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For comments

Hospital Efficiency and Data Envelopment Analysis (DEA)

An empirical analysis of district hospitals and grant-in-aid hospitals in Gujarat state of India

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Hospital Efficiency

An empirical analysis of district hospitals and grant-in-aid hospitals in Gujarat state of India

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Abstract

This study focuses on analysing the hospital efficiency of district level government hospitals and grant-in-aid hospitals in Gujarat. The study makes an attempt to provide an overview of the general status of the health care services provided by hospitals in the state of Gujarat in terms of their technical and allocative efficiency. One of the two thrusts behind addressing the issue of efficiency was to take stock of the state of healthcare services (in terms of efficiency) provided by grant-in-aid hospitals and district hospitals in Gujarat. The motivation behind addressing the efficiency issue is to provide empirical analysis of government's policy to provide grants to not-for-profit making institutions which in turn provide hospital care in the state. The study addresses the issue whether grant-in-aid hospitals are relatively more efficient than public hospitals. This comparison between grant-in-aid hospitals and district hospitals in terms of their efficiency has been of interest to many researchers in countries other than India, and no consensus has been reached so far as to which category is more efficient. The relative efficiency of government and not-for-profit sector has been reviewed in this paper. It is expected that the findings of the study would be useful to evaluate this policy and help policy makers to develop benchmarks in providing the grants to such institutions.

1. Introduction and objectives

Given the health-financing situation it has become imperative for health facilities in Gujarat to ensure more efficient means of providing services. In the present scenario, there is very little price competition and little incentive to contain costs and ensure efficiency. However, the budget constraint forces many of these institutions to provide more services for a given level of resources. Under the present circumstances, it is essential to find out the appropriate resource mix and its utilisation. Similarly, it is necessary to identify the sources of relative cost inefficiency – technical and allocative both. The focus of this paper is on assessing the hospitals in technical terms, i.e. the right amount of inputs to produce a given level of output.

Valdmanis (1992) provides summary of arguments on relative efficiency of public hospitals and not-for-profit hospitals. One of the arguments in support of greater efficiency of public hospitals that have been forwarded, is the fact that constraints due to the government's rigid budgetary allocation make sure that public hospitals operate with efficiencies greater than their other counterparts in not-for-profit and for-profit sector (Lindsay 1976). It is hypothesised that for-profit and not-for-profit hospitals operate at lower levels of efficiency due to having access to better resource base (Cowing and Holtman 1983) and less regulation on prices and costs. The expansion of facilities and excessive investments in medical technologies has resulted in creation of excess capacity in many areas (Newhouse 1970, Lee 1971 and Joskow 1980). Though most of the facilities in non-government sector equipped with the latest technologies, the allocative as well as the operative efficiency suffer due to this indiscriminate and excessive use of these resources (Sloan and Steinwald 1980).

There are other arguments as well, which suggest that public hospitals are less efficient because of bureaucratic processes and excessive hierarchical channels in the implementation of cost control measures (Clark 1980). Moreover, the fallback option of government support in financial terms also contributes towards the inefficiencies of public hospitals. In contrast to this, since grant-in-aid hospitals have to maintain financial viability of their enterprises in the absence of government-backed support, they are pushed to maintain efficiencies high enough to maintain allied activities (apart from maintaining financial viability) like charitable programmes, etc., thus resulting in greater operative and allocative efficiencies for non-government facilities.

The other motivation behind this study has been to understand how to address some of the concerns of benchmarking under changing scenario in the health sector. With the opening of private health insurance sector in the post-liberalisation period, the concepts of efficiency with which the resources are used would assume greater significance in the healthcare industry. The need for developing efficiency parameters and criterion, which helps in ranking of hospitals, is likely to assume critical importance. The impending and imperative competition between healthcare service providers and hospitals in the wake of the liberalisation of the insurance sector, necessitates such studies to be undertaken to estimate the state of affairs in terms of efficiency of hospitals, to identify areas needing improvement and sprucing up, so that the hospitals can be competitively placed. The present study suggests an application of data envelopment analysis technique to achieve this purpose. This technique provides an objective criterion to analyse and evaluate efficiency of facilities in relative context. The methodology does not impose criterion from outside but tries to evolve it from within the system.

2. Public Health Sector in Gujarat

Historically Gujarat has been a state with higher mortality and higher fertility than rest of India. For example, IMR in 1970 was 156 while it was 129 for India. Birth rate in Gujarat in 1970 was 41.2 while for India it was 36.8, crude death rate for Gujarat was 18.1 while that of India was 15.7. Over the last three decades Gujarat has made substantial progress in improving health indicators. This is reflected in decline of infant mortality, which is 64 as compared to all-India average of 72. Life expectancy at birth is at 62.8 (female) and 61.5 (male), which are still lower than all-India average of 63.4 (female) and 62.4 (male). Health infrastructure in Gujarat has a network of primary care facilities, secondary and tertiary care institutions, ESIS facilities and institutions in private and not-for-profit sector. Table 1 provides broad indicators of health infrastructure in the state.

Table 1: Public and Private Health infrastructure in Gujarat, 1999

	Number	Per 100000 Population	Beds	Per 100000 Population
Primary Care (Government)				
Sub-Centres	7274	15.15		
PHCs	993	2.07		
Urban FW Centres	106	0.22		
Post-partum units	89	0.19		
Dispensaries	63	0.13		
Mobile units	16	0.03		
Secondary and tertiary (Government)				
Government Hospitals	288	0.89	23625	49.20
General Hospitals – District	25	0.05	5536	11.53
Government Hospitals (Class I and II)	26	0.05	2011	4.19
Community Health Centres	223	0.46	7344	15.30
Mental Hospitals	4	0.01	683	1.42
Specialty Hospitals (Dental and others)	2	0.00	120	0.25
Teaching Hospitals	8	0.02	7931	16.52
ESIS Facilities				
Dispensaries	124		1445	
Hospitals	11			
Private sector (including NGOs)				
Grant-in-aid Institutions (NGOs)	140	0.29	4736	9.87
Hospitals	2152	4.48	32131	76.81
Dispensaries	6824	14.21	9176	19.12
Total			71113	148.15

Besides this there is also network of health facilities that has been specifically created for implementing various national health programmes. In terms of availability of personnel, the Gujarat state has 17738 registered doctors of which about 1/4th are working in the government health facilities. Besides this there are qualified personnel from other systems of medicines as well. These data are given in Table 2.

Table 2: Availability of Health Personnel in Gujarat

Category of Health Personnel	Number
Allopathic Doctors	17738
Government facilities	4265
Non-governmental organisations	5139
Practising privately	8334
Ayurvedic Doctors (Registered)	21033
Homeopath (4619) and Unani (234) (all registered)	4853
Registered Dentists (1 dentist per 39955 population)	1320
Total Doctors (1 doctor per 1068 population)	44944
Registered General Nurses (1 nurse per 3475 population)	13553
Registered ANM (1 ANM per 7776 population)	6057

Source: Basic Health Statistics, Gujarat 1998

In Gujarat there are about 45000 doctors from all systems of medicines. This works out to be about 94 doctors per lakh of population (about one doctor per 1068 persons). As compared to doctors the nurse to population ratio is significantly low (one nurse per 3500 population). The state experiences shortage of nurses. This has implications for delivery of hospital services and efficiency with which these services are delivered.

The total hospital beds work out to be 148 beds per lakh of population or one bed for 675 persons. The number of beds, hospitals and doctors per lakh of population are higher than the all-India average. Besides this there are other health facilities in private sector, which have not been included in above data because of poor systems of registration of private facilities. The Gujarat state is well ahead of rest of India in most indicators related to health infrastructure and facilities.

Health financing in Gujarat

Gujarat state ranks fifth in terms of per capital income and tenth in terms of its population in India. The state's GDP has grown at the rate of 12.6 per cent during 1997-98. Gujarat's economic performance is well above the average of all-India, however, state's public expenditure on health does not show similar pattern. The public health expenditure on health is about 0.87 percent of Gujarat's state GDP. This is lower than the all-India aggregate spending of 1.2 per cent on health sector. Government of Gujarat on average has spent about 0.80 per cent of state net domestic product on health sector during 1990-91 to 1996-97 and this percentage shows declining trend over the period. For example, as compared to 1990-91 this ration has declined by about 0.18 per cent in 1996-97. In terms of budget allocations to health sector, Gujarat ranks 12th in a sample of 15 states included in Table 3. In sum the total budget allocations to health sector are low and declining.

Table 3: Health Expenditure as Percentage of GSDP of the States

	1	2	3	4	5	6	7	Avg	(7) – (1)
States	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97		
Andhra Pradesh	0.94	0.90	0.95	0.96	0.90	0.84	0.95	0.92	0.01
Assam	1.04	1.20	1.05	1.17	1.16	1.23	1.20	1.15	0.16
Bihar	1.03	0.99	1.12	0.99	1.00	1.21	1.04	1.05	0.01
Gujarat	0.90	0.93	0.78	0.80	0.71	0.77	0.72	0.80	-0.18
Haryana	0.60	0.58	0.62	0.60	0.58	0.58	0.55	0.59	-0.05
Karnataka	1.04	0.98	1.09	1.03	1.03	0.98	0.93	1.01	-0.12
Kerala	1.51	1.27	1.15	1.26	1.27	1.32	1.30	1.30	-0.21
Madhya Pradesh	0.90	0.94	0.92	0.91	0.91	0.84	0.87	0.90	-0.04
Maharashtra	0.74	0.72	0.68	0.65	0.61	0.60	0.59	0.66	-0.15
Orissa	1.24	1.12	1.13	1.08	1.06	1.06	1.07	1.11	-0.17
Punjab	0.88	0.79	0.75	0.72	0.64	0.64	0.68	0.73	-0.20
Rajasthan	1.21	1.21	1.23	1.35	1.32	1.33	1.24	1.27	0.03
Tamil Nadu	1.21	1.15	1.14	1.06	1.00	1.03	0.99	1.08	-0.22
Uttar Pradesh	1.12	0.97	1.04	1.16	1.00	1.00	0.99	1.04	-0.13
West Bengal	1.24	0.96	0.99	1.02	0.88	0.90	0.90	0.98	-0.34

Source: Selvaraju (2000)

The annual budget of the government of Gujarat on health is Rs. 10.23 billion. This is 4.59 per cent of total state expenditure and 8.84 per cent of developmental expenditure. Table 4 provides health-financing information of government of Gujarat.

Table 4: Gujarat state expenditures on health sector (Rs. in crores)

	Net state domestic product	State government expenditure	Development expenditure	Medical and public health
1993-94	39190	8407.88	4967.34	366.32
1994-95	52013	9497.73	5221.72	414.57
1995-96	57861	10810.58	6133.51	470.83
1996-97	66883	12575.9	6914.89	522.93
1997-98	75335	15126.14	8416.46	639.73
1998-99	NA	19256.16	10785.81	877.17
1999-00	NA	22265.95	11563.93	1022.78

Source: Government of Gujarat budget documents

Medical and public health as per cent of

	Net state domestic product	State government expenditure	Development expenditure
1993-94	0.93	4.36	7.37
1994-95	0.80	4.36	7.94
1995-96	0.81	4.36	7.68
1996-97	0.78	4.16	7.56
1997-98	0.85	4.23	7.60
1998-99	NA	4.56	8.13
1999-00	NA	4.59	8.84

Source: Government of Gujarat budget documents

Public hospitals in Gujarat

The annual medical and public health budget of the Government of Gujarat is to the tune of Rs. 10.23 billion (year 1999-00). Of this the state spends about 25 per cent on hospitals and dispensaries. Given the declining budget allocations to the health sector in Gujarat the efficient use of existing resources assumes critical significance. The utilisation data of 57 public hospitals (this excludes CHCs) indicate that on an average each hospital gets about 413 OPD patients per day and admits 3 in-door patients each day. On an average each hospital carries about 12 X-rays, 136 laboratory tests each day and does about 300 major and minor operations per day. About 9727 people are directly employed in these hospitals of which 452 are full-time doctors.

Table 5: Health services provided by public hospitals in Gujarat

Number of Hospitals	57
Total number of beds	8492
Outdoor patients treated (per day)	23567
Indoor patients treated (per day)	3972
X-Rays taken for patients (per annum)	208501
Laboratory Tests (per annum)	2327277
Operations (per annum): Major	48136
	58108
Minor	
ECG (per annum)	30227
MLC (per annum)	65663
Blood Transfusion (per annum)	13940
Post Mortem (per annum)	6624
Ambulance call services (per annum)	21063
Emergency Care Centre services given to (number)	5291
Accident cases (per annum)	431

Source: Overview of Health services of Gujarat State – February 2000

3. Grant-in-aid Institutions in Health Sector in Gujarat

As compared to other states in India, Gujarat has significant presence of not-for-profit institutions in the health sector. The reach of many of these not-for-profit institutions in health in serving the community and addressing their health needs is quite impressive. Government of Gujarat encourages setting up grant-in-aid institutions and hospitals. Under this scheme, the government recognises not-for-profit institutions in health sector as grant-in-aid institutions and provides revenue grants to them to meet their operating costs. These institutions have also the flexibility to generate their own resources through user fees and donations. The government has developed a set of guidelines on this. The institutions, which are eligible for these grants, must be a not-for-profit institution and should be registered under the Societies Registration Act. These institutions can deliver services as a hospital or a dispensary for OPD or a blood bank or any other specialty service. However, the availability of grants is subject to budget allocations in the state budget.

The broad policy guidelines of the government with respect to these institutions are as follows:

Rules for providing grants	
Gram Panchayat	75 per cent of budget or the real deficit whichever is less
City (Nagarpalika)	70 per cent of budget or the real deficit whichever is less
Municipal Area	60 per cent of budget or the real deficit whichever is less

Chief Medical Officer at district level approves the budget of these institutions. He also monitors the performance of these facilities. These institutions are required to give 30 to 40 per cent of free care to poor patients.

There are about 139 grant-in-aid health facilities having bed capacity of 4736 in Gujarat. The government allocates about Rs. 250 million to all these institutions. During 1998-99 the budget allocations to hospitals and dispensaries in Gujarat was to the tune of Rs. 2090 million. The grant-in-aid budget constitutes about 17 per cent of total hospitals and dispensaries and about 2.5 per cent of total health and family welfare budget of the state. The budget allocation to these institutions increased by about 27 per cent during the current year. The government of Gujarat does not receive any support from central government on account of this budget head. The district-wise details of these institutions are provided in Appendix 1.

Grant-in-aid institutions have complete autonomy in recruitment, procuring of supplies and capital investment decisions. Most of the decisions are through the executive committee and in consultation with the governing board. The improvement in performance and efficiency of these facilities is important considerations in these decisions. The personnel in these institutions are not transferable and this ensures continuity and certainty in their positions. The user fees is one important source of finances. These institutions can raise funds through donations and grants from community and other non-governmental organisations including private sector and industry. This gives them much better financial flexibility.

These institutions also do have policy to provide free care to people who cannot afford to pay. However, this is restricted to a certain percent of hospital utilisation. From examining the geographic distribution of these institutions one can observe that most of these institutions are located in better-off regions of the State.

4. Methodology

The study of district hospitals and grant-in-aid hospitals comprised of several stages in which a step-by-step move towards data collection and data analysis took place. The various stages or steps involved in conducting this research are outlined in Figure 1 appended below.

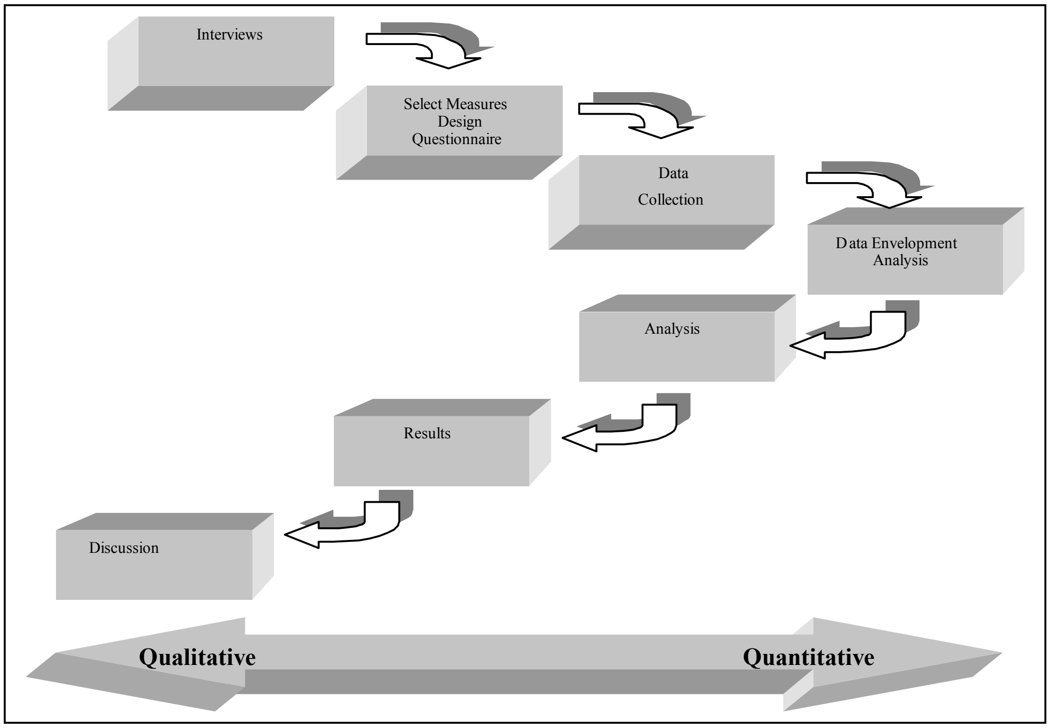


Figure 1: Steps involved in study of hospitals

In the first stage, hospitals were identified which would form the sample for this study. The sample for this study consisted of hospitals in the state of Gujarat only, as the health sector in India is under the effective control of the state government. However, the most important reason of basing the study in one state is to control for extraneous factors like different regulation criteria and rules existing in different states in India (as the health sector is state subject). District hospitals and Grant-in-aid hospitals with bed strength of more than 50 were selected in the state of Gujarat and the respective authorities of these hospitals were approached for a preliminary briefing as well as preliminary interviews to identify parameters to be measured about the study to be conducted.

In the next stage (which can be considered to be a parallel process) a detailed questionnaire was prepared using the input of measures from the preliminary interviews with the hospital authorities in as much detail as possible. The different sections of the questionnaire (a copy of questionnaire can be requested from authors) broadly being:

- infrastructure and physical facilities
- type of services provided, staffing
- utilisation of services
- availability of drugs, supplies and equipment
- expenditure and revenue
- management indicators

In all 41 hospitals (20 district hospitals and 21 grant-in-aid hospitals) responded to our questionnaire. The description code of these hospitals is given in Appendix 2. The next stage consisted of employing field investigators to collect the data under close supervision, and the input of the data collected in prescribed format, to prepare for the next and most crucial stage of data analysis.

Sample

A total of 21 district hospitals and 21 grant-in-aid institutions from all 6 regions in Gujarat were surveyed. There is representation of at least one hospital from each region. The overall summary of the sample is as follows:

	Total in Gujarat	Sample
District Hospitals	25	20
District Hospital Beds	5536	4053
Grant-in-aid Institutions	139	21
Grant-in-aid Hospital Beds	4736	2556

For the study of grant-in-aid institutions, it was decided to select institutions having bed strength of more than 50. Using this criterion, 36 institutions were identified of which 21 institutions responded. Grant-in-aid institutions include different levels of facilities such dispensaries, clinics, small hospitals and large hospitals. Total bed strength of these 21 institutions covered under this study is 2556. Eleven grant-in-aid facilities are at the taluka level, 7 at the village level and 3 facilities were at the district level. Of the 21 facilities, 15 were general hospitals, 2 eye hospitals, 2 gynaecology and surgical hospitals, 1 paediatric and 1 maternity and dispensary. Thirty-two per cent of grant-in-aid facilities cater to population between 50 thousand and above, 19 per cent of these facilities cater to population of more than 5 lakh, 2 per cent of facilities served population of less than 25000.

Data Envelopment Analysis

The study uses DEA (Data Envelopment Analysis) [Annexure-1 *Methodology on the Data Envelopment Analysis*] approach to analyse the data. In light of the points made in the background for this paper, it was essential to use a methodology that could assess and compare efficiency between these two categories of hospitals. Or, in other words, the tool used for the analysis should be compatible for both categories. This is where the use of DEA became imperative.

The other reason for use of DEA as an analysis tool was the flexibility of DEA in handling multiple input and output measures, which was required essentially in this study.

On the flip side, however, it has been found that researchers have been reluctant to use DEA as an analysis tool since it lacks a crucial error term (Valdmanis 1992). However, in DEA the selection of functional form is not the main consideration but to choose the right input and output variables since the model is non-parametric and derives the input-output production correspondence using linear programming techniques. The DEA technique has been discussed in detail in the section on Methodology Notes of this Journal.

5. Data and variables

For the purpose of analysis, the study developed and defined several variables from the primary data collected. The variables were of three types: input, output and explanatory variables. The different variables collated are identified in Table 6.

Table 6: Variable and their definitions

Variable	Type	Code	Description	Units
Input	Capital	PHY	Physical infrastructure	Index (0-1)
Input	Capital	EQPT	Equipments index	Index (0-1)
Input	Capital	Bed	Number of beds	Numbers
Input	Capital	DRUG	Expenditure on drugs (Rs. 00,000)	Expenses
Input	Capital	MAINT	Maintenance expenditure (Rs. lakhs)	Expenses
Input	Technology	ADV	Specialized infrastructure	Number
Input	Technology	EQADV	Specialized equipments	Numbers
Input	Staff	OPDW	OPD hours per week	Hours
Input	Staff	LABW	Laboratory hours per week	Hours
Input	Staff	DOC	Doctors	Numbers
Input	Staff	NURS	Nursing staff	Numbers
Input	Staff	PARA	Paramedical staff	Numbers
Input	Staff	ADMN	Administrative staff	Numbers
Input	Staff	NTECH	Non technical staff	Numbers
Output		ML	Medico legal cases	Cases treated
Output		LAB	Laboratory cases	Cases Treated
Output		IP	In patients	Cases Treated
Output		OPD	Out-patient cases	Cases Treated
Output		MCA	Maternal and child health cases	Cases Treated
Explanatory		PHC	Preventive health care	Index (0-1)
Explanatory		MCH	Maternal and child health care	Index (0-1)
Explanatory		MEDCR	Curative medical service	Index (0-1)
Explanatory		CDP	Communicable disease services	Index (0-1)
Explanatory		NCD	Non-communicable disease services	Index (0-1)
Explanatory		LABI	Staff per 100 beds	Number
Explanatory		HTI	High-tech equipment per 100 beds	Number

In the present study several variables have been measured using construction of index. An index is devised to measure in binary terms (0 for the non-availability and 1 for the availability) the presence or the absence of the different health care services provided (or equipments) out of a standard list of services (or equipments), where each service (or equipment) in the list of standard services (or equipments) carries equal weightage. The summation of the binary data for every hospital is then reduced to a decimal representation (the index) between 0 and 1, representing the ratio of the number of services (or equipments) provided by a particular hospital to total number of standard healthcare services (or equipments) that were required to be provided or available.

Input variables

The input variables are broadly classified into capital, labour and technological input. The degree of disaggregation within these categories depended on the homogeneity of an input category, the quality of data within which to measure this input. Fourteen variables were defined to measure input variable, common to all hospitals. The level of aggregation or disaggregation of each head (staff, capital or technology) depended on the information available. For example, the input variable of 'staff' could consist of total staff strength of a particular hospital. The break-up of the total staff strength in terms of the number of doctors, number of nurses, etc., were available, the input variable of total staff strength, under the head of 'staff input' was disaggregated as per information available into number of doctors, nurses, paramedical staff, administrative staff and others.

The essential physical infrastructure like OPD, consultation room, ward etc. are measured by creating an index to assess the presence and the absence of the *standard* items of infrastructure (the list included in the questionnaire was arrived in consultation with the technical personnel and pilot study). It is assumed that hospitals build up the required infrastructure according to the size of population they are catering to. In a similar fashion the index for basic equipments like stethoscope, spatula, etc. is created by considering the ratio of equipments, which are functional, to the total number of equipments available at that particular hospital. This ratio is further reduced to a fraction of the total number of equipments that are available in the standard list of equipments. It is assumed that the hospitals procures these required equipments according to the scale of operation but non-functional equipments lead to inefficiency as the potential of the infrastructure is under utilised, leading to low capacity utilisation, and therefore lower efficiency.

In order to measure the level of technological (advancement) tuning of the hospital the study considered the availability of high-tech equipments. The same has been done for measuring the level of infrastructure utilised by adding the number of special infrastructure facilities available in hospitals. The assumption underlying this index is that all hospitals included in this study are homogeneous in certain infrastructure and technological standards as they operate at same level.

Two measures of the capital input were available, a measure based on the number of beds per hospital and the expenditure on the maintenance of equipments, machinery, vehicles, infrastructure etc. to measure the quantity of capital investment. In order to measure the quality of service investment on essential drugs and the availability of stock of these drugs is used. Beds are often used to proxy for capital stock in hospital studies usually because a reliable measure of the value of assets is not available.

Staff inputs were measured by total time devoted for attending patients and the total manpower employed for attending the patients. The staff involvement is measured by the number of hours devoted to OPD and laboratory facilities. The disaggregated measure of staff is used by using the number of staff of each type deployed. This measure included salaried medical officers, which also include visiting medical officers with 50 per cent weightage as data on the hours worked or days worked by visiting medical officers were not available. So the contribution by these officers is considered as 50 per cent compared to that of salaried staff under assumption that they are invited for special services. Although it is possible to aggregate the staff measure but it is not done as it will help us in identifying the resource combination. For example, if we have two hospitals with different efficiencies and same total staff strength, then it should be possible to find various staff distribution to obtain right mix of staff in a hospital. Generally, it is argued that because of no-availability of particular type of staff the efficiency of operations of a hospital are below desired results. Analysis, which includes lower levels of aggregation in measuring staff inputs, could be developed using DEA approach. For this analysis, variables representing the inputs of medical doctors, nursing staff and other staff are used in analysis.

Output variables

Hospitals provide three major services: outpatient services, in-patient and laboratory services. Given this homogeneity in types of services provided, the number of cases treated/handled under each category was chosen as a representative measure of the three output variables. We also included the medico-legal cases as one of the output variables since this was assumed to have significant implications for the use of resources. Other variable such as number of maternal and child health cases handled was also included as one of the output variable. However, the sensitivity analysis results suggested that these variables did not influence the resource use in any significant manner.

Selection of variables

Once the various measures (or variables) and the measurement scales for input and output were derived from the data, the next step involved identifying the relevant input and output variables, which contribute towards explaining the right input and output measures of the hospital. To identify these relevant variables, a series of stepwise regressions were performed to identify the relation between these variables. The input variables, for which the co-efficient of regression (when regressed with any of the three output measures) turned out to be not significant after regression, were excluded from the final model. This step resulted in the elimination of the output variables of medico-legal cases and attendance at the maternal and child healthcare services, and the exclusion of the input variables like availability of basic essential drugs.

The explanatory variables consist of two types of variables: quantitative and qualitative. The quantitative variables are explained first.

Preventive Health Care service is measured by deriving an index for preventive health care services provided by the hospitals by equally weighing the presence and absence of the various standard services provided by the hospitals. It was hypothesised that this would help explaining variance of the number of cases treated. For this purpose an index was devised and the value of this index of the service ranges between 0 and 1. Similar indices are derived for the Maternal and Child Health care services and curative medical services. These indices, when regressed against the data for OPD cases and In-Patient cases, help explain the variance and correlation if any between these services and the OPD and In-Patient activities.

Assuming that a particular hospital participates in a national communicable and/or non-communicable disease programme if there is a felt need in the region in which the hospital is located, the participation (derived by using an index similar to the one used for the Preventive Health Care Services) in the communicable and non-communicable diseases program is another explanatory variable used to explain the general health of the region.

All the explanatory variables discussed above help us in measuring the various services provided in quantitative terms. In order to measure the quality of services, staff intensity index is created by measuring the staff (total staff strength) deployed per 100 beds.

Similarly, the technology factor is generated to identify technology advancement by the number of high tech (high priced) equipments deployed per 100 beds. This is under the assumption that the hospital procures the required high tech instruments in right proportion according to the regional requirement.

The model was run for the various input-output combinations as shown in Table 7. The model specifications were changed depending upon the correlation coefficients of the variables classified in input and the output by performing the stepwise regression. The specifications were altered and the scales redesigned to accommodate for the right measure of the various dimensions to be measured. For example, the index developed for the availability of the essential drugs by weighing the availability of drugs to the list of essential drugs was replaced by the expenditures on the drugs per annum. The results used in the final reporting are the ones enlisted in the specification 8. One can observe that the specification 7 is totally nested in the specification 8 where the only change is in the usage of the OPD and LAB working hours per week. Which resulted into a small difference in the efficiency of the inefficient firms whereas the one on the efficient firm continues to remain the same. The basis of the changing the specification was more driven by the behaviour of the efficient firms leaving efficient frontier and the firms joining the envelope.

Table 7: Model Specification

Variable	1	2	3	4	5	6	7	8
IP	O	O	O	O	O	O	O	O
LAB	O	O	O	O	O	O	O	O
MCA	O	O	X	X	X	X	X	X
ML	O	O	O	O	O	X	X	X
OPD	O	O	O	O	O	O	O	O
ADMN	I	I	X	X	I	I	I	I
ADV	X	X	X	I	I	I	I	I
Bed	I	I	I	I	I	I	I	I
DOC	I	I	I	I	I	I	I	I
DRUG	I	I	I	I	I	I	I	I
EQADV	X	X	X	I	I	I	I	I
EQPT	I	I	I	I	I	I	I	I
LABW	I	X	X	I	I	X	X	I
MAINT	I	I	I	I	I	I	I	I
MCH	I	I	X	E	X	X	X	X
NTECH	I	I	X	I	I	I	I	I
NURS	I	I	I	I	I	I	I	I
OPDW	I	X	X	I	I	X	X	I
PARA	I	I	X	I	I	I	I	I
PHY	I	I	I	I	I	I	I	I
CDP	I	X	X	X	X	E	X	X
HTI	X	X	X	X	X	X	E	E
LABI	X	X	X	X	X	X	E	E
MEDCR	I	I	X	I	X	E	X	E
NCD	I	X	X	X	X	E	X	X
PHC	I	I	X	I	X	I	X	X

I; input variable; O: output variable; X: not considered;
E: explanatory variable,

6. Analysis and results

A DEA model was run after feeding the input and output variables into the programme. The hospitals were clustered into two types: District Hospitals (DH) and Grant-in-aid hospitals (GH) and fed into the model for analysis of technical and allocative efficiency. The DEA programme used for the analysis uses the methods based on the work of Fare, Grosskopf and Lovell (1994).

There are two principle options available in the computer programme. The first involved the constant returns to scale (CRS) and variable returns to scale (VRS) models. As these hospitals cater to a similar kind of population and operate at same level, only CRS model was employed. No scale efficiencies were considered. Since no information was available on cost of inputs cost efficiency measures were not employed. The other option of the Malmquist DEA model was not employed, as it required time-series data, which was not available in this case. DEA was performed with both "input orientation" and "output orientation". In this case, the "input orientation" was used, as the requirements were to identify the inefficiencies in the usage of the various input resources of the hospitals under study.

However, the efficiency scores that were generated in this method were relative in nature. Therefore, there was a felt need to identify a common scale for measuring the efficiencies of the two different categories, and whether the efficiencies were significantly different or not when measured relative to a common scale. Thus, in addition to the above, these hospitals were spooled and their efficiencies measured to construct this common scale for comparing the efficiencies of the two categories independently. The Mann-Whitney Test (Rank Sum Test) was performed to determine whether the DH and GH had significantly different performances.

The results would be discussed in three different sections, dealing with the results for the district hospitals (DH), grant-in-aid (GH) hospitals and the spooled hospitals, to elucidate the status of the DH and the GH; and to explain how significantly different the DH and GH are in terms of their efficiencies in performance.

The technical efficiency for all the three types of analysis are given as under:

Table 8: Summary of efficiency

Hospital Type	Mean Efficiency	Std. Dev.	Max	Min	100% Efficiency
Government	0.85	0.203	1.00	0.416	0.50
Grant-in-aid	0.89	0.204	1.00	0.260	0.66
Spool	0.73	0.291	1.00	0.130	0.61

The efficiency score of 0.85 for DH indicates that on an average the hospitals could increase the output using the same level of resources or reduce the input usage or input costs by 15 per cent to deliver the same amount of health care. Only 50 per cent of DHs are able to efficiently use their resources. An interesting observation evident from the table is the lower efficiency score for the spooled data as compared to the DH and GH considered separately. The explanation for this observation is available in the discussions on the results for the spooled data.

The Mann Whitney (Rank Sum test) Test clearly demonstrated that the DHs and GHs were statistically significantly different at 5 per cent level of significance from each other. This suggests that these two sets of hospitals performed differently. The summary statistics of the test is provided in following table.

Number of District Hospitals (DH)	20
Number of Grant-in-aid Hospitals (GH)	21
DH (rank sum)	502
GIA (rank sum)	359
U- statistics	128
μ_Y	210
σ_Y	38.34
Z statistics (left tail)	-2.14
Z statistics (right tail)	+2.14
Alpha value	0.0132

The difference in the various measures between spooled data clearly indicates significant differences in the difference in the resources employed and the cost structures of DH and GH.

District Hospitals

The technical efficiency scores indicate, which of the hospitals are on the efficient (best practice) frontier (those with a score of one), and which are less efficient relative to hospitals on the frontier (those with scores less than one). The higher the score, the higher the potential increase in output (while maintaining inputs) relative to best practice. The various statistics for the input and output variables for the PHCs is given in Table 9.

Table 9: Descriptive statistics of variables for government hospitals

PHC	Mean	Median	Standard Deviation	Kurtosis	Skewness	Minimum	Maximum
LAB	113395	47241	196005	7	3	14172	736634
IP	33458	19947	32572	1	1	3603	119615
OPD	200574	166121	126885	7	2	68833	640302
PHY	0.78	0.77	0.09	-0.68	-0.02	0.64	0.95
SPL	6.75	6.00	3.09	-1.02	0.41	2.00	12.00
EQPT	0.82	0.87	0.19	4.85	-2.07	0.21	1.00
EQADV	54.05	50.00	25.31	-0.43	0.09	6.00	100.00
OPDW	35.65	36.00	3.59	1.57	0.72	28.00	44.00
LABW	91.70	46.00	64.48	-2.00	0.39	28.00	168.00
Bed	202.75	203.50	98.80	2.19	0.96	56.00	484.00
DOC	24.10	25.50	12.07	2.06	1.19	9.00	58.00
NURS	44.90	45.00	22.48	2.31	1.12	16.00	110.00
PARA	12.20	10.00	5.65	-1.13	0.47	5.00	23.00
ADMN	10.10	10.50	3.74	-0.69	0.07	3.00	17.00
NTECH	56.30	56.00	26.96	-1.14	0.07	17.00	103.00
DRUG	207.58	147.90	185.67	4.48	1.96	10.74	790.40
MAINT	36.39	16.85	52.82	11.60	3.20	1.10	236.88

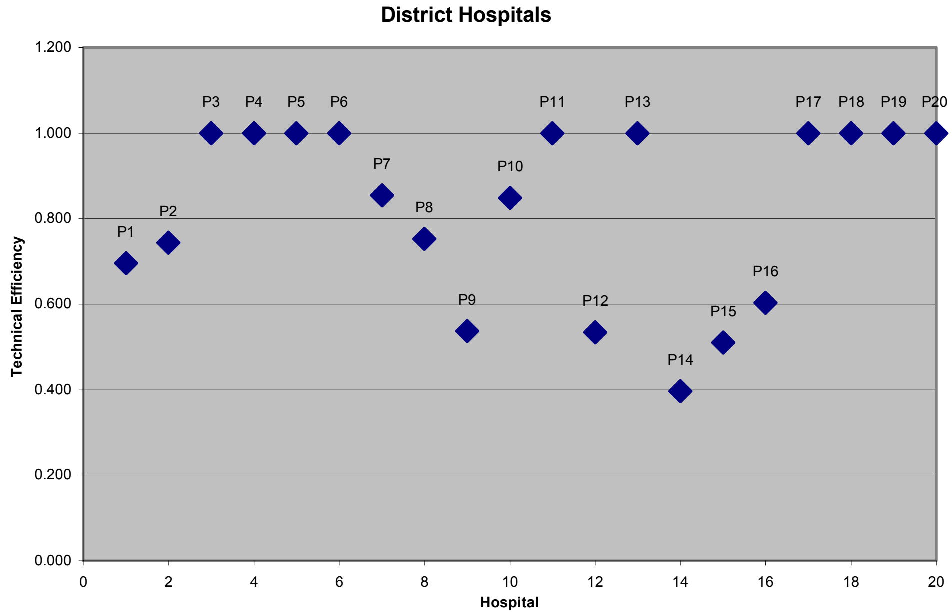


Figure 2

Technical efficiency scores only refer to relative performance *within* the sample. Hospitals given an efficiency score of one are efficient relative to all other hospitals in the sample, but may not be efficient by some absolute or world standard necessarily. The plot for the individual technical efficiency scores has been plotted in Figure 2. The labels of the hospitals are given against the data scatters. Fifty percent of the hospitals were operating on the efficient frontier. Sixty percent of the units achieved efficiency scores of greater than 80 per cent — that is, they may be able to reduce inputs by up to 20 per cent while maintaining the same number of completed treatments if they operate at what appears to be best practice. Five of the hospitals, especially those from the not-so-urbanised areas, were found to be in the band of 40 per cent to 60 per cent efficiency. This may be more so because of the comparatively lesser population catered to by these hospitals.

The allocative inefficiency of the hospitals on the efficient frontier is 0 by the basic definition. Of the 10 inefficient hospitals, 4 hospitals were found to be inefficient on 2 inputs, another 4 on 3 inputs and the other 2 on 4 inputs. Of the 10 inefficient hospitals, the allocative inefficiency mostly arose from physical infrastructure, equipment, doctors & nurses and administrative staff, whereas very few hospitals were found to be allocatively inefficient on their expenditure on maintenance and essential drug strength of paramedical and non-technical staff. In the absence of cost information detailed analysis for allocative efficiency was not possible.

Table 10: Descriptive statistics of variables for grant-in-aid hospitals

	Mean	Median	Standard Deviation	Kurtosis	Skewness	Minimum	Maximum
LAB	18157.9	9482.5	20882.6	1.211685	1.45491	573	69511
IP	6366.05	3608.5	8201.176	7.672684	2.633038	784	34994
OPD	43192.05	32807	30114.02	0.424677	0.96071	12198	119621
PHY	0.563636	0.568182	0.184431	-0.53204	-0.01282	0.227273	0.909091
ADV	4.9	4	3.127131	-0.33052	0.710933	1	12
EQPT	0.839853	0.882353	0.172682	2.194057	-1.48915	0.352941	1
EQADV	30.05	21.5	26.03939	-0.44336	0.94208	3	83
Bed	95.2	74.5	49.60115	-0.61897	0.771314	40	200
DOC	15.625	13	12.85432	1.8835	1.48033	2	48.5
NURS	14.8	10.5	14.84162	3.149251	1.760374	1	59
PARA	5.25	4.25	3.98847	3.055594	1.724021	1	17
ADMN	8.1	6	7.087053	2.76299	1.785271	1	27
NTECH	24.65	23.5	16.65762	-0.26338	0.771748	5	60
DRUG	156.9882	52.15845	220.6206	2.665982	1.925188	2.4764	758.2609
MAINT	33.46342	23.3527	36.62552	4.031113	1.798229	1.9177	148.2

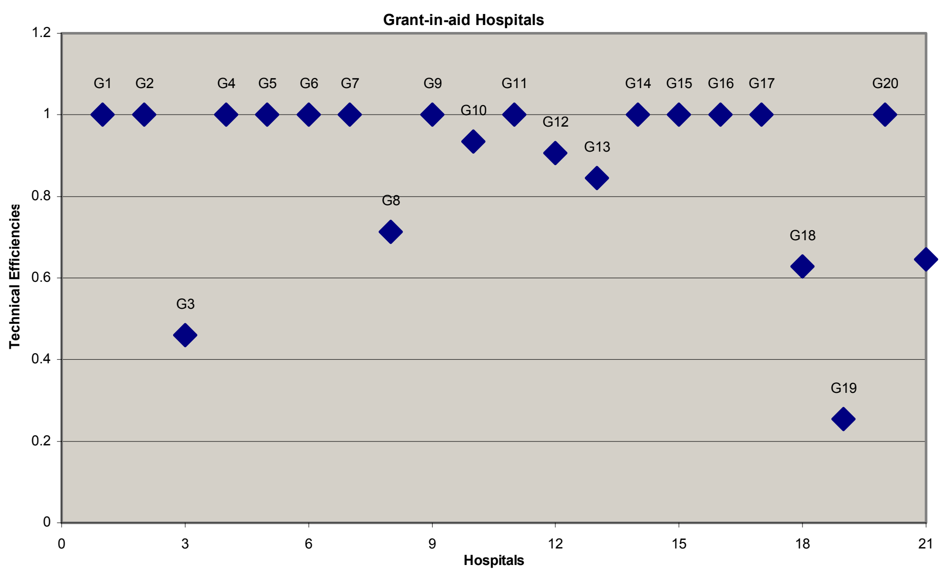
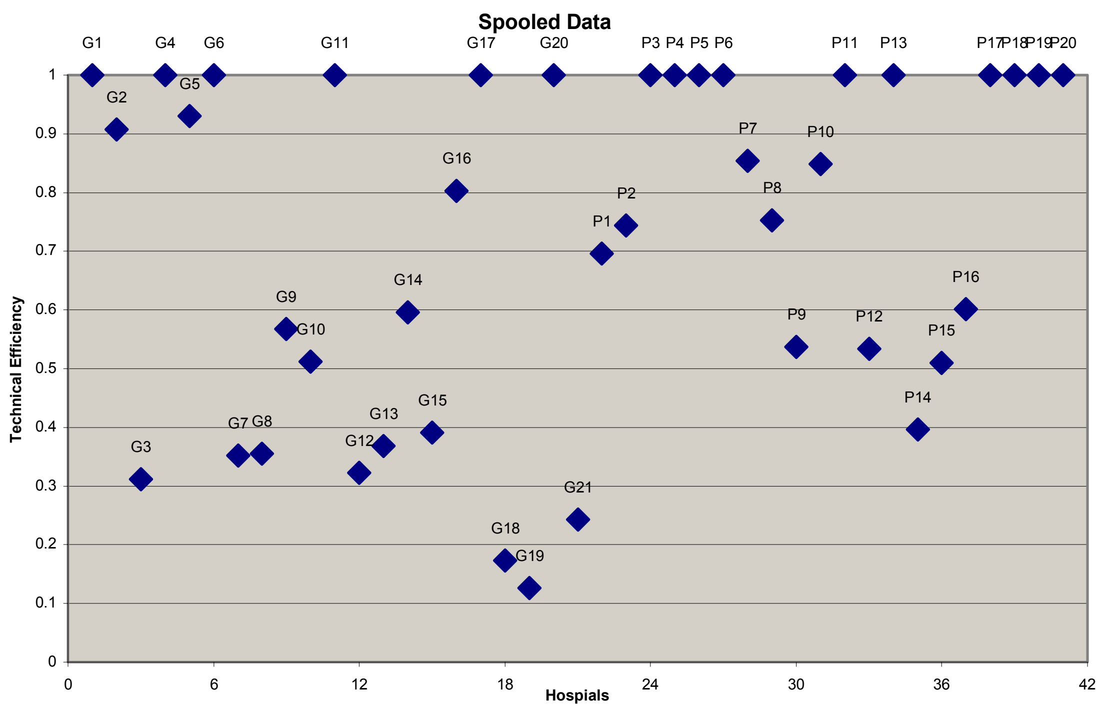


Figure 3

Of 21 GHs, 13 were found to be operating on the efficient frontier, and three were marginally in the 80 per cent to 100 per cent efficiency band. It is therefore clear that the relative efficiencies of the GHs among themselves is better then that of the DHs. Three hospitals are in the 60 per cent to 80 per cent band, while one each is in the 40 per cent to 60 per cent band, and the 20 per cent to 40 per cent band. In this analysis it is possible to figure out less efficient hospitals. The allocative inefficiency mainly arose from the staffing, expenditure on maintenance and deployment on advance equipments.

Table 11: Descriptive statistics of spooled data

	Mean	Median	Standard Deviation	Kurtosis	Skewness	Minimum	Maximum
LAB	64547.63	27483	144170.4	15.88911	3.984207	573	736634
IP	19596.46	8408	26897.15	4.837723	2.211547	784	119615
OPD	119913.9	79456	120122.3	7.769224	2.31272	12198	640302
PHY	0.67184	0.727273	0.177945	0.029134	-0.75735	0.227273	0.954545
ADV	5.804878	5	3.171904	-0.71247	0.489099	1	12
EQPT	0.834553	0.882353	0.178654	3.45905	-1.80153	0.214052	1
EQADV	42.19512	41	27.77159	-0.93226	0.33243	3	100
Bed	150.2195	137	93.59955	2.456472	1.240602	40	484
DOC	19.62195	16	12.95993	1.01159	1.069385	2	58
NURS	29.63415	22	23.93821	1.500247	1.099251	1	110
PARA	8.878049	7	5.980991	-0.49856	0.748964	1	23
ADMN	9.097561	8	5.612731	2.38213	1.319428	1	27
NTECH	40.56098	33.5	26.97851	-0.51056	0.646797	5	103
DRUG	181.2294	107.9	200.4519	2.696491	1.803932	2.4764	790.4
MAINT	38.22068	17.7	49.08826	6.960479	2.487717	1.1	236.8761



The spooling of hospitals helps us in analysing the hospitals of different category by subjecting them to same scale of measurement for inputs and outputs. In case of the spooled data we observe that the hospitals on the efficient frontier when analysed as clusters of DHs and GHs continue to remain same and there aren't any new entrants on the new frontier. But, many of the hospitals on the efficient frontier in GHs left the frontier when spooled with DHs. However, there is no effect on the DHs. The reason behind this is found to be the excessive usage of the advanced equipment, physical infrastructure and high maintenance costs. This shows that the GHs are better equipped in terms of high tech infrastructure but cater to less outputs. This may have implications for quality of service. The DEA analysis presented in this study has used some variables, which capture the quality of services. For example, the number of hours spent on various outputs, availability of physical infrastructure and spending on maintenance. In two cases the GHs performed in the band of 20 per cent efficiency. In the band of 20-40 per cent efficiency there are 6 GHs.

7. Summary and conclusion

This study uses DEA approach to analyse efficiency of district and grant-in-aid hospitals. The findings suggest that the efficiency variations are significant within district hospitals than within the grant-in-aid institutions. The overall efficiency levels of grant-in-aid institutions are higher than the district level hospitals. The grant-in-institutions are relatively more efficient than the public hospitals. These differences are statistically significant.

The study made an attempt to find whether location determines the efficiency levels of hospitals. For example, it may be argued that hospitals in remote areas, less dense or less urbanised areas would be relatively serving lesser population and therefore would be relatively less efficient. The mean difference of urban population and density of districts between less efficient hospitals and relatively efficient hospitals were not significantly different statistically. The location and bed size information of less efficient hospitals of district and grant-in-aid hospitals is provided in following tables.

District Hospitals

Location	Total Bed Size	Population Served
Ahmedabad	56	25000-50000
Kheda	110	Below 25000
Sabarkantha	250	50000-100000
Mehsana	293	100000-250000
Patan	175	100000-250000
Panchmahal	260	100000-250000
Bharuch	260	250000-500000
Navsari	240	100000-250000
Dangs	200	100000-250000
Valsad	156	100000-250000

Grant-in-aid Hospitals

Location	Beds	Level	Population served
Ahmedabad	50	Taluka	25000-50000
Gandhinagar	150	Village	50000-100000
Gandhinagar	126	Village	Below 25000
Vadodara	135	District	Over 500000
Vadodara	92	Village	50000-100000
Surat	200	Taluka	100000-250000
Surat	70	Taluka	Below 25000

Population served by these hospitals is as indicated by the hospital superintendents in questionnaire. One can observe that less efficient hospitals as identified by DEA analysis are not located in one specific area. Most of the hospitals come from better-off districts. The hospital sizes also vary. The level of efficiency is not clustered for a particular size group.

The following table indicates the resources deployed by all district hospitals and less efficient hospitals.

	All DHs	Less Efficient DHs	%
Total Expenditure (Rs. Crore)	42.42	19.98	47
Total Hospital Beds	4053	2000	49
Number of Wards	140	58	41
Operating Theatre	48	26	54
Intensive care unit beds	35	24	69
No. of Ambulances	52	27	52
Other Vehicles	17	10	59
Total OPD cases	3909515	1448435	37
Total Medical cases	632264	195495	31
Laboratory	1653158	415703	25
Inpatient admissions	669160	153007	23
Total staff strength	2715	877	32
Total Doctors (Allopathic)	455	228	50
Total Doctors (ISM)	14	1	7

The methodology used in this paper helps to identify the facilities, which can improve their performance. In past the monitoring and evaluation of these institutions have remained an important issue. The government through decentralised set-up and through the district level health authorities monitors these institutions. The role of government is quite critical in ensuring that these grants are used effectively. This will require developing performance-based indicators to monitor these grants. The methodology suggested in this paper helps us to identify relatively less efficient hospitals. The amount of resources used by all grant-in-aid institutions and less efficient institutions are shown in the following table.

	All GHs	Less Efficient GHs	Percentage
Total Expenditure	118180774	68867063	58
Government Grants	91347076	53931646	59
Other sources	26833698	14935417	56
Total number of hospital beds	2104	823	39
Number of paid hospital beds	849	466	55
Number of free hospital beds	467	195	42
Total staff strength	1531	726	47
Total Doctors (Allopathic)	376	205	55
Total Doctors (ISM)	17	13	76
Number of wards	169	52	31
Number of operating theatres	41	14	34
Number of ICU Beds	41	18	44
Number of Ambulances	22	9	41
Number of vehicles	8	0	0
Total OPD cases	1116963	241428	22
Total Medical cases	145624	48843	34
Laboratory	211187	54041	26
Inpatient Admissions	125402	42558	34

The methodology suggested in this paper can be used by the Department of Health and Family Welfare to develop benchmarks for monitoring and evaluating the performance of both district and grant-in-aid instructions. Based on the findings the steps can be initiated to improve the efficiency of resource use in hospitals.

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Exhibit 1: District-wise and speciality-wise Grant-in-aid Hospitals in Gujarat

District	Number of institutions	Total beds	Total employees	Total grant given	Per bed grant	Per employee grant
Ahmedabad	23	1692	2714	168118542	99361	61945
Gandhinagar	3	120	55	3464667	28872	62994
Vadodara	8	205	121	7736194	37738	63935
Panchmahal	7	119	68	1599045	13437	23515
Banaskantha	7	244	143	5337006	21873	37322
Rajkot	7	99	120	997792	10079	8315
Bhavnagar	5	250	174	6277658	25111	36078
Surendranagar	9	110	82	1489478	13541	18164
Amreli	3	67	46	2052121	30629	44611
Kutch	6	64	8	274517	4289	34315
Surat	9	356	393	14078127	39545	35822
Valsad	5	99	97	1888242	19073	19466
Sabarkantha	9	470	217	10189568	21680	46957
Kheda	14	1012	772	12781683	12630	16557
Bharuch	9	402	259	7821236	19456	30198
Mehasana	11	310	194	8247130	26604	42511
Total	139	5619	5466	252353006	252364230	582706

Source: Overview of Health Services of Gujarat State - February 2000

Type	Type	Beds	Employees	Grant	Per Bed
Blood Banks	3	na	na	1213864	na
Cancer	3	509	1086	161941549	318156
Children's	2	90	58	2614993	29055
Clinic	18	61	69	1176530	19287
Dispensary	18	71	74	2225990	31352
Eye	13	454	152	6968567	15349
General	29	1299	669	29526594	34209
Hospitals	35	2919	3180	41690658	14283
Maternity	8	204	140	3772445	18492
Medical Council	1	na	na	na	na
Mental	1	0	29	940000	na
Orthopaedic	3	12	6	231118	19260
Physiotherapy	1	na	na	50698	na
Red Cross	3	na	3	na	na

Exhibit 2: Item code for each of the sample hospitals used in the study

Code	District Hospital Location	Code	Grant-in-aid Hospital Location
P1	Ahmedabad	G1	Ahmedabad
P2	Kheda	G2	Ahmedabad
P3	Surendranagar	G3	Ahmedabad
P4	Surendranagar	G4	Gandhinagar
P5	Gandhinagar	G5	Gandhinagar
P6	Banaskantha	G6	Gandhinagar
P7	Sabarkantha	G7	Gandhinagar
P8	Mehsana	G8	Gandhinagar
P9	Patan	G9	Gandhinagar
P10	Godhra	G10	Gandhinagar
P11	Dahod	G11	Vadodara
P12	Bharuch	G12	Vadodara
P13	Rajpipla	G13	Vadodara
P14	Navsari	G14	Vadodara
P15	Dangs	G15	Vadodara
P16	Valsad	G16	Vadodara
P17	Junagarh	G17	Vadodara
P18	Porbandar	G18	Surat
P19	Rajkot	G19	Surat
P20	Jamnagar	G20	Surat
		G21	Bharuch

Annexure: 1

Methodology note

DATA ENVELOPMENT ANALYSIS (DEA)[1]

Abstract
Measurement of efficiency of any organisation (e.g., hospital, bank etc.) that uses multiple inputs and generates multiple outputs is complex and comparisons across units are difficult. Charnes and Cooper (1985) describe a non-parametric approach in such situations to measure efficiency and the technique is known as data envelopment analysis (DEA). DEA is basically a linear programming based technique used for measuring the relative performance of organizational units where the presence of multiple inputs and outputs makes comparisons difficult. DEA involves identification of units, which in relative sense use the inputs for the given outputs in most optimal manner and DEA uses this information to construct efficiency frontier over the data of available organisation units. DEA uses this efficient frontier to calculate the efficiencies of the other organisation units that do not fall on efficient frontier and provide information on which units are not using inputs efficiently. The objective of this note is to introduce the technique and demonstrate it through an example to show how relative efficiencies can be determined and identify units that are relatively less efficient.

8. Data envelopment analysis and different efficiency concepts

DEA calculates the efficiency of a given organization in a group relative to the best performing organization in that group. DEA is generally used to measure efficiency of government service, non-profit organizations or private sector firms. These individual units analysed are also referred to as decision-making units DMUs in DEA. The DMUs for which efficiency score are measured can be a whole agency such as hospitals, banks or units within organizations such as separate wards in a hospital. To begin with it is very essential to understand the various concepts of efficiency.

[1] This note has been prepared as part of the capacity development effort of Health Policy Development Network (HELPONET), India. This project is supported by the International Health Policy Program (IHPP), Washington D.C.

Technical efficiency

It deals with the usage of labour, capital, and machinery as inputs to produce outputs relative to best practice in a given sample of DMUs. In other words, given same technology for all the DMUs no wastage of inputs is considered in producing the given quantity of output. An organisation operating at best practice in comparison to all others in the sample is said to be totally technically efficient. The organisations are benchmarked against the best organization and their technical efficiency is expressed as a percentage of best practice. Managerial practices and the scale of operations affect technical efficiency. This is due to scale of operation and is based on engineering relationships but not on prices and costs.

Allocative efficiency

It deals with the minimization of cost of production with proper choice of inputs for a given level of output and set of input prices, assuming that the organization being examined is already fully technically efficient. Allocative efficiency is expressed as a percentage score, with a score of 100 percent indicating that the organization is using its inputs in the proportions which would minimize costs. An organization that is operating at best practice in engineering terms could still be allocatively inefficient because it is not using inputs in the proportions, which minimize its costs, given relative input prices.

Cost efficiency

It deals with combination of technical and allocative efficiency. An organization will only be cost efficient if it is both technically and allocatively efficient. Cost efficiency is calculated as the product of the technical and allocative efficiency scores (expressed as a percentage), so an organization can only achieve a 100 per cent score in cost efficiency if it has achieved 100 per cent in both technical and allocative efficiency.

These concepts are best depicted graphically, as in Figure 1 which plots different combinations of two inputs, labour and capital, required to produce a given output quantity. The curve plotting the minimum amounts of the two inputs required to produce the output quantity is known as an efficient frontier (or isoquant). It is a smooth curve representing theoretical best engineering practice[2]. The DMU can gradually change input combinations given current technological possibilities. If an organization is producing at a point on the efficient frontier then it is technically efficient. However this does not suggest whether it will be cost effective. We bring the budget (availability of resources) into picture.

The given budget of a DMU can buy either labour or capital. Given the prices of these two inputs one can buy various combinations of these inputs. The straight line denoted as the budget line plots combinations of the two inputs that have the same cost. The slope of the budget line is given by the negative of the ratio of the capital price to the labour price. Budget lines closer to the origin represent a lower total cost. Thus, the cost of producing a given output quantity is minimised at the point where the budget line is tangent to the efficient frontier. At this point both technical and allocative efficiencies are attained.

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[2] The curve is convex shaped and suggests different combinations of inputs of capital and labour to generate same output. The shape of the curve also suggests that if one reduces one input (labour or capital), the requirement of other input increases at higher rate to get the same output. For example, if one reduces the capital beyond a limit, the need for labour increases infinitely to get the same output.

The point of operation marked A would be technically efficient but if we use A' combination of inputs to produce the same output, it will be technically inefficient because more inputs are used than are needed to produce the level of output designated by the efficient frontier. Point B is technically efficient but not cost efficient because the same level of output could be produced at less cost at point C.

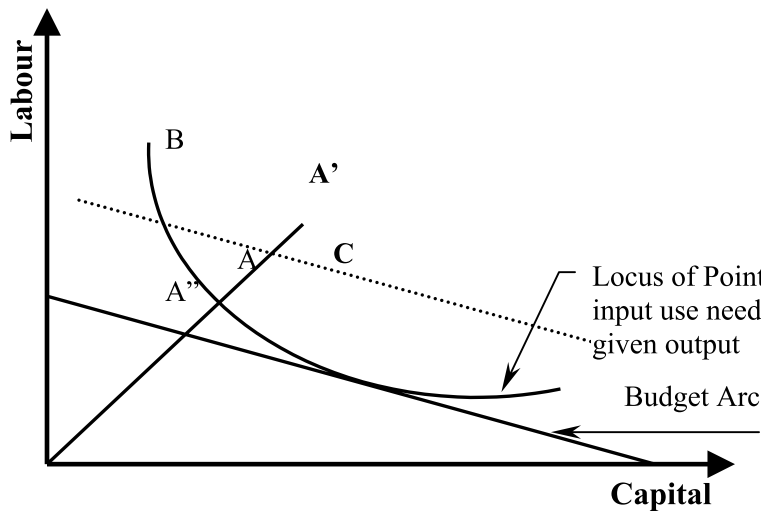

Figure 1: Efficiency concepts

Thus, if an organization moved from point A to point C its cost efficiency would increase by (OA' – OA") / OA'. This would consist of an improvement in technical efficiency measured by the distance (OA' – OA) / OA' and an allocative efficiency improvement measured by the distance (OA – OA") / OA. Technical efficiency is usually measured by checking whether inputs need to be reduced in equal proportions to reach the frontier. This is known as a 'radial contraction' of inputs because the point of operation moves along the line from the origin to where the organization is now.

9. Operationalising the concepts

In practice it is difficult to get the smooth curve as shown in Figure 1. This assumes that we know the theoretical best practice and since this information is not available this cannot be calculated from sample data. In practice the data is observable for only a sample of organisations. This data provide some limited information on what could be best practice. However, there is difficulty in assuming whether any of the organisations included in the sample can be considered achieving best practice. Given the complexity of inputs particularly in services organisation such as hospitals the sample points may not cover all of the range of possible input combinations.

There are several ways to use the data from the sample to try and approximate the smooth curve in Figure 1. The most frequently used techniques to estimate the frontier are DEA and stochastic frontier analysis. DEA is a deterministic means of constructing a 'piece-wise linear' approximation to the smooth curve of Figure 1 based on the available sample. In other words, the distribution of sample points is observed and a 'kinked' line is constructed around the outside of them, 'enveloping' them (hence the term data envelopment analysis).

Stochastic frontier analysis is an alternative approach using regression techniques. It tries to take account of outliers, which either are very atypical or appear to be exceptional performers as a result of data measurement errors. The relevance of stochastic frontier analysis to budget sector applications is limited to those situations in which a single overall output measure or relatively complete price data are available. This is not often the case for service providers. This appendix does not cover discussion on stochastic frontier analysis (for this see Fried, Lovell and Schmidt 1993). The DEA approach for calculating technical efficiency can be shown with a simple numerical example: a sample of five hospitals that use two inputs staff and beds (same as labour and capital in previous section) to produce one output, say, treated cases. Since the hospitals differ in terms of number of beds; to facilitate comparisons, input levels must be converted to those needed by each hospital to produce one treated case. The hospital input and output data are presented in Exhibit 1.

Exhibit 3: Hospital Data

Hospital	*Medical Staff*	*Beds*	*Treated cases*	*Medical staff per treated case*	*Beds per treated case*
1	200	600	200	1	3
2	600	1200	300	2	4
3	200	200	100	2	2
4	600	300	200	3	1.5
5	500	200	100	5	2

The five hospitals range in size from 200 to 1200 beds, and there is a similarly large range in the numbers of staff and treated cases. The medical staff per treated case and beds per treated case also show variation across hospitals. Given the large differences in these hospitals' characteristics (staff, beds, treated cases, medical staff per treated case and beds per treated case) it is not obvious how to compare them or, if one is found to be less efficient, which other hospital it should use as a role model to improve its operations. The answers to these questions become clearer when the data for staff per treated case and beds per treated case are plotted in Figure 2, where data are abstracted from differences in size.

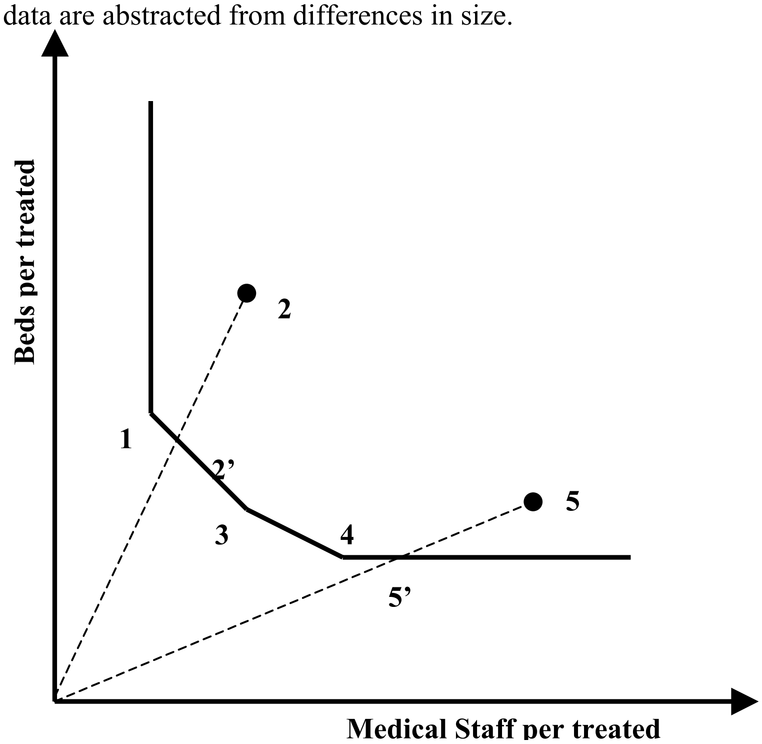

Figure 2: Hospital input–output data

The hospitals closest to the origin and the two axes are the most efficient, so a 'kinked' frontier can be drawn from hospital 1 to hospital 3 to hospital 4. For the moment, the parts of the frontier above hospital 1 and to the right of hospital 4 are drawn by extending the frontier beyond these points parallel to the respective axes. The kinked frontier in Figure 2 envelopes all the data points and approximates the smooth efficiency frontier in Figure 1 based on the information available from the data.

10. Which are the most efficient or best practice hospitals in the sample?

Hospitals 1, 3 and 4 are on the efficient frontier, so are assumed to be operating at best practice. However, hospitals 2 and 5 are northeast of the frontier, so are considered to be less efficient. This is because they appear to be able to reduce their input use and still maintain their output level compared with the performance of the best practice hospitals. For example, hospital 2 could reduce its use of both inputs by one third before it would reach the efficient frontier at point 2'. Similarly, its technical efficiency score is given by the ratio 02'/02 which is equal to 67 per cent in this case. This is because the 'hypothetical' hospital 2 has a value of 1.33 for staff per treated case and a value of 2.67 for beds per treated case. In terms of actual input levels, hospital 2 would have to reduce its number of staff from 600 to 400 and its number of beds from 1200 to 800. At the same time, it would have to maintain its output of 300 treated cases before it would match the performance of the hypothetical best practice hospital 2'.

But how is the hypothetical best practice hospital 2' derived? It is formed by reducing the inputs of hospital 2 in equal proportions until reaching the best practice frontier. The frontier is reached between hospitals 1 and 3 in this case, so the hypothetical hospital 2' is a combination, or weighted average, of the operations of hospitals 1 and 3. If hospital 2 is looking for other hospitals to use as role models to improve performance, then it should examine the operations of hospitals 1 and 3 because these are the efficient hospitals most similar to itself. In DEA studies these role models are known as the organization's 'peers'.

The other less efficient hospital — hospital 5 — is in a different situation. It is north-east of the efficient frontier, but contracting its inputs in equal proportions leads to the hypothetical hospital 5', which still lies to the right of hospital 4 on the segment of the frontier which was extended parallel to the staff per treated case axis. Thus, the peer group for hospital 5 solely consists of hospital 4 because it is the only one which 'supports' that section of the frontier on which the hypothetical 5' lies. But hospital 5' is not fully efficient because the number of staff per treated case can be reduced, while the number of beds per treated case is held constant, thus moving from 5' back to 4. That is, to maximize its efficiency given the available data, hospital 5 has to reduce one input more than the other. In this special case, a radial contraction of inputs means that the frontier is reached, but a further reduction of one of the inputs can be achieved without a reduction in output. This extra input reduction available is known in DEA studies as an input 'slack'. Thus, it is important in DEA studies to check for the presence of slacks as well as the size of the efficiency score.

It is relatively easy to implement this simple example of data envelopment analysis in a two-dimensional diagram. The analysis becomes complex when one includes multiple inputs and outputs. For example the staff can be further classified into doctors, nurses and other para-medical staff. Similarly, other capital inputs such as number of X-ray machines can also included in other capital inputs. The outputs can also be measured in multiple ways such as OPD patients, in-patients and laboratory tests conducted. With a larger number of inputs and outputs and more organisations, it is necessary to use mathematical formulae and computer packages.

11. Questions that DEA can help us answer

By providing the observed efficiencies of individual organisations, DEA may help identify possible benchmarks towards which performance can be targeted. The weighted combinations of peers, and the peers themselves may provide benchmarks for relatively less efficient organizations. The actual levels of input use or output production of efficient organisations (or a combination of efficient organisations) can serve as specific targets for less efficient organisations, while the processes of benchmark organisations can be promulgated for the information of managers of organisations aiming to improve performance.

The ability of DEA to identify possible peers or role models as well as simple efficiency scores gives it an edge over other measures. Fried and Lovell (1994) listed the following as questions that DEA can help to answer for managers:

- How do I select appropriate role models to serve as possible benchmarks for a program of performance improvement?
- Which facilities are the most efficient?
- If all my operations were to perform according to best practice, how many more service outputs could I produce and how much could I reduce my resource inputs by, and in what areas?
- What are the characteristics of efficient operating facilities and how can they guide me in choosing locations for expansion?
- What is the optimum scale for my operations and how much would I save if all my facilities were the optimum size?
- How do I account for differences in external circumstances in evaluating the performance of individual operating facilities?

The simple model of DEA already outlined can satisfy the first four of these questions. To answer the last two, some extensions to the model are needed.

12. Extensions to the DEA model

Over the years there have been several extensions and the range of topics, which it can explore, have increased. Particularly interesting is the decomposition of the technical efficiency score into components resulting from: the scale of operations; surplus inputs which cannot be disposed of; and a residual or 'pure' technical efficiency. A further extension which is often important is to allow for differences in operating environments; this involves trying to adjust for factors which might be beyond managers' control, and which thus possibly give some organizations an artificial advantage or disadvantage. Each of these issues is addressed in turn below.

Scale efficiency

The simple example presented above was based on the assumption of constant returns to scale. Given this assumption, the size of the organisation is not considered to be relevant in assessing its relative efficiency. Small organizations can produce outputs with the same ratios of input to output, as can larger organisations. This is because there are no economies (or diseconomies) of scale present, so doubling all inputs will generally lead to a doubling in all outputs. However, this assumption is inappropriate for services which have economies of scale (or increasing returns to scale). In these services, doubling all inputs should lead to more than a doubling of output because providers are able to spread their overheads more effectively or take advantage of procuring supplies and other items in bulk. For other services, organisations might become too large and diseconomies of scale (or decreasing returns to scale) could set in. In this case, a doubling of all inputs will lead to less than a doubling of outputs. It would be to an organisation's advantage to ensure that its operations are of optimal size - neither too small if there are increasing returns nor too large if there is decreasing returns to scale.

If it is likely that the size of service providers will influence their ability to produce services efficiently, the assumption of constant returns to scale is inappropriate. The less restrictive variable returns to scale frontier allows the best practice level of outputs to inputs to vary with the size of the organisations in the sample. This is demonstrated using the simplified one input (medical staff) and one output (treated cases) example shown in Figure 3.

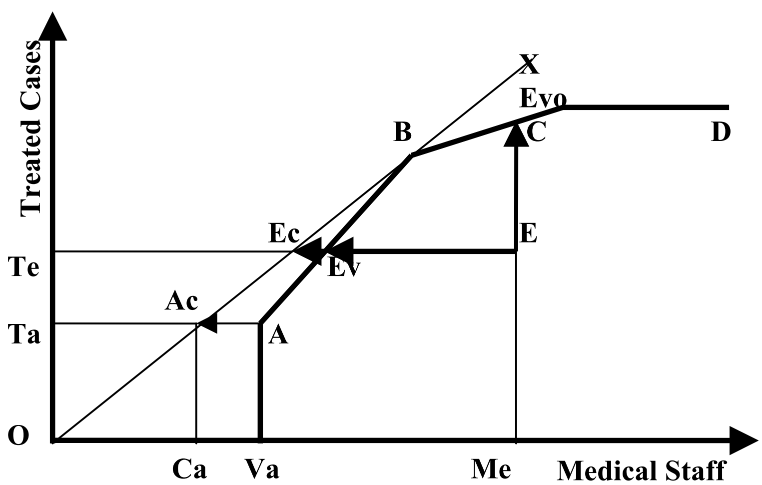

Figure 3: The production frontier and returns to scale

The constant returns to scale frontier is the straight line emanating from the origin (OBX), determined by the highest achievable ratio of outputs to inputs in the sample, regardless of size. The variable returns to scale frontier (VaABCD) passes through the points where the hospitals have the highest output to input ratios, given their relative size, then runs parallel to the respective axes beyond the extreme points. The scale efficiency of an organisation can be determined by comparing the technical efficiency scores of each service producer under constant returns to scale and variable returns to scale.

The distance from the respective frontier determines technical efficiency under each assumption. The distance between the constant returns and the variable returns frontiers determines the scale efficiency component. The distance from the variable returns frontier determines technical efficiency resulting from factors other than scale. Thus, when efficiency is assessed under the assumption of variable returns, the efficiency scores for each organization indicate only technical inefficiency resulting from non-scale factors. Technical efficiency scores calculated under variable returns, therefore, will be higher than or equal to those obtained under constant returns.

This can be demonstrated using the examples in Figure 3.

- Hospital B is the only one that has no scale or non-scale inefficiency under either assumption. It represents the *optimal scale* within the sample.
- Hospitals A, C and D are scale inefficient but do not have any inefficiency resulting from non-scale factors under the variable returns assumption. For example, the scale efficiency score of hospital A is determined by the ratio of distances TaAc/TaA, which is less than one. Hospital A has increasing returns to scale because it would approach the optimal scale in the sample if it increased its size. Hospitals C and D are producing outputs with decreasing returns to scale and are too large to be considered scale efficient, with hospital D being the furthest from optimal scale.
- The technical inefficiency of hospital E under constant returns (TeEc/TeE) is made up of both scale inefficiency (TeEc/TeEv) and non-scale technical inefficiency (TeEv/TeE).

Input and output orientation

Another issue that can be illustrated in Figure 3 is the question of output and input orientation. The examples so far have been input oriented — that is, by how much can inputs be reduced while maintaining the same level of output? However, the corresponding output-oriented question could be equally important — by how much can output be increased while keeping the level of inputs constant? The latter question may be more relevant for many government service providers, particularly those supplying human services, as the community often wants more of these services while budgetary pressures make it difficult to increase inputs.

In Figure 3 the input-oriented technical efficiency score for hospital E under variable returns to scale was given by the ratio of distances TeEv/TeE. The technical efficiency score for hospital E, using an output orientation and again assuming variable returns to scale, is given by the ratio of distances MeE/MeEvo.

If an organization is technically inefficient from an input-oriented perspective, then it will also be technically inefficient from an output-oriented perspective. However, the values of the two technical efficiency scores typically will differ, as will the presence and extent of slacks. Depending on whether an input-saving or output-expanding orientation is utilised, the peers for hospital E will also differ. Its peers are hospitals A and B under input orientation but hospitals B and C under output orientation. This reflects the fact that hospital E can learn different things from the two sets of peers. Hospital C is better at producing more output from a roughly similar input level to that of hospital E, while hospital A produces less output than does hospital E but uses considerably fewer inputs.

13. Strengths of DEA

As the earlier list of applications suggests, DEA can be a useful tool. A few of the characteristics that make it powerful are:

- DEA can handle multiple inputs and multiple outputs.
- It does not require an assumption of a functional form relating inputs to outputs.
- DMUs are directly compared against a peer or combination of peers.
- Inputs and outputs can have very different units. For example, beds, number of medical staff, number of patients treated, expenditure on medical supplies etc.

14. Limitations of DEA

The same characteristics that make DEA a useful tool can also create problems. An analyst should keep these limitations in mind when choosing whether or not to use DEA.

- DEA results are sample specific.
- Since DEA is an extreme point technique, measurement error can cause significant problems.
- DEA is good at estimating "relative" efficiency of a DMU but it converges very slowly to "absolute" efficiency. In other words, it can tell you how well you are doing compared to your peers but not compared to a "theoretical maximum."
- Since DEA is a nonparametric technique, statistical hypothesis tests are difficult.
- Since a standard formulation of DEA creates a separate linear program for each DMU, large problems can be computationally intensive.

Exhibit 4: Comparison of the main benchmarking techniques

Problem	DEA	Regression	SFA
Multiple inputs and outputs	Simple	Complex—rarely undertaken	Complex—rarely undertaken
Specification of the functional form	Not required	Required and may be incorrect	Required and may be incorrect
Outliers or unusual observations	Inaccurate efficiency assessment	Not as sensitive	Not as sensitive
Sample size	Small sample size can be adequate	Moderate sample size required—statistics become unreliable if too small, and important factors may be incorrectly omitted from the model	Large sample size required
Explanatory factors highly collinear	Better discrimination	Possible misleading interpretation of relationships	Possible misleading interpretation of relationships
Explanatory factors have a low correlation	All efficiency scores tend to be close to unity	No problem	No problem
Noise, such as measurement error	Highly sensitive	Affected, but not as severely as is DEA	Specifically modelled, although strong distributional assumptions are required
Testing, including variable selection	Sensitivity analysis is possible but complex, so is more subjective	Straightforward statistical testing	Straightforward statistical testing

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