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A New Approach to Evaluate and Measure Hospital Efficiency

H. DAVID SHERMAN

Sloan School of Management - M.I.T.
50 Memorial Drive
Cambridge, Mass. 02139
SSM Working Paper #1427-83

MASSACHUSETTS
INSTITUTE OF TECHNOLOGY
50 MEMORIAL DRIVE
CAMBRIDGE, MASSACHUSETTS 02139

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Abstract

A new technique for identifying inefficient hospitals, Data Envelopment Analysis (DEA), is field tested by application to a group of teaching hospitals. DEA is found to provide meaningful insights into the location and nature of hospital inefficiencies as judged by the opinion of a panel of hospital experts. The insights about hospital efficiency provided by DEA are not generated from the widely used efficiency evaluation techniques of ratio analysis and econometric-regression analysis. DEA is, therefore, suggested as a means to help identify and measure hospital inefficiency as a basis for directing management efforts toward increasing efficiency and reducing health care costs.

1. Introduction

One approach that a hospital administrator or regulator can pursue to reduce health care costs is to reduce inefficiencies in hospital operations. Only after hospital inefficiencies are identified and measured can remedial action be taken to improve efficiency and thereby reduce hospital operating costs. This paper field tests a new approach to identify and measure hopsital inefficiencies, Data Envelopment Analysis (DEA), which provides insights that are not available from currently used techniques and which can form the basis for managerial action to improve hospital operating efficiency.

The following section describes the need for applying such efficiency evaluation techniques to hospitals. Section 3 describes the weaknesses in currently used techniques for measuring hopital efficiency and the ways in which DEA circumvents these weaknesses. Section 4 describes the application of DEA to a set of teaching hospitals and the evaluation of the results by a panel of hospital experts and by management of one of the hospitals identified as inefficient. The final section 5 discusses the strengths and limitations of DEA and the ways it can be useful in future hospital application.

2. Efficiency Measurement Techniques are needed to help reduce health care costs

Rising health care costs are of widespread concern to government, individuals, and insurers. In the past, hospitals generality were reimbursed for services based on the cost of providing those services. This type of retrospective reimbursement does not provide strong incentives to reduce hospital costs, i.e., it allows hospitals to recover their costs regardless of

their level of efficiency. Recently, reimbursement systems have been attempting to reduce the rate of increase in hospital costs through prospective rate setting and reimbursement for hospital services [4] [15]. Propective systems basically require a hospital to agree on a reimbursement rate structure for services to be rendered in the future based on budgets prepared by a hospital and accepted by the regulator and/or payor. While several studies (e.g., [4] and [15]) suggest that prospective reimbursement systems lead to lower rates of cost increases, they do not create the type of direct price competition which is expected to induce efficient behavior (in the microeconomic theory sense). Hospitals do compete on many dimensions for financing, donations, patients, and affiliations with medical schools and physicians, but success along these dimensions of competition would not necessarily result in efficient hospital operations. While the new prospective reimbursement mechanisms provide incentives to prevent a hospital from becoming less efficient, they do not assure that hospitals will become efficient partly because strategies to maximize reimbursement may not lead to improvement of efficiency and partly because prospective reimbursement systems are largely based on current cost levels which are not necessarily efficient cost levels. That is, prospective systems may only motivate a hospital to limit the rate of cost increases from an already <u>inefficient</u> cost level. Hence other more direct approaches to improve hospital efficiency are needed as one means of reducing health care costs.

Can hospitals reduce operating costs by improving operating effciency? The answer to this question is, at worst, unclear and, at best, yes. The efficient amount of resources required to produce hospital services is not well understood or specifiable in any detail ([2], [15] and [9]). If the efficient amount of resources needed to produce each type of patient care were known, the efficient cost of providing hospital services could be directly

determined. Numerous studies (e.g., [9]) have attempted to identify the efficient hospital production relationships using econometric-regression techniques. These studies share a common methodological weakness in that they are based on estimating average input-output relationships based on data which includes both efficient and inefficient hospitals. They may provide good predictions of what costs will be assuming a constant level of inefficiency but they say nothing about efficient relationships ([14]).

Other studies suggests that many hospitals are operating with varying degrees of inefficiency which could be reduced by managerial action if the proper incentives existed. The U.S. General Accounting Office (GAO) study of U.S. hospitals [15] indicated that a large percent of these hospitals lack a number of good management practices which represented key ways of improving hospital operating efficiency. The GAO study suggests that many hospitals operate with distinct inefficiencies and that identifying and reducing these inefficiencies would be desirable because of the cost savings that would result. This result is quite believable. The absense incentives to maximize efficiency gives a hospital manager considerable latitude to emphasize concern for effectiveness of care to the detriment of efficiency.

A methodology that would locate inefficient hospitals, indicate the magnitude of the inefficiency and the general location of that inefficiency could be used to help hospital managers analyze and implement programs to improve efficiency. In addition, it might be possible to study the management techniques found in the more efficient hospitals and transfer them to the less efficient hospitals as a means of improving their efficiency. Regulators could use this information to encourage and even subsidize the less efficient hospitals to obtain appropriate consulting services to help reduce their inefficiencies. A stronger use of these insights would be to actually penalize the less efficient hospitals by reducing their reimbursement rates to

levels of more efficient hospitals or by limiting their capital expansion as a way of applying direct pressure to improve efficiency.

Data Envelopment Analysis is a technique recently developed by A. Charnes, W. W. Cooper, and E. Rhodes ([5], [6], and [7]) which compares organizations that use multiple inputs (such as labor, capital, materials) to produce multiple outputs (such as various types of patient care, teaching, research). It compares these organizations and identifies those which are relatively inefficient as well as the magnitude of these inefficiencies.[1] This study represents the first field application and test of DEA in hospital evaluations. The motivation for use of DEA in the health sector is twofold. 1) The multiple outputs of hospital and specifically the case mix can be directly accommodated with DEA and 2) the alternative techniques are less reliable and definitive in their ability to identify hospital inefficiencies.

3. Efficiency measurement techniques for hospitals

There are two widely used approaches to evaluate hospital efficiency:

1. Ratio Analysis (i.e., "rules of thumb") - use of various ratios for a group of comparable hospitals to locate relationships which are abnormally high or low such as cost per patient day, cost per patient, personnel full-time equivalents per patient. Examples of this type of ratio data are Monitrend reports of the American Hospital Association and the Massachusetts Rate Setting Commission ratios used for cost audits [11].

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[1]DEA has been shown to be theoretically sound [5], [6], and [7] and has been found to be reliable in controlled applications [13] and has also been used in areas such as education and court systems efficiency evaluations.

2. Econometric regression techniques - used to estimate hospital cost relationships and production relationships. Examples of this type of study are numerous. Feldstein's study of hospitals [9] reflects many of the more traditional alternatives using econometric-regression techniques. These approaches attempt to estimate marginal cost per patient, the breakdown of fixed versus variable cost, existence of economies of scale, and the efficient rates of substitution between inputs.

Both ratio analysis and regression methodologies have distinct limitations with respect to evaluating hospital efficiency. These limitations, may be summarized as follows.

<u>Ratio analysis - Problems in evaluating hospital efficiency</u>

Ratio analysis calculates and attempts to understand relationship between two variables such as cost per day, cost per patient, etc. By their nature, each ratio is limited to one output and cannot easily accommodate multiple outputs and inputs. If a hospital treated only two types of patients and trained residents, it would have three outputs. Assume, for example, that cost per patient day is calculated as total number of patient days ÷ total costs. This ratio would be biased by the lack of recognition that there are two different types of patients being treated and because training outputs are ignored. Hence, a higher cost per patient day could be due to the case mix, the intensity of training activity, excessive prices paid for resources used, or excessive amounts of resources used (generally referred to as operating or technical inefficiency).

The efficient cost is not known for most hospital sevices. Consequently, when comparing hospitals, those hospitals with cost per patient or cost per

day some distance above the mean cost might be considered potentially inefficient. There currently is no way, however, to determine objectively how far above the mean is inefficient or even if the mean is efficient. It is conceivable that all the hospitals operating at the mean cost per patient day are also inefficient. To compensate for the unidimension of a single ratio, large sets of ratios are developed as in Monitrend reports. One hospital may appear relatively efficient on one group of ratios and inefficient on another while another hospital may have the opposite result for the same ratios. There is no objective means of assigning relative weights to these ratios. Consequently, it is difficult to conclude which hospitals are inefficient using ratio analysis. Ratio analysis may be very useful in identifying what aspect of a hospital's operation is out of line with the norm, but it is of limited help in locating the inefficient hospitals among a large group of hospitals.

Econometric-Regression Analysis - Problems in evaluating hospital efficiency

Regression analyses is more comprehensive than ratios because it can accommodate multiple ouptputs and inputs, but other significant problems are encountered. The use of least square regression techniques result in estimates of average (or central tendency) relationships which are not necessarily efficient relationships as noted above.

A second problem is an estimate of the hospital cost function using this technique results in a mean relationship which does not directly locate inefficient hospitals. Designation of the relatively inefficient hospitals again requires that hospitals with costs some arbitrary distance from the mean be labelled as potentially inefficient. More importantly, numerous econometric-regression types of hospital studies have been used to identify economies of scale, marginal costs of patient care and rates of substitution

among outputs and inputs. These results say nothing, however, about what the efficient rates of substition, efficient scale size, and efficient rates of transformation are because they are based on an average of the behavior of efficient and inefficient hospitals combined. Use of regression techniques would only provide insights into efficient hospital behavior if all the hospitals in the study were known to be efficient. While this problem was noted early on by Feldstein [9], econometric-regression techniques are among the most accessible and have consequently been widely used in hospital industry cost studies.

Data Envelopment Analysis

DEA addresses the limitations associated with ratio analysis and regression techniques It is explicitly able to consider the multiple outputs and inputs of a hospital. Specifically, the multiple outputs reflected in the case mix and the multiple resources used to produce these services to gain an overall evaluation of hospital efficiency. In addition, it can incorporate other hospital outputs like teaching, research, and community education programs to gain a comprehensive efficiency measure of hospital performance.

Data Envlopment Analysis is a linear programming technique which compares a set of an organization's actual inputs used to produce their actual output levels. DEA locates those units that are the relatively more and less efficient and measures the inefficiency compared with the more efficient units in the set. Inefficient units are those with an efficiency ratio of less than 1 ($E < 1$) and those units are strictly inefficient compared to other units in the set. Units with an efficiency ratio of 1 ($E = 1$) are not necessarily absolutely inefficient but rather represent the "best practice" group of units which means that they are not clearly inefficient compared to other units in the set. This situation arises because the identity of absolutely efficient

hospitals is not known because of lack of knowledge of the truly efficient input-output relationships. Hence a hospital that is found to be relatively efficient may also be able to improve its operating efficiency. A hospital that is found to be inefficient will have true inefficiencies at least as large as the amount located with DEA. An inefficient hospital, as identified by DEA, is defined to have the ability to produce its same level of outputs (patient care, teaching) with fewer inputs based on the actual output-input levels of hospitals that were compared with the inefficient hospital.

The DEA model is described in the appendix to this paper. (See exhibit 3.)

To apply DEA, it is necessary to identify and obtain the data for set of outputs and inputs relevant to the hospitals' operations. Each of the outputs and inputs need only be measured in their natural physical units without the need to use a homogeneous measurement unit like dollars. For example, DEA can include as outputs the number of each patient diagnosis type treated and the number of each type of individual trained, and it can include inputs measured in units of full-time equivalents of each personnel type, number of beds available, etc.

4. Field Test of DEA to evaluate Teaching Hospital Efficiency

A set of teaching hospitals in Massachusetts were used to evaluate the ability of DEA to locate relatively inefficient hospitals. This researcher had no a priori knowledge about which of these hospitals were relatively inefficient nor was any accepted benchmark available that independently indicated which of these hospitals were more or less efficient. In lieu of an absolute benchmark of efficiency, a panel of hospital experts including regulators, managers, and hospital management consultants that were familiar with the hospitals in the state were enlisted to evaluate the accuracy of the

DEA results and to help identify the outputs and inputs that were relevant for the efficiency evaluation. (The procedures followed are described in greater detail in [14].)

Choice of Sample

The state rate setting commission had already adoped a ratio analysis approach to evaluate hospitals whereby a hospital over one standard deviation above the mean cost per day or mean cost per patient was deemed potentially inefficient [11]. This ratio analysis was applied within groups of hospitals that were designated as "comparable" groups. These comparable groups were developed by the rate setting commission using cluster analysis modified by discussions with the hospitals. One of these comparable groups of hospitals, a set of teaching hospitals, was selected for this study and the data used was from reports required to be submitted annually to the rate setting commission by each hospital in the state [12]. Data was available for seven of the nine hospitals in this group, so the DEA was used to evaluate just those seven hospitals. The study focused on one part of the hospital, the medical surgical area as defined in [12], to reduce the complexity of analyzing the efficiency in an entire hospital and because this represented the largest single cost area separately reported on by hospitals in the state. Data from 1976 was used because it was believed that some of the negative connotations of being labelled "inefficient" would be diffused if the study tested DEA using a prior year. The study began in 1979 so that the 1976 year of operations was not so old as to have faded from the memory of those familiar with these hospitals.

Identification of relevant outputs and inputs

The identification of the relevant outputs and inputs had to be based on an understanding of what resources are used to provide the types of services

offered in the Medical Surgical (MS) area. In this study, the variable selection was also tempered by the data that would be available from public reports from these hospitals.

The outputs and inputs used are described in table 1.

The elaborate process of defining these outputs and inputs is described in exhibit 1 in the appendix. The process began with a list of all the identifiable and relevant direct outputs and inputs of the medical surgical area. This list was refined by eliminating input measures like square feet of building space which was believed to be less directly associated with efficiency and which was already reflected in part by one of the input measures used - bed days available. The most problematic compromise was the use of only two case types, over and under 65 year of age rather than the more direct and complete measures like diagnostic related groups (DRG's) [3].

While age does appear to be a key factor in the resource required to treat a patient [3] [13], age alone is an incomplete measure. Proceeding with only age as a case mix breakdown would mean that the DEA results might be skewed because other case mix dimensions of the hospitals' outputs are not accounted for. This problem is somewhat reduced in the set of hospitals used because they were already believed to be "comparable", i.e., all of these hospitals had a relatively severe (resource intensive) set of patient diagnoses characteristic of these teaching hospitals. In addition, the Medical Surgical area was moderated in its case mix complexity because patients were generally admitted to this area only after being stabilized in the intensive care, emergency care, or operating recovery room areas. DEA would evaluate these hospitals' use of the three inputs in table 1 to produce patient care and training as measured by the four outputs in table 1. To the extent that there are other outputs and inputs not included, the DEA results may be less than comprehensive. The experts agreed that the data that was specified in table 1

Table 1

The inputs and outputs selected and used for the DEA analysis were as follows:

INPUTS

(1)	FTE's	- Full-time Non-Physician Equivalents specifically employed in the Medical Surgical (MS) area during Fiscal Year 1976 (FY)
(2)	Supply $'s	- Total dollar value of supplies and purchased services used in MS area during FY 1976
(3)	Bed days	- Number of bed days available in MS area during FY 1976

OUTPUTS

(1)	Patient days with age $\geq$ 65	- Number of patient days of care in MS area for patients 65 or over during FY 1976
(2)	Patient days age < 65	- Number of days of care for patients under 65 during FY 1976
(3)	Nurses trained	- Number of nursing students trained during FY 1976 in their first, second or third years of the hospitals' nursing schools
(4)	Interns/ Residents trained	- Number of interns and residents receiving one year of training at the hospital during FY 1976

was a reasonable list of relevant outputs and inputs that characterize medical-surgical area activities but that a more detailed case mix measure would have been a desirable addition if it were available.

The actual output and input data used are reported in exhibit 2 of the appendix.

DEA results versus the use of ratio analysis

The DEA results are summarized in Table 2 which indicates that hospital D and G are relatively inefficient compared with the other hospitals in the data set, i.e. efficiency rating of less than 1.0. (The hospital names are disguised but these names were made available to the expert panel.)

The rate setting commission's ratio analysis suggested that only hospital C (and specifically not hospitals D and G) may be relatively inefficient in the prices they pay for inputs and/or the amount of inputs used (Table 2, columns 4 and 5). DEA goes beyond these ratios and suggests that hospitals D and G are also relatively inefficient and that compared to other hospitals in this group, these inefficient hospitals should be able to produce their same level of services (outputs) with fewer inputs and, therefore, at lower cost.

Interpretation of DEA results

The meaning of the inefficient rating derived from DEA can be understood by examining the results for hospital D. DEA indicates that hospital D is inefficient with an efficiency rating of .88 based on comparison of hospital D with all seven hospitals. More specifically, DEA indicates that the inefficiency was located and measured by comparing hospital D with its efficiency reference set hospitals A, C, and E, noted in table 2. This information is a direct output of DEA. By identifying the efficiency reference set, DEA allows one to focus on a subset of these hospitals to better understand the inefficiencies present. This comparison is illustrated in table 3 which indicated that a weighted composite of the efficiency

reference set hospitals would yield a hypothetical hospital that produces as much or more outputs as the inefficient hospital D but also uses less inputs than D. In this example, the composite is constructed by applying the weights, (the dual variables from the DEA-linear program), of 0.138, 0.296, and 0.498, respectively, to the actual outputs and inputs of hospitals A, C, and E. Columns (4), (5), and (6) of table 3 indicate that a combination of the actual operations of these three hospitals would result in a hypothetical hospital that would use 55 fewer FTE's, $182,330 fewer supply dollars, and 9090 fewer bed days to produce the same amount of patient care and 34 additional units of training.

Experts assessment of DEA results

The experts agreed that the two hospitals identified as inefficient, D and G, was a reasonable and believable result though one expert expressed some doubt about the magnitude of the inefficiency found in hospital D.

The reaction of the experts provides added insights into the need for techniques like DEA. These experts were not able to provide a ranking of relative efficiency before the DEA results were obtained for two reasons: (a) they do not generally evaluate hospital performance based on output-input efficiency criteria but rather were more aware of cost per patient and cost per day types of data, and (b) the experts were not as knowledgeable about an individual department like Medical Surgical but rather had general impressions of these hospitals' overall performance. Their reaction to the validity of the DEA findings were, nevertheless, very strong and they indicated that the two hospitals identified as inefficient reflect a believable result based on knowledge of these hospitals and the quality of their management. DEA effectively located two inefficient hospitals that would not be so identified or measurable with commonly used techniques.

Table 2

Comparison of teaching Hospitals' Medical Surgical (MS) area

Hospital** (1)	DEA Efficiency Rating (2)	Efficiency Reference Set (ERS) (3)	MS Cost Per Patient Day (4)	MS Cost Per Patient (5)
A	1.0	-	$34	$408
B	1.0	-	38	418
C	1.0	-	39	429
D	0.88	A, C, E	32	407
E	1.0	-	27	243
F	1.0	-	29	348
G	0.93	E	36	324
		Average Cost	$34.29	$368.14
		Standard Deviation	$ 4.27	$ 62.45

Table 3

Comparison of Hospital D with its efficiency reference set hospitals A, C, and E

Hospital D - DEA Efficiency Rating = .800

		(1) Hospital A (a)		(2) Hospital C (a)		(3) Hospital E (a)		(4) Composite = (.138A+.296C+.498E)	vs.	(5) Hospital D (1976 actual) (a)	(6) Hospital D - composite Column (5)-(4)
FTE		310		165.6		206.4		195	<	250	55
Supply $		134,600		131,300		151,200		133,670	<	316,000	182,330
Bed days		116,000		65,520		102,100		85,310	<	94,400	9,090
Nurse Training	(b) (.138)	291	(b) +(.296)	141	(b) +(.498)	157	=	160	=	160	-
Medicare Days		55,310		32,910		32,480		33,530	=	33,530	-
Non-Medicare Days		49,520		25,770		55,300		41,983	≈	41,990	-
Intern/Resid. Training		47		26		82		55.3	>	21	34.3

(a) actual inputs and outputs per Exhibit 2

(b) weights (dual variables) from DEA (see [ ])

Evaluation of DEA results by management of inefficient hospital D

To further test the validity of these results, they were reviewed with the director and financial officer of inefficient hospital D. They agreed that the medical surgical areas of these seven hospitals were comparable and that the outputs and inputs selected reasonably captured the key inputs and outputs of the area. While the case mix data was questioned, they did not feel that their case mix was more severe or resource consuming than others in the group so that this was not believed to be the cause of the inefficiency identified in hospital D.

They located three potential explanations for the inefficiencies identified by DEA.

- The supply cost data was found to be overstated by $141,000 due to an accounting tranfer that appears elsewhere in the report to the rate setting commission and which was subsequently determined to be a peculiarity that affected hospital D's report but did not affect the data for the other six hospitals.

- The bed days was determined by management to be excessive and were reduced subsequent to 1976 by 6935 bed days as was verified by examining subsequent years' agency reports.

- Personnel levels of hospital D were compared with other hospitals in the group and noted that they were somewhat higher than comparable hospitals by about 5.4 FTE's, but that this was a result of a conscious decision to maintain a somewhat larger staff to provide more personalized patient care.

In summary, management of hospital D found a data problem, an excessive level of bed days available which was subsequently adjusted and an excess FTE

level that continued to exist.

The DEA evaluation was rerun with the corrected supply dollar level and with the reduced level of beds to determine if these adjustments would make hospital D efficient compared with the other six hospitals. It was found that hospital D was still inefficient compared to the other six hospitals, but with a higher efficiency rating of .96 instead of the original rating of .88. Hence, hospital D remained inefficient and this was believed to be due in part to personnel levels. Another DEA evaluation which reduced FTE's by the amount calculated by management (5.4 units) and also reflected the above adjustments were found to be adequate to make hospital D efficient.

Hospital D could become relatively efficient by making adjustments to its inputs of a lower magnitude than was indicated by DEA as indicated in table 4. This reflects the existence of a number of alternative paths that any inefficient hospital may select to become relatively efficient. A number of alternative paths including the one noted in column 1, table 4 is available directly from DEA. Other paths that are considered more practical by management may also make a hospital relatively efficient. The ability of these other alternative paths to make an inefficient hospital become relatively efficient can also be evaluated using DEA for sensitivity analysis as was described above. In the case of hospital D, the adjustments that management considered necessary to make it efficient as represented in column 2 of table 4 was found to be one adequate path to relative efficiency.

Table 4

	(1) Excessive Inputs based on DEA evaluation of Hospital D (Table 3)	(2) Input Adjustments and Excesses Noted by Hospital D Management	(3) Cause of Excess Inputs
FTE's	55	5.4	Intentionally richer staffing
Bed days Available	9090	6935	Reduction of 19 beds to compensate for low occupancy rate
Supply $	$182,230	141,000	Transfer due to unique accounting system

Conclusion of the field application of DEA to hospitals

The key results of this field study may be summarized as follows:

- DEA accurately located two inefficient hospitals that would not be identifiable using the types of ratio analysis used by the state rate setting commission.

- DEA could explicitly consider different outputs measured in their natural units and was able to identify as well as measure the relative magnitude of inefficiency present, i.e., the amount of potential resource reduction possible if these inefficient hospitals attained the operating efficiency of the relatively more efficient hospitals in the study.

- DEA results could be understood, interpreted, and accepted by administrators familiar with these hospitals to help locate the source of the inefficiency. This could lead to managerial action to reduce these inefficiencies and/or to clarify the magnitude of the inefficiencies or slack that management chose to incorporate into their operating plans.

5. Future Use of DEA for Hospital Efficiency Evaluations

The field test result of this study buttressed by the theoretical formulation and other tests of DEA described in [5], [7] and [13] suggest that DEA is a promising tool to evaluate hospital efficiency. These studies indicate that DEA is reliable in the location of relatively inefficient units and in its ability to suggest the general magnitude of input reductions required to make an inefficient unit relatively efficient. It is particularly useful in hospital applications because it can simultaneously accommodate multiple outputs and inputs and does not require specific knowledge of the efficient amount of inputs required for each hospital output.

Operational issues in applying DEA to hospitals

Input-Output specifications -- a key ingredient in the DEA evaluation is the location and measurement of the relevant inputs and outputs. The advantage of DEA over other techniques is that each input and output can be measured in their natural physical units without the need to apply a weighting system to collapse these different units into dollars or any other single unit measure. Hence, it is sufficient to know, for example, how many patients of each diagnosis was treated as an output measure and how many FTE's of each personnel type are utilized to produce the outputs. This is of major significance because it means that case mix can be explicitly considered in the efficiency evaluation by considering each case type (e.g., diagnostic related group case type) to be a separate output.

Defining and measuring the relevant physical inputs and outputs may require additional effort, since many hospital information systems tend to emphasize and collect only the dollar cost of inputs due to the importance of the reimbursement systems and the widespread concern about the dollar cost of health care. Similarly, comprehensive case mix output data are only beginning to be captured in a form which is useable for assessment of hospital efficiency via DEA or other techniques. These data collection efforts are needed to help identify a path to reducing inefficiency and costs, regardless of the methodology to be used. Specifically, a hospital located as inefficient using this data with DEA will be strictly inefficient and consequently will have the ability to produce the same level of outputs with a reduced level of inputs which can translate into lower costs.

Use of DEA to hospitals to improve technical efficiency

Based on this pilot study, DEA may be applied to hospitals in the following ways.

- Segments of hospitals like the Medical Surgical area as well as an

entire hospitals' operation may be compared to locate the relatively inefficient hospitals.

- Location of relatively inefficient hospitals can be used to allocate resources to reduce these inefficiencies, i.e., remedial resources can be focused on the hospitals most likely to have inefficiencies that can be reduced by in depth study of their operations. This may provide a basis for regulators or insurers to encourage and perhaps subsidize the hiring of consultants or auditors to evaluate ways of increasing the inefficient hospitals' efficiency levels which should ultimately translate into lower operating costs or increased service levels.

- DEA results can be used by managers or regulators to compare techniques used in relatively more and less efficient hospitals and to identify techniques used by more efficient hospitals that can be transferred to and adopted by the inefficient hospitals. As suggested in the field study, DEA not only locates the inefficient units but it also locates the relatively efficient hospitals against which that hospital was most directly found to be inefficient. In this way, the group of hospitals to be compared is significantly reduced from the original size of the groups being evaluated. In this study, hospital D needed only be compared to three hospitals (A, C, and E) rather than all of the six hospitals and hospital G needed only be compared with hospital E.

- Regulatory organizations can use DEA to select out the more efficient hospitals as a basis for rate setting. They could require that less efficient hospitals receive no more than the rates required to reimburse the more efficient hospitals for similar services. This might provide an

incentive for less efficient hospitals to become at least as efficient as the relatively more efficient hospitals in the data set.

- Use of DEA can encourage managers to specifically consider physical input-output efficiency as distinct from other performance dimensions such as maximization of reimbursement revenues and minimizing of material costs and salary levels as a direct means of reducing health care costs. This suggests that DEA has capabilities not found in other measurement techniques such as ratio analysis. At the same time, other techniques can address efficiency dimensions not addressed by DEA such as the cost per FTE, cost per unit of a drug. DEA is, therefore, a useful complement to other techniques rather than a replacement for other techniques.

Exhibit 1

Input and Output Variables Identified as Relevant to MS Operations based on Review of the MS Area Description, HRSA 401 Reports, and Review by Hospital Experts.	Variables Used in DEA Analysis of Teaching Hospitals (N = not used) (Y = used)	Justification for Selection and/or Non-use of the Variables
INPUTS		
Labor Inputs		
• MS Physicians	N	Hospital based physicians are highly variable and a function of hospitals' policies and their chosen organization & accounting system. This variable does not reflect the true physician inputs of the hospital. No physician input measure was used because of unavailability of a comparable measure that captures hospital and independent physician inputs.
• Non-physician Staff in MS – Full Time Equivalents (FTE's)	Y Non-physician FTE's used as input in DEA Analysis	This is the common labor input measure which includes nurses and support staff on MS floors.
• Housekeeping Dept., FTE's Input to MS Area	N	These areas have FTE's which provide services directly or indirectly to MS area FTE's and patients. No measure of the proportion of time allocated to MS is available. The cost allocations used by hospitals are based on estimates which are influenced by reimbursement incentives and which are generally not based on any time or unit charge systems.
• Nursing Service Administration, FTE's Input to MS Area	N	
• RN-LPN Nursing Education Dept., FTE's Input to MS Area	N	
• In Service Nursing Education Dept., FTE's Input to MS Area	N	
• Dietary, FTE's Input to MS Area	N	
Capital Inputs		
• Number of Beds in MS Area	Y # Bed days of care available per year = # Beds x 365	Reflects the aggregate level of capital resources in terms of equipment and building space utilized to provide MS patient care.
• Floor Area in MS Area	N	Both variables are available but were not used.
• Age of Plant in MS Area	N	"Floor area" is misleading because a new plant may have less floor area with a more efficient layout, or vice versa. The age of the plant was not directly available. Depreciation was the only indicator of the relative age of the plant, and it is not a reliable measure. Some hospitals have zero depreciation expense due to fully depreciated plant purchased in some earlier unknown year. This would also require a method of transforming age and space to a single comparable measure of space adjusted for age which would be highly subjective.

• Fixed Assets used in MS Area – Major Movable Equipment	N	Depreciation expense is the only available measure and many hospitals have fully depreciated equipment, i.e., zero depreciation, which does not reflect the actual assets utilized in the MS area.
Other Inputs		
• Supply Dollars and Purchased Service Dollars	<u>Y</u> Supply and Purchased Service Dollars	Information on physical units of supplies or services purchased was not available. All hospitals in the study had small amounts of purchased services which were less than 10% of the supply dollars. In the absence of a unit measure of supplies, the dollar measure was used as an approximation of the unit volume.
• Energy Usage in MS Area	N	Excluded because this relates primarily to total plant operating efficiency as distinguished from MS efficiency. No allocation based on MS usage was available.
OUTPUTS		
• Patient Days of Care in MS Area	<u>Y</u> Patient Days of Care in MS Area	This is a basic output measure of medical care, unadjusted for case mix as reflected in the MS area description. Reimbursements are primarily oriented around a per diem rate.
• Admissions	N	Admissions is an alternative output measure which encompasses number of patients treated and their length of stay, in contrast to patient days of care which does not reflect length of stay. It was not used because case mix surrogates available were patient-day oriented rather than admissions oriented.
• Medical Admissions	N	
• Surgical Admissions	N	Breakdown of admissions by medical vs. surgical was desirable but many hospitals do not report these separately. There is also no correspondence between severity level or resource utilization levels and the medical surgical dichotomy.
• Case Mix Measures to Differentiate Hospital Patient Care Levels and Resource Utilization of the Case Load		
Diagnostic Related Groups (DRG's) reflecting the number of patients or patient days devoted to treatment of each diagnosis.	N	DRG's are currently one of the best potential output measures for DEA application. This output measure approach could not be used in this study because of lack of availability on a complete, or even adequate basis.
Patients or Patient Days over and under 65 years of age	<u>Y</u> % Medicare Days, % Patient Days with age ≥ 65	Available for all hospitals and believed to be an adequate surrogate for case mix for MS in teaching hospitals, but clearly inferior to DRG's.
• Nurse Training	<u>Y</u> Number of nursing students	An output of MS area where most clinical training occurs requiring resources of the MS area. To some unmeasurable extent these are inputs, which suggests that they may be treated as both inputs and outputs in some future study.

• Interns and Resident Training	Y Number of Interns and Residents in Training	Training occurs in the MS area (as well as other areas) requiring added resources of the MS area. No breakdown is available as to amount of training in MS vs. other areas. Therefore, this is treated as though the same percentage of all training occurs in the MS area for each hospital.
• Medical Students	N	Breakdown is not available and there is no systematic record of the amount of student time spent in the MS area.
• Quality of Medical Care in MS Area	N	There is no available quality rating by hospital or by hospital area. All teaching hospitals are believed to be generally of high quality, possibly varying in quality by department.
• Quality of Training of Interns, Residents and Nurses	N	An objective quality rating for teaching programs is not available.

Exhibit 2

Inputs and Outputs Data used for DEA Evaluation
Medical Surgical (MS) area of Teaching Hospitals

Hospital	Inputs			Outputs			
	Full Time Equivalent non-physician	Supply Dollars	Bed days Available	Patient days ≥ 65 years of age	Patient days under 65 years of age	# of Nurse students	# of Interns and Residents in training
A	310	134,600	116,000	55,310	49,520	291	47
B	278.5	114,300	106,800	37,640	55,630	156	3
C	165.6	131,300	65,520	32,910	25,770	141	26
D	250.0	316,000	94,400	33,530	41,990	160	21
E	206.4	151,200	102,100	32,400	55,300	157	82
F	384.6	217,000	153,700	48,780	81,920	205	92
G	530.4	770,800	215,000	58,410	119,700	144	89

Appendix -- Exhibit 3

The DEA Model

DEA measures the efficiency of hospital o compared with the n hospital in the data set as follows:

Objective:

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

where o is the hospital being evaluated in the set of j = 1, . . ., n hospitals. (This analysis is run repetitively with each hospital in the objective function to derive an efficiency rating for each of the n hospitals).

Constraints:

Less than Unity Constraints : $1 > \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}$; $j = 1, . . ., n$ (1)

Positivity Constraints : $0 < u_r$; $r = 1, . . ., s$
$0 < v_i$; $i = 1, . . ., m$

Data:

Outputs: y_{rj} = observed amount of r^{th} output for the j^{th} hospital

Inputs: x_{ij} = observed amount of i^{th} input for the j^{th} hospital

The data used for each hospital are the y_{rj} outputs; and the x_{ij} inputs. The u_r, v_i values are determined from the data by the above model. DEA provides an ex post evaluation of how efficient each hospital was with the actual inputs (x_{ij}) used to produce its outputs (y_{rj}) without explicit knowledge of the input-output relationships it used. The weights in the form of the u_r and the v_i are not known or given a priori. They are, instead, calculated as (u_r, v_i) values to be assigned to each input and output in order to maximize the efficiency rating --E_o^*-- of the hospital being evaluated. That is, the solution sought is the set of (u_r, v_i) values that will give the hospital being rated the highest

efficiency ratio, E_o^*, but not result in an input-output ratio exceeding 1 (100% efficiency) when applied to any and all other hospitals in the data set. (See [5] and [7] for further details).

Applying DEA to a set of hospitals' results in an efficiency rating for each hospital of 1 (relatively efficient) or less than 1 (relatively inefficient). These ratings, however, represent <u>relative</u> efficiencies based on comparison of hospitals in the data set (j = 1...n hospitals). A hospital that is found to be inefficient ($h_o < 1$) is strictly inefficient compared to other hospitals in the data set as is shown in [13].

Note that the u_r, v_i values calculated by DEA are objectively determined weights which may not correspond to relative values that a hospital would assign to outputs and inputs. This is actually a strength and not a weakness of DEA. A hospital located as efficient using DEA is so identified only after all possible weights have been considered to give that hospital the highest rating possible consistent with the contraint that no hospital in the data set can be more than 100% efficient. Hence, any other set of weights applied to all hospitals would only make an inefficient hospital appear less efficient, i.e., DEA gives the benefit of the doubt to each hospital in calculating the efficiency value.

The DEA evaluation also provides insights far beyond the identification of the inefficient hospitals (see [13]) as is illustrated in the hospital application in table 3 and further described in [13].

References

[1] Anthony, R. and R. Herzlinger, Management Control in Nonprofit Organizations, (Homewood, IL: Irwin, 1980).

[2] Astalfo, A. "Must We Really Improve Productivity", Hospital Financial Management, Vol. 31, Feb. 1977, p. 30.

[3] Bentley, J.D. and P. W. Butler, Describing and Paying Hospitals - Developments in Patient Case Mix (Washington, DC: Association of American Medical Colleges, 1980).

[4] Biles, B, C. J. Schramm, J. G. Atkinson, "Hospital Cost Inflation Under State Rate Setting Programs", New England Journal of Medicine, 1980, Vol. 303, pp. 664-668.

[5] Charnes, A., W. W. Cooper, and E. Rhodes, "Measuring Efficiency of Decision Making Units", European Journal of Operational Research, Vol. 2, No. 6, November 1978, pp. 429-444.

[6] Charnes, A., W. W. Cooper, and E. Rhodes, "Short Communication: Measuring Efficiency of Decision Making Units", European Journal of Operations Research, Vol. 3, No. 4, July 1979, p. 339.

[7] Charnes, A., W. W. Cooper, and E. Rhodes, "Evaluating Program and Managerial Efficiency: An Application of Data Envelopment Analysis to Program Follow Through", Management Science, Vol. 27, No. 6, June 1981, pp. 668-697.

[8] Dowling, W. C. "Hospital Production: A Linear Programming Model", (Lexington, MA: Lexington Books, 1976).

[9] Feldstein, M., Economic Analysis for Health Service Efficiency, (Amsterdam, Holland: North-Holland, 1968).

[10] Massachusetts Rate Setting Commission, "Executive Summary - FY 1981 Groups of Hospitals", (internal unpublished document of MRSC, 1980).

[11] Massachusetts Rate Setting Commission, Hospital Bureau, "Grouping of Hospitals for Purposes of Determining Reasonable Cost Levels", Document No. 114.1 CMR, Rate Setting Commission, 1980.

[12] Massachusetts Rate Setting Commission, Commonwealth of Massachusetts Hospital Uniform Reporting Manual (Comm. of Massachusetts Publication: #10865-202-130-9-78-C.R., 1978).

[13] Sherman, H.D., "Identifying Inefficiencies in Multiple Output-Multiple Input Organizations", Sloan School of Management, M.I.T. Working Paper #1316-82, Cambridge, Mass., February 1982.

[14] Sherman, H.D., Measurement of Hospital Technical Efficiency: A Comparative evaluation of Data Envelopment Analysis and other Efficiency Measurement Techniques for Measuring and Locating Inefficiency in Health Care Organizations", unpublished Doctoral Dissertation Harvard Graduate School of Business Administration, 1981.

[15] U.S General Accounting Office, Report to Congress - Rising Hospital Costs Can be Restrained by Regulating Payments and Improving Management HRD-80-72 (Washington, DC: U.S. General Accounting Office, September 19, 1980).

[16] Weiner, S.M., "External Incentives for Institutional Productivity - The Role of Planning, Regulation, and Private Initiatives in the Hospital Setting", Paper presented to the Conference on Incentives for Improving Productivity in Health Care, The National Council on Health Planning and Development, January 31-February 1, 1980.