**Title**

**Efficiency Evaluation of Public Hospitals in Saudi Arabia: An Application of Data Envelopment Analysis**

**Authors**: Ahmed D Alatawi\*, a,b, Louis W Niessen c,d,Jahangir A. M. Khan c,e

**Affiliations:**

a Liverpool School of Tropical Medicine, Department of Clinical Sciences, Liverpool, United Kingdom.

b University of Al-Jouf,Pharmacy College, Department of Clinical Pharmacy, Skaka, Saudi Arabia.

c Liverpool School of Tropical Medicine, Department of International Public Health, Liverpool, United Kingdom.

d  University of Warwick, Division of Health Sciences, Coventry, United Kingdom.

e Karolinska Institute, Department of Learning, Informatics, Management and Ethics, Stockholm, Sweden.

1. **Ahmed Alatawi**\*, MSc, Pharm.D. **(Corresponding author)**

PhD Candidate - Health Economist

Health Economics Group, Department of Clinical Sciences, Room 1966-215, Liverpool School of Tropical Medicine, LSTM, Pembroke Place, Liverpool, L3 5QA, United Kingdom.

Mobile: +4407491496786

Fax: +44(0)151 705 3370

Email: Ahmed.alatawi@lstmed.ac.uk

1. **Louis Niessen, Professor**

Chair of Health Economics.

Health Economics Group, Department of Clinical Sciences, Room 1966-206, Liverpool School of Tropical Medicine, LSTM, Pembroke Place, Liverpool, L3 5QA, United Kingdom.

Tel: +44 (0)151 705 3779. Email: louis.niessen@lstmed.ac.uk

1. **Jahangir A. M. Khan, PhD**

Senior Lecturer in Health Economics

Health Economics Group, Department of International Public Health, Room 1966-215, Liverpool School of Tropical Medicine, LSTM, Pembroke Place, Liverpool, L3 5QA, United Kingdom.

Tel: +44 (0)151 702 9345. Email: jahangir.khan@lstmed.ac.uk

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# Abstract

**Objective:** In this study, we assess the performance of public hospitals in Saudi Arabia. We detect the sources of inefficiency and estimate the optimal levels of the resources that provide the current level of health services. We enrich our analysis by employing locations and capacities of the hospitals.

**Design:** We employ the Data Envelopment Analysis (DEA)to measure the technical efficiency of 91 public hospitals. We apply the input-oriented CCR and BCC models under constant and variable returns-to-scale (CRS and VRS). The assessment includes four inputs and six output variables taken from the Ministry of Health databases for 2017. We conducted the assessment via PIM-DEA 3.2 software.

**Setting:** Ministry of health-affiliated hospitals in the Kingdom of Saudi Arabia (KSA).

**Results:** Findings identified 75.8% (69 of 91) of public hospitals as technically inefficient. The average efficiency-score was 0.76, indicating that hospitals could have reduced their inputs by 24% without a reduction in health-service provision. Small hospitals, (efficiency-score 0.79), were more efficient than medium-sized and large hospitals. Hospitals in the central-region were more efficient (efficiency-score 0.83) than those located in other geographic-locations. More than half of the hospitals (62.6%) were operating sub-optimally in terms of the scale-efficiency, implying that to improve efficiency, they need to alter their production capacity. Performance analysis identified the overuse of physician’s numbers and shortage of health-services production, as major causes of inefficiency.

**Conclusion:** Most hospitals were technically inefficient and operating at sub-optimal scale size and indicate that many hospitals may improve their performance through efficient utilization of health resources to provide the current level of health services. Changes in the production capacity are required to facilitate optimal use of medical capacity. The inefficient hospitals could benefit from these findings to benchmarking their system and performance in light of the efficient hospital within their capacity and geographic location.

**Strengths and limitations of this study:**

* The study challenged to find data on economic values, the severity of cases and the quality of services. We expanded the selection of the variables to cover a broad range of health services and resources in the hospitals.
* The hospital mortality rate was included in output variables as a proxy of the service quality in the studied hospitals.
* We did not apply output-oriented DEA models; alternatively, we adopted input-orientation, since we aimed to estimate the optimum levels of the resources without deteriorating the health services.
* Further estimation of the optimal levels of resources is required to examine the allocation of these resources among the hospitals.
* This is the first performance assessment of public hospitals in Saudi Arabia that uses real data obtained directly from official databases of the Ministry of Health.

# Introduction

Increasing demand for healthcare and the expenditure required to provide efficient, equitable and effective healthcare systems, are global concerns. The Kingdom of Saudi Arabia (KSA) has experienced these recently, alongside substantial population growth, increased life expectancy and the proliferation of lifestyle-related disease. These have increased the demand for health services at a time of the scant resource.1,2,3

During 2015, KSA government spending on health was 71.3% of the country’s total health expenditure, which corresponds to 4.1% of GDP for that year.4 Healthcare expenditure in KSA increased by 24.7% between 2013 and 2017 (Table 1).1,2,5 While public spending on health in KSA is remarkably high in comparison to many high-income countries (71.3% for KSA versus 61.2% for high-income countries), the number of hospital beds is considerably lower. 3,4 In other words, the cost of each hospital-bed in the KSA is remarkably higher than those in other high-income countries.

Although much has been done to promote the efficient use of resources, this has proven insufficient to meet the rising health expenditure and demand for healthcare in KSA.6,7 Providers seem to find it very challenging to deliver adequate provision using current resources.8 There seems to be an imbalance between health service availability, and health spending, so better use of resources is necessary if KSA is to have an efficient and appropriate health system.7 It is thus important to investigate how existing resources can be used more efficiently for meeting the demand for healthcare in the country.

Governments worldwide conduct performance assessments of their health sectors, to ensure that public funds are effectively utilized.9 Efficiency evaluation is carried out under different concepts, such as technical, allocative, cost and overall efficiency.9 Of these, the technical efficiency approach is most commonly used. This is based on Farrell’s theory of 1957, which introduced a measure of technical efficiency based on a comparison of the inputs and outputs of set entities, called decision-making units (DMUs).10

Hospital efficiency is crucial to the efficiency of the health system generally, as hospitals are key consumers of health resources.11,12 Hanson et al. (2002) found that public hospitals consume around 40% of the total health budget in many sub-Saharan African countries.11 Public hospitals used almost 44% of the health spending in the United Kingdom in 2012/13.13

In general, there is a scarcity of studies and empirical works on the performance assessment of public hospitals, and this rarity is particularly acute in the context of KSA.14 Systematic review of public hospital efficiency studies in the Gulf region and similar countries has shown the number of studies to be limited, as efficiency analysis is a novel approach to research in the Gulf, including KSA.14 The review found only two studies based in KSA context; a study by Helal and Elimam in 2017 15, which assessed the efficiency of health services at districts level in KSA. Another efficiency analysis conducted in 2013 of 20 public hospitals, under private sector management, which found that 60% of the study sample had not achieved the efficient score.16

Hospital efficiency has hitherto been measured mainly by frontier analysis methods, either through non-parametric data envelopment analysis (DEA) or as parametric stochastic frontier analysis (SFA).9 These methods compare hospital performance with an estimated efficient frontier comprising the best-performing hospitals.17,18

Data envelopment analysis has for many years been the most commonly used technique for measuring the relative efficiency in healthcare .12,19 Systematic reviews of efficiency studies have often identified that DEA to be the predominant method of public hospital efficiency assessments among studies reviewed.12,14,19 Hollingworth et al. (2003, 2008) conducted systematic reviews of efficiency analysis internationally and noticed that DEA was used in around half of the studies, a further fifth used DEA in with some form of secondary regressions. 12,19 Another review18, of efficiency in Iranian hospitals, found DEA was applied in all reviewed studies; three of those studies also used SFA to estimate efficiency scores. A systematic review of health system efficiency studies in OECD countries20 found that DEA was applied in 64% of them.

In this study, we conduct a performance assessment of the MOH-administered general hospitals in KSA. We measure the technical efficiency of public hospitals and identify the sources of inefficiency and estimate the optimal levels of the resources. We also provide subscriptions for improvements so as the inefficient hospitals to be rendered efficient. At a post optimality phase, we enrich our analysis by employing information about the geographical location and the capacity (number of beds) of the hospitals. Thus, this performance assessment provides useful information to the decision-makers, which can be employed for policy reforms, to optimise the use of health resources in public hospitals and consequently improve the efficiency of healthcare systems.

## Public health system in KSA

Under article 31 of the national constitution, the KSA government guarantees free medical care to all citizens.8 The government finances the public sector annually, largely from revenue derived from oil and gas production.21 Table 1 shows the proportion of national budget allocated to the KSA’s Ministry of Health (MOH).5 Thus, the available resources should be utilized optimally.

The MOH is the primary provider of healthcare services in KSA, administering 60% of all provision. 22 It is the dominant provider of health services in the public sector.22,23 Other government agencies, including the Ministry of Defence, the national guard and universities, share the remaining of healthcare provision, as does the private sector.21 The MOH delivers primary, secondary and tertiary healthcare through 2,361 primary healthcare centres and 282 hospitals, administering 43,080 beds throughout the country.5 Other MOH functions include strategic planning, formulation of health policy, supervision of all health service delivery programs and the monitoring and management of all other health-related activities.22 Public (MOH-affiliated) hospitals in KSA can be broadly classified into two groups, general hospitals with different capacities (number of beds) and specialised hospitals. General hospitals provide a wide range of health services, while specialised hospitals deliver health services for a specific health condition or to a particular group of beneficiaries. General hospitals in KSA are located in various geographic locations and serve populations of different demographic characteristics and needs, which may affect the hospital performance, as observed in other studies.8,24

**Table 1:** Budget appropriations for the MOH with respect to government budget (SR = Saudi Riyal)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | GovernmentBudget Billion SR | MOH Budget Billion SR | Percentage of MOH to the government budget | No. of Hospitals | No. of Beds |
| 2013 | 820 | 54.3 | 6.63% | 268 | 38970 |
| 2014 | 855 | 59.9 | 7.02% | 270 | 40300 |
| 2015 | 860 | 62.3 | 7.25% | 274 | 41297 |
| 2016 | 840 | 58.9 | 7.01% | 274 | 41835 |
| 2017 | 890 | 67.7 | 7.61% | 282 | 43080 |

*Source; Ministry of Health; Statistical yearbook, 2017.*

# Methods

## Population and selection of sample

As the application of DEA is based on a homogenous (comparative) sample that use similar inputs to produce similar outputs, we focused on examining the technical efficiency for general hospitals.9

Hollingsworth (2008) and Varabyova (2016) argued that hospitals under evaluation should be of the same type and provide the same services and health activities.19,20 Since the inclusion of divergent specialist units in the same sample will confound the results — frontier techniques are susceptible to outliers.19,20 Specialised hospitals often lack types of secondary service, e.g. surgical operations rarely occur in psychiatric hospitals, and such hospitals, if included, will appear as inefficient while surgery is considered as one of the outputs.18,19,25 Therefore, we excluded specialised hospitals from this analysis.

Similarly, small hospitals (with 50 beds or fewer) provide primary care services while lacking secondary and tertiary health services, and consequently miss a significant number of output variables (e.g. inpatient services, patient discharge, surgical operations, laboratory testing) compared to larger hospitals. In this study we also excluded the smaller hospitals, to ensure greater homogeneity in performance evaluation across the units.9,26

Ultimately, the homogenous sample used in the analysis included 21,528 out of 398,68 (54%) of the total active hospital beds provided by the MOH in KSA. We included in the assessment 97 general hospitals and removed six of them, due to missing data. The data of hospital inputs and outputs for 2017 was collected by the lead author from official statistical, informational and research databases of Administration of Statistics and Information and Administration of Research and Studies, which affiliated with the MOH, following approval from the designated authority. Data collection took place from May to July 2018.

The sample hospitals are in 64 cities, affiliated to 20 administrative districts, located in five geographic regions, namely central, west, east, south and north regions. The general hospitals in the sample are classified into four groups based on their capacity (number of beds): small (fewer than 200 beds), lower-medium (200 to 299 beds), upper-medium (300 to 499 beds) and large (500 or more beds) hospitals, following Gok’s27 categorization. However, these hospitals are affiliated, organized and funded by the MOH, and have not autonomy in terms of funding or organising structure by themselves or other agents. Thus, we applied the DEA model for all 91 hospitals. Then, we presented the efficiency scores in each capacity and each geographic location. Figure 1 illustrates the number of hospitals and hospital beds in each category of capacity and location.

Figure 1 to be inserted here

## Inputs and outputs

The selection of input and output variables is a crucial step in performance measurement because the results of any efficiency assessment depend significantly on the variables used in the estimation models.28 The literature has focused on labour (e.g. health professionals) and capital (e.g. the number of beds), as input variables, while some studies included consumable resources.9,28 The main categories of output used in healthcare-related efficiency studies were healthcare activities (e.g. number of outpatient visits, inpatient services, number of surgeries) and health outcomes (e.g. mortality rate).9,18,20

In our study, we selected the hospital outputs that depend on the selected inputs, which cover a broad range of health services provided and health resources used by public hospitals in KSA. In particular, four inputs and six outputs were chosen based on the availability of the data in the KSA context, which were rationally approved in previous theoretical and empirical studies. 9,12,19

The input variables chosen are (1) number of hospital beds; (2) number of full-time physicians; (3) number of full-time nurses and (4) number of full-time allied health personnel (i.e. pharmacists, midwives, medical technicians, medical radiologists, physiotherapists) employed in the hospital. The output variables used in this study are: (1) outpatient visits (number of patients receiving outpatient treatment within a year); (2) discharged patients (number of patients receiving inpatient treatment within a year); (3) total number of surgical operations during the year; (4) number of radiological investigations conducted in hospital during the year; (5) number of laboratory tests during the year; (6) hospital mortality rate (ratio of inpatient deaths during hospitalization to the total number of inpatients that year). The last output variable is an indicator of health service quality and health outcomes in hospitals, as argued by Sahin and Ozcan.29 Reduction in the mortality rate and increase quantity of life signify an improvement in the health outcomes of the public hospital of investigation. Therefore, the mortality rate could be a proxy for a weighted health quality measure in our assessment.30 The inverse value for the mortality rate (one divided by mortality rate) is included as an output value in the assessment, meaning that hospitals with higher mortality rate would have a smaller ratio as output values.29 As the model assumes that output and input variables are isotonic, (i.e., increased input reduces efficiency as well as increased output increases efficiency). We had to apply this correction; otherwise, a higher mortality rate would incorrectly contribute to a better hospital outcome.30

The number of hospitals (DMUs in DEA context) should be at least two times larger than the sum of inputs and outputs.31 However, Hollingsworth (2014)32 suggested that the number of units used in efficiency assessment should be at least three times the sum of inputs and outputs. In accordance with the above-mentioned rule of thumb, in this study we include 91 hospitals, more than three times the combined number of input and output variables.

**Patient and Public Involvement**

No patients were involved in this study, and we used anonymous data from MOH databases.

## Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a powerful technique that is based on linear programming. It was developed for measuring the performance of a set of comparable entities, called Decision Making Units (DMUs), which convert multiple inputs into multiple outputs.26,32 In this method each hospital is compared against the estimated efficient frontier comprising the best-performing hospitals.17,18

DEA has been already the most commonly used technique for measuring the relative efficiency in healthcare.12,19 In systematic reviews, we can observe that DEA is the predominant method of public hospital efficiency assessment.12,14,19 DEA is widely applicable since does not require any a priori specification of the underlying functional form that relates the inputs with the outputs.9 In addition, the use of DEA is justified by its ability to incorporate multiple inputs and outputs in different units of assessment.9,32

Several DEA models have been developed to analyze the efficiency based on Farrell’s concept.10 The most well known and basis for the rest DEA models is the CCR model developed by Charnes, Cooper and Rhodes,33 which assumes that production has constant returns to scale (CRS) and the BCC model developed by Banker, Charnes and Cooper, 34 under the assumption of variable returns to scale (VRS).9,12 The choice of CCR or BCC model depends on the context of the problem under examination, i.e. the technology linking the inputs to outputs in the transformation process.9

Generally, the CCR model — whereby the efficiency frontier has a constant slope (CRS), which means that any change in the inputs results to a proportional change in the outputs.26 Constant returns to scale CRS may be adopted when machines are involved in the process, which roughly means that the production can be doubled by doubling the levels of inputs. However, when employees (human factor) participate in the production process, then it is naive to expect that they could work at a constant rate. The CCR efficiency assessment by the may be affected if the DMUs are not operating on the optimal scale since CRS does not distinguish between the scale and pure (managerial) technical efficiency.35 If the efficiency analysis considers a managerial perspective, a BCC technology assumption will be appropriate to understand if a scale of operations or provider’s practice affects productivity.27,36 Scale efficiency is defined as a ratio of CRS to VRS efficiency scores and provides evidence on whether the DMU is operating on the optimal scale size.12,20 Furthermore, the efficiencies of DMUs can be comprehensively analysed using both CRS and VRS assumption for more realistic changes in the production process, and implications in the real world.9,26 Other systematic reviews 20,25 have reported similar findings where studies used both CRS and VRS assumptions in efficiency measurements.

Rationally, the commonly-used orientations in DEA analysis are input orientation (i.e. minimization of inputs with the given amount of outputs) and output orientation (i.e. inputs are held constant, and outputs are proportionally increased).26 Previous empirical studies 35 have argued that hospitals have relatively little control over their outputs (for example, expanding surgical operations), but more control over the inputs (e.g. medical devices), where they have the social responsibility to provide medical treatment through the public hospitals in general. Thus, most studies adopt input orientation for efficiency assessment of the hospitals.20,25,37 In a few studies, output orientation is adopted in response to the strategic health plans of the countries aiming to expand healthcare provision during a specific period.38,39 However, in our study we aim to estimate the optimal levels of the resources without deteriorating the levels of the health services that the hospitals provide. In this way, we provide the central authorities with the potential savings that could be made in the health sector.

The efficiency of a hospital is defined as the ratio of the weighted sum of outputs (total virtual output) to the weighted sum of inputs (total virtual input), with the weights being obtained in favour of each evaluated unit by the optimization process. Assume *n* DMUs, each using *m* inputs to produce *s* outputs. We denote the vector of inputs for DMU *j* is and the vector of outputs is . The model (1) is formulated and solved for each hospital in order to obtain its efficiency score. The variables *η=(η1,…,ηm)* and *ω=(ω1,…,ωs*) are the weights associated with the inputs and the outputs, respectively. These weights are calculated in a manner that they provide the highest possible efficiency score for each hospital *jo* under evaluation.

The input-oriented BCC model that provides the efficiency for the hospital *jo* under VRS assumption is given below:

|  |  |
| --- | --- |
|  | (1) |

Notice that by excluding the free of sign variable *ωο* from the model (1), the CCR model is obtained. The fractional model (1) can be transformed into a linear program by applying the Charnes and Cooper (1962) transformation (C-C transformation hereafter).40 The transformation is carried out by considering a scalar such as and multiplying all terms of model (1) with *t>0* so that *v = tη*, *u = tω, uο = tωο*. The linear equivalent of the model (1) is formulated as:

|  |  |
| --- | --- |
|  | (2) |

Once an optimal solution *v\**, *u\**, *uο\** of the model (2) is derived, the input-oriented BCC-efficiency for the hospital*jo* under evaluation is obtained directly from the objective function.

Banker et al. (1984) determined the returns to scale (RTS) using the optimal value of the free variable *uo* in the multiplier model (2).34 Given the point that lies on the efficient frontier, the returns to scale at this point are identified by the following three conditions:

1. Increasing returns to scale (IRS) prevail at  if and only if for all optimal solutions. Meaning the increase in all production factors (inputs) resulted in more production (outputs).
2. Decreasing returns to scale (DRS) prevail at  if and only if for all optimal solutions, meaning an equal increase in all production factors led to less production.
3. Constant returns to scale (CRS) prevail at  if and only if in any optimal solutions, where an equal increase in all production factors led to the same amount of increase in production.

Improvement management software (PIM-DEA version 3.2) was used for DEA analysis.41

# Results

Descriptive statistics, concerning the inputs and outputs of 91 general hospitals during 2017, are presented in Table 2. The average hospital size is 236.57 beds, with a range of 100 to 711 beds. Full-time physicians ranged from 38 to 894, with a mean of 212. The number of nurses is on average, 495 but ranged from 74 to 1,930. Full-time allied health personnel ranged from 37 to 1,149, with an average of 280.

***Table 2:*** *Descriptive statistics of the inputs and outputs of the 91 hospitals*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Mean** | **Standard Deviation** | **Min** | **Max** |
| **Inputs** |  |  |  |   |
| Hospital beds | 236.6 | 137.6 | 100 | 711 |
| Physicians | 212.3 | 168.7 | 38 | 894 |
| Nurses | 495.2 | 403.6 | 74 | 1,930 |
| Allied Health Personnel | 280.1 | 219.1 | 37 | 1,149 |
| **Outputs** |  |  |  |   |
| Outpatient visits | 72,986.5 | 72,475.3 | 1,785 | 466,608 |
| Discharged patients | 26,016.4 | 55,856.4 | 19 | 503,216 |
| Surgical operations | 2,638.4 | 2,151.2 | 172 | 9,464 |
| Laboratory tests | 965,840.8 | 1,095,415.6 | 794 | 5,512,774 |
| Radiology Investigations | 53,531.4 | 46,788.7 | 107 | 221,980 |
| Hospital mortality rate  | 0.0224 | 0.0212 | 0.0003 | 0.125 |

Concerning the outputs, the average number of patient visits to outpatient departments is 72,986 and ranged from 1,785 to 466,608 visits. Discharged patients receiving inpatient services during 2017 averaged 26,016, ranging from 19 to 503,216. Surgical operations ranged from 172 to 9,464, with a mean of 2,638 surgeries per hospital. Means for laboratory and radiology tests are 965840 and 53531 respectively, during 2017. The average mortality rate is 2.24%.

Table 3 presents the results of DEA models, summary statistics of average technical (CRS and VRS) efficiency, and scale (SE) efficiency scores, as well as concerning the return to scale.

***Table 3:****Technical efficiency scores and returns to the scale of the public hospitals in KSA*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **CRS technical efficiency** | **VRS technical efficiency** | **Scale efficiency** | **CRS [N (%)]** | **IRS [N (%)]** | **DRS [N (%)]** |
| **All hospitals (n=91)** |
| Mean | 0.76 | 0.87 | 0.87 | 34 (37.4) | 40 (44) | 17 (18.6) |
| Std. Dev. | 0.23 | 0.18 | 0.18 |
| Min | 0.11 | 0.30 | 0.19 |
| No. full score | 22 (24.2%) | 47 | 25 |
| **Large hospitals: >=500 beds (n= 8)** |
| Mean | 0.65 | 0.75 | 0.87 | 2 (25) | 1 (12.5) | 5 (62.5) |
| Std. Dev. | 0.27 | 0.30 | 0.13 |
| Min | 0.28 | 0.30 | 0.59 |
| No. full score | 1 (12.5) | 4 | 1 |
| **Upper-medium hospitals: 300-499 beds (n= 22)** |
| Mean | 0.76 | 0.80 | 0.94 | 7 (31.8) | 5 (22.7) | 10 (45.5) |
| Std. Dev. | 0.19 | 0.19 | 0.07 |
| Min | 0.39 | 0.41 | 0.76 |
| No. full score | 3 (13.6) | 7 | 3 |
| **Lower-medium hospitals: 200-299 beds (n= 22)** |
| Mean | 0.73 | 0.79 | 0.90 | 10 (45.5) | 10 (45.5) | 2 (9.1) |
| Std. Dev. | 0.25 | 0.19 | 0.18 |
| Min | 0.11 | 0.50 | 0.22 |
| No. full score | 4 (18.2) | 4 | 4 |
| **Small hospitals: <200 beds (n= 39)** |
| Mean | 0.79 | 0.96 | 0.82 | 15 (38.5) | 24 (61.5) | 0 (0) |
| Std. Dev. | 0.23 | 0.09 | 0.22 |
| Min | 0.19 | 0.67 | 0.19 |
| No. full score | 13 (33.3) | 31 | 13 |

The average CRS technical efficiency score for MOH general hospitals is 0.76, with a standard deviation (SD) of 0.23, which indicates that these hospitals could reduce the use of all their inputs on average by 24% without any reduction in the number of services provided. Also, the VRS technical score on average is 0.87 (SD 0.18). The distribution of technical, pure technical and scale efficiency scores is given in Figure 2.

Figure 2 to be inserted here

The lowest technical efficiency score reported is 0.11, but 22 hospitals out of 91 (24.2%) are both technically and scale efficient, which indicates that these hospitals utilize their inputs optimally. Among the inefficient hospitals, 55 hospitals (60.4%) achieved efficiency scores of at least 0.50 (Figure 2) and 14 hospitals (15.4%) reported efficiency scores below 0.50. Average scale efficiency scores are 0.87, with (SD 0.18). Although 47 hospitals (52%) reported an efficient score on VRS (pure efficiency), only 25 (27%) hospitals are efficient on the scale.

Concerning the returns to scale, we have found that 34 hospitals (37.4%) operate under constant returns to scale (CRS); while 40 hospitals (44%) operate under increasing returns to scale (IRS), and 17 hospitals (18.6%) decreasing returns to scale, However, hospitals that were operating on either IRS or DRS needed to alter their capacity to operate on the optimal scale size, i.e. at the constant return to the scale, which would be required to achieve technical efficiency.

We present in table 3 the efficiency scores of the 91 hospitals for each capacity (size category). From the capacity perspective, small hospitals had higher levels of technical (CRS and VRS) efficiencies than medium-sized (both lower- and upper-medium) and large hospitals. Table 3 shows that small hospitals have on average technical efficiency of 0.79 (SD 0.23); one-third of the hospitals in this category are technically and the scale efficient. The average technical efficiency of lower-medium hospitals is 0.73 (SD 0.25), with a higher percentage of inefficient hospitals (81.8%) than for small hospitals. Although upper-medium-sized hospitals reported a slightly higher average technical efficiency score of 0.76 (SD 0.19), fewer hospitals in this category reported an efficient score, meaning a higher percentage of inefficiencies (86.4%). Large hospitals were the least efficient when compared to other categories. The average technical efficiency of large hospitals was 0.65 (SD 0.27); only one was technically efficient.

Regarding scale-efficiency scores, upper-medium (0.94) and lower-medium (0.90) sized hospitals operate at a more optimal scale than small (0.82) or large hospitals (0.87). Also, 45.5% of lower-medium hospitals operate on the CRS, followed by small hospitals (38.5%). However, most of the remaining hospitals in these categories, i.e. lower-medium (45.5%) and small size (61.5%) hospitals are operating on IRS. In contrast, most large hospitals (62.5%) showed DRS, and two of them were on CRS, indicating a need to downsize these hospitals to improve technical efficiency. Similarly, 45.5% of upper-medium-sized hospitals operate on DRS and one-third of this category is operating on CRS.

Table 4 shows the average efficiency scores in five geographical regions; however, based on the analysis of all 91 hospitals together. Hospitals in the central region reported the highest average technical efficiency score of 0.83 (SD 0.18), followed by eastern hospitals with an average score of 0.80 (SD 0.28). Hospitals in western KSA reported the least average score, 0.68 (SD 0.20).

**Table 4** Technical efficiency scores and returns to the scale of the hospitals categorized by location

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **CRS technical efficiency**  | **VRS technical efficiency**  | **Scale efficiency** | **CRS [N (%)]** | **IRS [N (%)]** | **DRS [N (%)]** |
| **South region hospitals (n= 22)**  |
| Mean | 0.75 | 0.89 | 0.83 | 9 (40.9)    | 9 (40.9)    | 4 (18.2)    |
| Std. Dev. | 0.25 | 0.18 | 0.23 |
| Min | 0.11 | 0.41 | 0.22 |
| No. full score | 4 (18.2) | 13 | 4 |
| **East region hospitals (n =8)** |
| Mean | 0.80 | 0.85 | 0.90 | 4 (50)    | 1 (12.5)    | 3 (37.5)    |
| Std. Dev. | 0.28 | 0.21 | 0.16 |
| Min | 0.27 | 0.50 | 0.54 |
| No. full score | 1 (12.5) | 4 | 1 |
| **North region hospitals (n =17)** |
| Mean | 0.75 | 0.84 | 0.90 | 7 (41.2)    | 9 (52.9)    | 1 (5.9)    |
| Std. Dev. | 0.28 | 0.23 | 0.20 |
| Min | 0.19 | 0.30 | 0.19 |
| No. full score | 6 (35.3) | 9 | 6 |
| **Central region hospitals (n =24)** |
| Mean | 0.83 | 0.89 | 0.93 | 10 (41.7)    | 11 (45.8)    | 3 (12.5)    |
| Std. Dev. | 0.18 | 0.16 | 0.10 |
| Min | 0.49 | 0.50 | 0.69 |
| No. full score | 8 (33.3) | 12 | 8 |
| **West region hospitals (n =20)** |
| Mean | 0.68 | 0.85 | 0.81 | 4 (20)    | 10 (50)    | 6 (30)    |
| Std. Dev. | 0.20 | 0.17 | 0.17 |
| Min | 0.37 | 0.42 | 0.46 |
| No. full score | 3 (15) | 9 | 3 |

The percentage of efficient hospitals in the north (35.3%) and the central (33.3%) regions are higher than the other regions. The eastern, western and southern regions have a higher percentage of inefficient hospitals. Both central and southern regions reported a relatively higher VRS efficiency score of 0.89. In terms of average scale efficiency scores, central region hospitals (0.93), and hospitals in the north- and east (both 0.90) were operating at a more optimal scale than those in the west (0.81) and south (0.83). Half of the sample hospitals in the eastern region operate on CRS, followed by hospitals in the central and north regions (both 41%). The findings also revealed that 52.9 % of north region hospitals were operating on IRS, while 37.5% of east region hospitals were operating on DRS.

The performance analysis identified the slacks, which showed either excess input utilization or shortages of output production. Table 5 shows the average amount of slack in hospitals deemed inefficient. These results represent the combined scores of slack for all inefficient hospitals, for each input and output. Table 5 also shows the percentage of change (slacks) in the number of inputs or outputs required to eliminate the inefficiencies and achieve target levels.

**Table 5** Slacks evaluation for inefficient hospitals

|  |  |  |
| --- | --- | --- |
| **Input slacks** | Mean (SD) | Percentage of change |
| Hospital beds | 48.4 (76.6) | -20.4% |
| Physicians | 47.5 (72.6) | -22.4% |
| Nurses | 102.9 (173.1) | -20.8% |
| Allied Health Personnel | 58.38 (98.3) | -20.84% |
| **Output slacks** |  |  |
| Outpatient visits | 8866.1 (23712) | 12.2% |
| Discharged patients | 3700.6 (8214.2) | 14.2% |
| Surgical operations | 282.6 (730.9) | 10.7% |
| Laboratory tests | 66105.6 (140332.4) | 6.8% |
| Radiology Investigations | 2204.6 (6944.1) | 4.1% |
| Mortality rate | 0.006 (0.014) | 21.7% |

In terms of inputs, results show that an excess of physicians was the leading cause of inefficiencies in public hospitals. A feasible, achievable reduction in the number of physicians was, on average, 22.38 % of the current values (compared with the amounts given in Table 2). The next most substantial slack was observed in allied health personnel, at 20.84%. Surpluses of hospital beds and nurses were also important causes of inefficiency and should be reduced on average by 20.44% and 20.77%, respectively. In addition to the input reduction, the average number of services should be increased to meet targets. Furthermore, the quality of health services in public hospitals would have improved with a decrease in the hospital mortality rate.

# Discussion

This study evaluated the technical efficiency of public hospitals affiliated to the KSA’s MOH, using data envelopment analysis. The analysis showed that 75% of sample hospitals could not utilize their intact resources to generate specified outputs. The average CRS technical efficiency score was 0.76, indicating that hospitals could produce their current level of outputs with 76% of inputs currently used, and thereby achieve efficiency. Efficiency scores ranged from 0.11 to 1.00 (Figure 2), revealing considerable variations in efficiency scores among hospitals.

Moreover, the average VRS technical efficiency and scale efficiency scores were both 0.87. This indicated that inefficiency might be due to administrative gaps to overcome external environmental factors and limitations in managing internal operations in the hospitals. Notably, Helal and Elimam 15 in 2017, assessed the efficiency of health services at districts level in KSA based on MOH data 2014, found an average efficiency score of 0.92, and 45% of the districts achieved the technical efficiency score. Efficiency analysis of 20 public hospitals, under private sector management in KSA, found that 60% of the study sample had not achieved the efficient score, with an average score of 0.84.16

The results of the study presented here suggest that small hospitals were relatively more technically efficient than medium-sized and large hospitals (Table 2). Other efficiency studies have reported similar findings: Gok 27 found that small hospitals achieved higher efficiency scores than medium-sized and large ones. This might be due to the different locations and missions of small and large hospitals.27,36 In this study’s sample, small hospitals were mainly in peripheral cities and towns in KSA, which lacked other sources of public or private healthcare. Service provision in those hospitals might be relatively high compared to the health resources used. Large hospitals (500 or more beds) tended to be in larger cities in urban areas, where many other health providers shared the healthcare of much of the urban population, which might generate a relatively decreased level of health services production in respect of inputs used.

Regarding the different missions, large hospitals consumed a high amount of health resources to meet the various requirements of comprehensive care.27 Since some of these were teaching hospitals, however, teaching activities were not counted in the outcome measurements.27,28 In such large hospitals, treatment processes might be more complicated, and some of the productions of these hospitals could not be assessed in the hospital outcomes.42

This study found 57 hospitals (62.6%) operating on non-optimal scale size; 44% were operating on the IRS, while 18.6% showed DRS (Table 3). This indicated that the efficiency of healthcare in KSA might be improved through the downsizing of hospitals on DRS and reallocating these inputs to the hospitals operating in the IRS. Moreover, five out of eight large hospitals (500 or more beds) were operating on DRS, implying that to improve efficiency, they needed to reduce their production capacity. This is supported by other research findings.43

This study found that 61.5% of small hospitals had been operating on IRS, none was on DRS. It can thus be argued, like Kiadaliri and colleagues (2011), that the increase of capacity (inputs) of this category should be increased by reallocating resources from the larger hospitals for improving efficiency.43 The efficient scale of public hospitals was in medium-sized establishments (200 to 499 beds). Although half of the hospitals located in the east were operating on the most productive scale size (CRS), three were operating on DRS. Around 53% of the hospitals in the north were operating on IRS, whereas 30% of western region hospitals, which reported the lowest efficiency scores, were operating on DRS.

Our analysis found that hospitals located in the western region were relatively less efficient than hospitals located in other regions. The central region hospitals appeared to be the most efficient. Atılgan44 reported in the same line as our findings, i.e. location-specific differences in efficiency scores for general MOH hospitals in Turkey. Atılgan argued that this could be due to case mix and/or case severity differences between hospitals. We observed that five out of eight large hospitals in our sample are located in the west region. We can argue that hospitals in the west region might be treating more severe cases than hospitals in other regions in KSA, which might have led to different levels of efficiency scores in hospitals across regions.18 Another explanation could be that hospitals in this region consumed more inputs in anticipation of the annual pilgrimage season, for which the government of KSA allocates more resources to such hospitals.

Regardless of the capacity or location-based performance variations, improving the scale efficiency of hospitals would require long-term effort, reflected in amendments to health policies, strategic plans and the autonomy of hospital-managers.43 The prevailing ability of patients to access health services should not be compromised while reallocating the resources to the other hospitals until Pareto optimality is achieved.9

The use of DEA can identify sources of inefficiency, helping hospital managers and health policy-makers to reach informed decisions.36 The analysis showed that the number of full-time physicians was a slightly larger notable reason for inefficiency than the other factors, with an average excess of 22.4%, from an input perspective. Other inputs among labour variables that showed a surplus in use were the number of nurses and the number of allied health personnel, in addition to the excess number of hospital beds (capital variable). The analysis revealed a shortage of outputs production, e.g. hospitals needed to increase the number of outpatients and hospitalized inpatient services on average by 12.2% and 14.2% respectively, to be efficient.

Given our findings, health policy-makers may consider redeploying their labour forces from inefficient hospitals to more efficient ones.36,43 Public hospitals can consider taking measures for utilizing existing beds effectively to increase efficiency. For example, in this study, many large hospitals had been operating on DRS; however, most of the small hospitals were operating on the IRS. Healthcare administrators should assess the legal conditions and regulations for the effective use of medical capacity in light of the findings of this slack analysis.

It had been argued by Afzali28 and Hollingsworth12 that many hospital databases are compromised by insufficient data on a broad range of hospital functions and care, e.g. preventive care, health promotion, staff development activities.Thus, improving hospital's databases through high-quality data collection and processing techniques — including data from different health provision levels, capturing valid data that reflects the severity of cases and related health services, quality of care and pattern of activities — is very important.29,44 Such improvement would facilitate further efficiency research by indicating weaknesses in healthcare production processes and consequently would guide policy-makers in potential reforms of health policy and directives.

In recent years, KSA has been facing the global trends of rising healthcare costs in addition to the high growth rate of population and high prevalence of chronic diseases. The government thus realized that the existing healthcare financing system with oil revenue is unsustainable.45 It thus can be argued that optimum use of existing health resources, which is a fundamental requirement for achieving universal health coverage as advised by the World Health organization46 can appropriately be applied for KSA. An application of these findings is useful for high income, and Gulf countries in particular, which have the same health financing systems and comparable demand for health services.2,3,14 Our findings from this current analysis of KSA public hospitals indicated that there is a large scope for improving efficiency in utilizing healthcare resources. We recommend the policy-makers to consider the appropriate use of resources within hospitals as well as reallocate resources across hospitals, given the findings of this research. Thus, to meet the efficient use of health resources to ensure the maximum value for money, which is expected to contribute significantly towards achieving universal health coverage in KSA.

The study faced the challenges of finding data on economic values of the inputs, also the severity of cases and the quality of services of the outputs. We, however, could use the mortality rate as the proxy for the quality of services. The performance assessment is devoted on how to utilize the resources of the health sector optimally in order to provide the given levels of health services. Thus, we rationally adopted input orientation in the assessment. However, the DEA methodology also permits the assumption of output orientation. We did not apply output-oriented DEA models because outputs of a different type than the ones used in the current study would need to be available.

In this study, we provide the optimal levels of resources that render efficient each hospital given the health services levels that each one of them provides. Further to estimating the optimal levels of resources, a different yet important assessment is to examine the allocation of these resources among the hospitals. This extension is left for future research. Despite a few limitations, the study site (KSA), and data sources might create strong interest among policy-makers, stakeholders, researchers, and academics. This is the first research study of technical efficiency based on official data from KSA, that has considered public hospital capacities and geographical locations.

# Conclusions

Given the scarcity of resources, growing expenditure on health and demand for health services, more attention should be paid to improving the efficiency of healthcare by better utilization of current resources. In this study, inefficiency existed in most public hospitals, and these could reduce their inputs by 24% without any reduction in service provision. Small hospitals and hospitals in the central region of KSA were relatively more efficient. A high proportion of hospitals were operating at non-optimal scale size, while an efficient scale of the operation was observed in medium-sized hospitals. The finding suggests that it would be helpful to adjust production capacity by downsizing hospitals operating on DRS and reallocating the resources to hospitals on the IRS, as reflected in the scale analysis. Performance analysis shows the surplus of the health workers and a shortage of health services to be significant causes of inefficiency, implying that health regulators might redeploy their labour forces for effective utilization of medical capacity. A possible reallocation of the resource must take place without compromising patients’ current access to public-funded health services.

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**Contributors**

AA, LN and JK contributed to conceptualizing the research question, study design and settings and literature search. AA contributed to data collection and variable extraction. AA and JK conducted the data analysis, interpretation, and writing of the manuscript. AA, LN and JK contributed to writing, reviewing and revising the manuscript. All authors finally reviewed the manuscript critically and approved the final version for submission.

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**Competing interest**

None declared.

**Data sharing statement**

Data were extracted from the hospital databases at Administration of Statistics and Information in The Ministry of Health. Additional data are available if requested.

**Ethics approval**

Ethics approval was obtained from the Ethics Committee of Institutional Review Board (IRB) of King Fahad Medical City, the Ministry of Health in Saudi Arabia (IRB log No. 18-166E).

**Patient consent for publication**

Not required.

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**Tables**

Table 1: Budget appropriations for the MOH with respect to government budget (SR = Saudi Riyal).

Table 2: Descriptive statistics of the inputs and outputs of the 91 hospitals.

Table 3: Technical efficiency scores and return to the scale of the public hospitals in KSA.

Table 4 Technical efficiency scores and returns to the scale of the hospitals categorized by location.

Table 5 Slacks evaluation for inefficient hospitals.

**Figures**

Figure 1: Number of hospitals and hospital beds in each capacity and geographical location, 2017.

Figure 2. Distribution of technical efficiency scores of the hospitals on technical (CRS), pure technical (VRS) and scale efficiencies.



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