	6178	17332	3947	22136	2
406	19646	335	4244	76	5320	15787	4976	18361	1
501	27328	1388	11238	117	13385	32432	10982	48391	2
502	18235	364	7930	380	5663	20592	2231	36722	2
504	13177	432	6708	385	5148	23166	4633	13728	1
505	15318	525	5757	96	4976	18018	4290	21107	1
508	15154	747	3856	39	3947	18190	1030	6178	1

Finally, a word of caution is that the quality of DEA results is determined by the inputs and outputs included. Had data on expenses and quality indicators been available, results would have possibly been different.

4. Results

A commercial package named IDEAS (1 Consulting, Inc.) which is designed for solving the DEA model is used in this study. However, any LP package can be used for this purpose.

Table (2) : Distribution of PHC centres over their relative efficiency range

EFFICIENCY RANGE	NUMBER
1 - 1.000	31
.9 - 0.999	4
.8 - 0.899	2
.7 - 0.799	2
.6 - 0.699	0
.5 - 0.599	1
Average efficiency	96%

Efficiency rating as related to PHC performance can be explained as the maximum proportion of the inputs mix which is necessary for the target centre to achieve at least the current outputs, in order to be classified as relatively efficient. For example results in Table (3) indicates that centre 501 is inefficient, with an efficiency rating of 0.52. This means that centre 501 should be able to produce its current output level using 48% less of each input.

4.1 Relatively inefficient units

DEA identifies for each inefficient centre its reference set of efficient units which have a similar input (output) orientation in Table (3). It also provides performance targets that can be set by management for the centre to improve its efficiency.

Table (3) : Relatively inefficient units and their comparison set

CENTRE	EFFICIENCY SCORES	REFERENCE SET
109	0.84156	103, 110, 205, 305, 308, 310
111	0.92547	103, 104, 110, 311, 502, 508
207	0.75743	104, 110, 204, 208, 310, 508
307	0.87541	104, 202, 204, 311
312	0.99536	103, 104, 204, 310, 504
402	0.76565	103, 110, 310, 311, 508
404	0.92049	103, 104, 110, 202, 311
501	0.52143	103, 104, 110, 202, 311
505	0.94956	104, 309, 310, 508

i- ***Reference set***

The reference set is a very useful indicator as it shows clearly how an inefficient centre performance is weak in comparison to its reference set . For example, Table (4) shows the inputs and outputs of centre 207, which is identified as relatively inefficient, and those of its reference set.

On examining figures in Table (4), it is easy to spot the weak performance of centre 207. For example, centre 207 has more of every input in comparison with centre 310 while centre 310 outperformed centre 207 by 39% in its total output (aggregated number of patients) even though centre 207 is located in an area with more population than that of centre 310. On examining the two locations we notice the absence of quality private health care in the area of centre 310.

Table (4) : Comparison of an inefficient centre with its reference set

	Inefficient centre	Reference set					
	207	104	110	204	208	310	508
OUTPUTS							
Outpatient visits	13501	12212	11636	9308	4266	22383	15154
Pregnant visits	139	428	1381	169	67	305	747
Others	1733	9928	4788	3377	2342	1901	3856
Total vaccination	125	344	85	158	18	151	39
INPUTS							
Physicians	6864	3947	4805	4633	5491	5663	3947
Nurses	17675	16817	13728	9438	11154	15272	18190
Administrators	7894	7036	2059	5148	5491	5491	1030
Others	8237	18876	8065	1201	1201	4976	6178
Population Cato.	2	1	2	2	1	1	1

Another factor could be the socio-economic background differences between the two locations.

Thus DEA information is helpful for GAPHC to set specific targets for personnel deployment among PHC centres or even to relocate such centre and to stimulate further investigations outside the context of DEA.

ii- ***Target setting***

Performance targets reveal the potential cost saving, or in other words, the excess resources that could have been saved. As a by-product DEA yields a set of projected input/output levels that would render a centre a relatively efficient for every inefficient unit.

Table (5) presents the projected outputs and inputs for Centre 207 and the increment in each output and reduction in each input suggested in order to achieve a rating of 1. Some adjustments may not be feasible in practice; it may be that an input/ output is not under management control. This is typical in the case of PHC centres.

The number of patients using the service is not under direct management control. Input adjustments are possible because they are under GAPHC control. The results given in Table (5) indicate a straightforward implication for efficiency targets that centre 207 is over-staffed. Another reaction the GAPHC should investigate is "the small number of people using the service". Is it due to the quality of the service or is it simply due to the population's socio-economic background. Kao (1994) suggested the inclusion of upper and lower bounds to each input and output in order to get meaningful results.

The extent of the possible resource saving could be determined by further comparison of the practice pattern of Centre 207 and its reference set. The substantial savings realized by using DEA in banks (Sherman and Ladino, 1995) are encouraging to benefit from the information that DEA provides. Table (6) presents total inefficiencies for the forty centres. There is an excess of 7 general practitioners, 18 nurses, 9 administrators and 41 other personnel. Meanwhile, the service could be increased to serve a further 18.180 patients.

4.2 Relative efficient units

Identification of most efficient units helps in identifying good operating practices which can be adopted by other units but efficient units are not identical in their performance. Some are more likely to be good examples than others.

Table (5) : Output/input adjustments for centre 207

	DATA	*PROJECTED*	*INEFFICIENCY*
OUTPUTS			
Outpatient visits	13501	13501	0
Pregnant visits	139	245	106
Others	1733	3133	1400
Total vaccination	125	125	0
INPUTS			
General Practitioner	6864	5199	-1665
Nurses	17675	13388	-4287
Administrators	7894	5368	-2527
Others	8237	6239	-1998

Table (6) : Total inefficiencies in PHC centres in the city of Jeddah.

CENTRES	OUT PATIENTS	PREGNANT CHECK-UP	OTHERS	VACCINATED CHILDREN	PHYSICIANS	NURSES	ADMINISTRATORS	OTHERS
109	0	0	475	0	-1251	-6482	-2081	-2474
111	7230	0	144	0	-345	-1215	-294	-10706
207	0	106	1400	0	-1665	-4287	-2527	-1998
307	7257	375	0	56	-599	-1860	-1500	-12544
312	0	252	0	0	-322	-73	-1248	-45
402	0	0	349	24	-1568	-4786	-3623	-3459
404	0	220	0	126	-491	-1378	-314	-8242
501	0	0	0	69	-6406	-15521	-7125	-33664
505	0	21	0	76	-726	-909	-216	-10366

Careful investigation of their performance must be undertaken before drawing any general rules as targets to be applied to the others. Thanassoulis *et al.*, (1987) suggested the following points should be investigated:

1- What aspects of unit's performance contribute to its efficiency ratings?
2- Does the unit show well-rounded performance?
3- On which aspects of performance does the unit appear stronger?
4- Can the relatively efficient unit improve its efficiency further?

These suggested points will be investigated below on the DEA results of PHC centres in Saudi Arabia:

1- Which inputs/outputs contribute to the centre efficiency rating most? A basic advantage of DEA is that the weights (multipliers) for the inputs and outputs are selected automatically (Charnes *et al*., 1978) on solving the LP model. This advantage could lead to misleading results where a centre might assign very low weights to certain inputs and outputs in order to look efficient. Such centre can be efficient only in operations which generate the outputs or utilize the inputs which were actually taken into account in determining its efficiency rating. These operations might not represent the most essential functions of the centre.

To alleviate the bias of weights flexibility, restrictions can be imposed on their values (Dyson and Thanassoulis,1988), (Wong and Beasely, 1990). Another alternative is to examine the following two aspects of the relatively efficient units in order to differentiate between them:

(a) The frequency of the efficient centres that appear in the comparison set (reference set) of the inefficient units. Table (7) displays the frequency of the efficient centres that appeared in the comparison set of the inefficient centres. Note that Centres 104, 103, 110, 310 and 311 appeared more frequently than the others. This reflects that these centres can offer good practice examples to the others; while centres 205, 208, 308, 309, 502 and 504 are more of self evaluated. Their performance can't be readily adopted by the others.

(b) Virtual input (output) attributable to a given input (output) is the product of that input (output) and its corresponding weight. The inputs and outputs on which an efficient centre offers high virtual values are those with the highest weight in comparison with other units. They give indications of good practice in particular areas; ***e.g.*** Centres 105 and 303 are strong in outpatient service where more than 90% of its output is contributed by outpatients served. While Centre 308 gives good practice on vaccination service (76%) offered for children under one year old; but, poor performance on outpatients service (only 10%) (See Table 8).

2- Which centres show well-rounded performance? The virtual inputs and outputs of a centre show how well rounded its performance is. For example, centres that rely on one or two of its inputs\outputs mix for their efficiency rating, such as centres 310 and 311, are likely to be less satisfactory performers than centres such as centres 103 or 110 which rely on contribution to their relative efficiency rating from a balanced proportions of their inputs and outputs (Table 8).

Table (7) : Frequency of efficient centres that appear in the comparison set of the inefficient centres

CENTRE	103	104	110	202	204	205	208	305	308	309	310	311	502	504	508
FREQUENCY	6	7	6	3	3	1	1	1	1	1	5	5	1	1	4

Table (8) : Virtual outputs and inputs of some relatively efficient units

CENTRE	OUT PATIENTS	PREGNANT CHECK-UP	OTHERS	VACCINATED CHILDREN	PHYSICIANS	NURSES	ADMINISTRATORS	OTHERS
101	0.32	0.21	0.07	0.41	0.07	0.50	0.14	0.29
102	0.20	0.08	0.63	0.08	0.60	0.06	0.06	0.27
103	0.26	0.24	0.25	0.24	0.26	0.25	0.25	0.23
104	0.34	0.15	0.15	0.36	0.24	0.29	0.24	0.23
105	0.97	0.01	0.01	0.01	0.72	0.27	0.00	0.00
106	0.27	0.14	0.17	0.42	0.17	0.46	0.17	0.20
107	0.63	0.22	0.14	0.00	0.25	0.24	0.25	0.26
108	0.47	0.28	0.11	0.14	0.12	0.43	0.20	0.25
110	0.26	0.24	0.26	0.24	0.13	0.25	0.13	0.48
202	0.21	0.22	0.36	0.22	0.16	0.15	0.16	0.53
203	0.16	0.00	0.84	0.00	0.25	0.26	0.24	0.25
204	0.09	0.09	0.41	0.41	0.02	0.71	0.24	0.02
205	0.25	0.26	0.32	0.16	0.12	0.24	0.12	0.52
206	0.80	0.02	0.15	0.02	0.01	0.79	0.07	0.13
208	0.08	0.09	0.73	0.10	0.06	0.66	0.06	0.22
301	0.52	0.16	0.17	0.16	0.26	0.25	0.25	0.24
302	0.13	0.11	0.55	0.22	0.06	0.81	0.06	0.06
303	0.91	0.03	0.03	0.03	0.02	0.35	0.61	0.02
304	0.26	0.13	0.47	0.13	0.31	0.40	0.14	0.15
305	0.67	0.11	0.11	0.11	0.20	0.20	0.22	0.39
306	0.56	0.05	0.34	0.05	0.89	0.03	0.04	0.03
308	0.10	0.09	0.05	0.76	0.05	0.05	0.05	0.86
309	0.62	0.09	0.20	0.09	0.04	0.82	0.04	0.09
310	0.53	0.16	0.16	0.16	0.07	0.79	0.06	0.07
311	0.63	0.09	0.19	0.09	0.08	0.42	0.05	0.45
401	0.21	0.26	0.42	0.11	0.06	0.75	0.13	0.06
403	0.69	0.06	0.19	0.06	0.02	0.82	0.14	0.02
406	0.70	0.13	0.16	0.00	0.15	0.14	0.57	0.14
502	0.02	0.02	0.75	0.21	0.52	0.32	0.14	0.01
504	0.07	0.07	0.41	0.45	0.05	0.35	0.06	0.54
508	0.59	0.14	0.14	0.14	0.15	0.14	0.15	0.56

3- Which aspect of the center's performance is stronger? Virtual inputs and outputs indicate (as mentioned earlier) the units' strong aspects of performance. For example centres 105, 206 and 303 having over 80% of their output contributed by outpatients might reflect the efficiency of their physicians more than those in other centres. However, it is hard to be positive about such conclusion; this efficiency might be on the expenses of other resources. The centre may be achieving a high level in the output in question by devoting its resources almost exclusively to that output rather than by performing all relevant operations efficiently . This calls for further investigation of the centre.

4- Finally, can a relatively efficient centre improve its efficiency further? Efficiency Assessment by DEA identify efficiency units in relation to the other units included in the assessment and not in absolute terms. Therefore, the potential for further improvement in the efficiency of DEA efficient units must not be overlooked . Such improvement necessitates further investigations in two directions:

(a) Applying DEA to those efficient ones only and examine the results. This type of test can be repeated several times and is known as multi-stage DEA analysis (Chilingerian and Sherman, 1996). It is expected to refine the initial results and some efficient units might be classified as inefficient ones.

(b) Investigating the operating characteristics of the efficient units outside the DEA context. Giving considerations to the observations mentioned in 1, 2 and 3 above, at least 16 centres of those classified as relatively efficient indicate some sort of weakness (They do not appear in any of the frequency sets neither they showed a proportional virtual inputs and outputs.

5. Conclusions

DEA has been applied in PHC in Saudi Arabia. In spite of the limitation of Data availability, the research reveals valid results; centre 207 has been closed by the authorities while this research is being written. Based on available data the following results can be concluded.

1. Over all efficiency of 96% indicate a potential saving of 4% in inputs; i.e., equivalent to 75 employees and 18,180 more patients can be served. Such resources can be redirected to expand services in other areas or to provide other services in health care in general. Further studies based on both quantitative and qualitative methods must be conducted.

2. Among the relatively efficient centres, 60% are shown to be biased toward one input or one output. Further investigation is required to learn more about this skewed efficiency. Does it reflect strong performance that can be learned from and generalized; or does it reflect unfairness towards the other functions which must be performed by the centre, namely, bad utilization and allocation of resources.

3. It could have been of equal importance to compare efficiency results against effectiveness. Absence of accurate data on effectiveness hinders such analysis.

4. DEA can be used to assist the decision of closing down some centres or setting up new ones.

5. The results of the present study prove that DEA is a useful tool and that ORTs in general are equally applicable to problems in developing countries. However, the need for a well-designed database is a prerequisite in order for the system to benefit from ORTs.

6. Finally, as we mentioned earlier, data interpretation of results should be treated with caution due to the limitation of data available and to the limitations inherited in DEA itself . DEA identifies but cannot be positive about efficiency. DEA identifies inefficient units but cannot be positive about efficient units. As a minimum they offer initial diagnoses of centres' performance which necessitate further comprehensive investigations in many different directions.

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Appendix A

The DEA Model measures the efficiency of Centre *o* compared with the *n* centres in the data set as follows:

$$\max E_0 = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}$$

subject to:

Less-than-unity constraints

$$1 > \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}; \; j = 1, \ldots\ldots, n$$

Positivity constraints

$$O < u_r; r = 1, \ldots., s$$

$$O < v_i; i = 1, \ldots., m$$

where:

o is the Centre being evaluated in the set of *j*=1,..., *n* centres.

Outputs:

y_{rj} = observed amount of r^{th} output for the j^{th} centre

s = the number of outputs produced by each centre.

Inputs:

x_{ij} = observed amount of i^{th} input for the j^{th} centre

m = the number of inputs used by each centre.

Decision variables:

u_r = the weight assigned to output r computed in the solution to the DEA model.

v_i = the weight assigned to input i computed in the solution to the DEA model.

E_0 = the efficiency index assigned to the Centre *o*.

For computational purposes the above fractional linear program is transferred into standard linear program. Then its dual is solved repetitively with each centre in the objective function to derive the efficiency rating for each of the n centres. For details on different versions of DEA see Charnes *et. al.* (1994), Banker (1984), Banker *et. al.* (1984) and Banker & Morey (1986a&b). We implemented the following input oriented model :

where :

λ_j : is the weight of the j th unit .

$$\text{Min} \quad z_o$$

$$\text{s.t.} \quad \sum_{j=1}^{n} l_j x_{ij} - z_o x_{ijo} \le 0 \qquad i = 1, .., .., m.$$

$$\sum_{j=1}^{n} l_j y_{rj} \ge y_{rjo} \qquad r = 1, .., .., s.$$

$$\sum_{j=1}^{n} l_j \ge 1$$

$$l_j \ge 0 \qquad j = 1.., .., n.$$

قياس الكفاءة النسبية في مراكز الرعاية الصحية في المملكة العربية السعودية

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المستخلص : يستعرض هذا البحث إمكانية تطبيق أدوات بحوث العمليات في المملكة العربية السعودية.حيث تم اختيار أسلوب تحليل مغلف البيانات وهو تطبيق حديث نسبياً للبرمجة الخطية. وقد تم تطبيق هذا الأسلوب على مراكز الرعاية الأولية في مدينة جدة وذلك بهدف قياس الكفاءة النسبية لكل منها.

النتائج الأولية التي حصلنا عليها كانت إيجابية (رغم محدودية البيانات). كما أنها تؤكد الدراسات السابقة والمؤكدة لقوة ومصداقية أسلوب تحليل مغلف البيانات في قياس الكفاءة النسبيةللوحدات الإدارية المتماثلة الأهداف. تهدف الباحثة إلي إقناع متخذي القرار في القطاع الصحي والقطاع الحكومي بصفة عامة بأهمية أسلوب تحليل مغلف البيانات في ترشيد توزيع الموارد. هذا بالإضافة إلى أهمية التوسع في استخدام أساليب بحوث العمليات والشائعة الاستعمال في الدول الغربية والتي من الممكن تطبيقها في المملكة بعد إجراء تعديلات بسيطة لا تكاد تذكر.