Evaluating Hospital's Units Efficiency: An application of Data Envelopment Analysis

Muhammad Atif [1], Umair Ahmed [2] & Dr. Naveed [3]

[1] M.Phil. Scholar – Abasyn University of Science & IT, Peshawar
[2] Lecturer In Management Sciences- Qurtuba University of Science & IT, Peshawar
[3] Assistant Professor - Qurtuba University of Science & IT, Peshawar

ABSTRACT

Data Envelopment Analysis (DEA) is a method based on linear programming that has been extensively applied to measure the relative efficiency of different hospitals, units, organizations, departments etc. There is an increasing trend of investigating the efficiency and performance level of public sector and non-profit organizations like health services sector. In this regard, Data Envelopment Analysis (DEA) approach is proven to be very helpful by examining the common inputs and outputs for different units. The main aim of this paper is to measure the relative efficiency of different departments of Lady Reading Hospital (LRH) Peshawar by applying DEA technique. Similar inputs and outputs were measured for all the selected six departments of the hospital. Linear program was developed for all inputs and outputs and were put in TORA software. The results obtained from the software proved that all the selected six units of hospital were found efficient and it is recommended to maintain the consistency of efficiency and stability.
Keywords: Data Envelopment Analysis, Lady Reading Hospital, Relative Efficiency, Hospital, Units.

1. Introduction:

It is common sight in most of the under developed and developing countries, where patients waiting in long queues and strive to be seen by a doctor and treated with the available limited health facilities in both public and private hospitals. Although, both types of hospitals always strive for finding human resources in the form of doctors, nurses and other technical staff, because of certain factors there is always need for more drugs, beds and doctors at the hospital.

Because of such situations, there is always possibility of misuse or inefficient usage i-e underutilization of available resources. Such underutilization or misuse causes loss of human lives and increase mortality rates and panics especially at public hospitals. While the doctors and nurses often seems helpless to save their lives, because the available limited resources are not allocated in right proportion. There is always possibility of inefficiency in allocating resources in between hiring of more staff such as doctors, nurses, technical staff etc. or spending resources on more facilities i.e. beds, drugs, and other technical equipment (Egger 2005).

In the case of such inefficiencies and wastefulness, the cost is often born by patients and general public, especially those who pay directly on the occasion in the hope of best optimum services. The patients grieve more because of inefficiency and wastefulness, a major part of their income is

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spent on low quality health services including risks to human life and waste of precious time. In such situations, health services, overall, are negatively perceived by general public with adverse feedback.

Many under developing countries are unsuccessful to achieve a standard health system because of lack of resources and utilization of available resources efficiently. Besides poor education infrastructure and education rates does not provide required job skills and there is often need for more doctors and other relevant staff in the health units.

Ityavyar (1988) argues that it is necessary to utilize resources efficiently in any sector or system of the society with special regard to health sectors because of risks to human lives. The author further argues, that it is important to invest and allocate the resources to health sector to reduce mortality rate and sustain a healthy society.

1.2 Purpose of the study:

The researchers developed a method for evaluating the comparative efficiency of different departments or units of an organization or comparing performance of different organizations. All the departments, unit or organizations have same inputs and outputs that is to be analyzed.

For this purpose, the aim of this research paper is to investigate the performance of the different departments of Lady Reading Hospital by using the Data Envelopment Analysis (DEA), which is a best method for examining the comparable inputs and outputs of different departments of the said Hospital. By applying the technique of Data Envelopment Analysis (DEA), the obtained results can also be helpful in improving the performance of evaluated departments of the hospital. This paper is the first attempt to evaluate the efficiency of LRH Peshawar via DEA method.

2. Literature Review:

Many researchers have been conducted research on the significance of efficiency in hospitals. Most of the researches were focused on getting the maximum output with the available scarce inputs (Sorkis and Talloru, 2002).

Research led by Park et.al. (2011) had the main objectives and purpose to study the efficiency of a Hospital in Colorado by using the method of Data Envelopment Analysis (DEA). The study mainly concentrated on revenue generation of hospital and utilization of available resources.

Al-Shayea (2011) applied DEA tool to measure and analyze the relative efficiencies of different departments of King Khalid University Hospital that offers comparable facilities with the help of one year available data. The outcome of the study showed that only two departments out of nine were operating 100% efficiently with available resources.

Using similar technique of DEA, M. Sahin, Gok and Sezen (2011) evaluated comparative efficiency between public and private hospitals in Turkey over data from period between 2001-06. The results of the study concluded that public hospitals were performing efficiently in comparison to private hospitals. The reasons identified for efficiently performance of public hospitals were health reforms introduced by the government.

Haron and Chellakumar (2012) investigated the performance of small, medium and large size manufacturing companies in Kenya by using the technique of Data Envelopment Analysis (DEA). After applying DEA technique, it has been proved that small-medium Enterprizes performed better as compare to the medium-sized and large-sized companies. The data obtained from companies sources for the period of three years from 2009 to 2011.

Al-Najjar and Al-Jaybajy (2012) analyzed, using DEA technique, oil refineries in Iraq over the data obtained from period between 2009-10. The purpose of the study were to identify inefficient refineries that were wasting resources. The outcome of the study proved that nearly half of the refineries were performing inefficiently and wasting resources. However as the data of the year 2010 evaluated, it was noted by the authors that more than 58% were performing well.

Above in view of the previous literature, the researchers have conducted studies to measure the efficiency of health units and other organization over comparative basis using DEA technique. This reflects the importance of the current study that attempts to measure the relative efficiency of different departments of Leady Reading Hospital, Peshawar.

2.1 Data Envelopment Analysis (DEA):

Data Envelopment Analysis (DEA) is a technique that is used to measure the efficiency with compare to other units/organization with the selected similar inputs and outputs (Taylor, 2001). Data Envelopment Analysis is a best tool of linear programming to measure the relative efficiency with the given available inputs and outcome of a particular or different units (SCRC, 1997).

Every organization, by using their inputs like, employees, raw material, machinery, budget etc. generate multiple outputs such as profit, market share, growth etc. By using the available inputs, it is a quite challenging for a firm to use the inputs efficiently, to get the desirable outcomes. In this regard, the technique of Data Envelopment Analysis is proved to be helpful (David T. Boyd, Larry A. Kronk, Sanithia C. Boyd 2006)

3. Research Method:

The main aim of the Data Envelopment Analysis (DEA) technique is to measure the relative inefficiency of the selected Decision Making Units (Charnes et. al., 1994). The method for solving the problem of linear programming was advanced by Banker, Charnes and Cooper (BCC Model) for the purpose to minimize the given inputs resources which is represented by E. Thus the objective function is as follows:

Min E

After developing the objective function, the first constraint will be called composite constraint, which is the weight (g) each, of each particular unit. The weight of all units is set to be equal to 1, which is given below:

g1 + g2 + g3 + g4 …n = 1

After developing composite constraint, linear program has to be developed for various similar inputs and outcomes for each selected unit, to measure the relative efficiency. The linear programming model for all the similar inputs and outputs can be written in the following way:

For Output Variables:

Output for the Composite Department	≥	Output for County Department

For Input Variables:

Input for the Composite Department	≤	Resources available to the Composite Department

If the outcome for the objective function "E" is below 1, the particular unit can be proven as an inefficient unit as compare to other units, or otherwise. This also shows that the underutilization of inputs by a particular department.

By using the DEA method for the purpose of measuring relative efficiency, it is require that all the inputs and outcome of all selected units must be nonnegative (Alan Stainer 1997) (AL-Shammari, 1999).

3.1 Problem formulation:

The efficiency of the following six departments of the Lady Reading Hospital Peshawar will be measured by using the DEA Model;

1. Cardiology

2. Pediatrics

3. ENT (Ear, Nose & Throat)

4. Endocrinology

5. Gynecology

6. Psychiatry

Four similar inputs were selected to measure the efficiency of each department. These inputs are as follows:

1. The total number of Consultants (Specialists) employed in each selected department.

2. The total number of Doctors (Medical Officers) employed in each department.

3. The total number of Nursing staff in each department

4. The total number of patient beds available in each department.

Two similar outputs were selected to investigate the performance of each department of the hospital LRH. The outputs are given below:

1. The total number of Patient served on monthly basis in each department.

2. The total number of Doctors trained (TMO) in each department.

Linear program was developed for the given inputs and outputs of all the selected departments of LRH. The mathematical form of the problem which is proposed by American authors Anderson et al. (2012) is given below.

Let C1 is Cardiology, P2 is Pediatrics, E3 is ENT, EN4 is Endocrinology, G5 is Gynecology and S6 is Psychiatry.

3.3 Objective Function:

Objective is to minimize and efficiently use of the selected inputs so that all the departments of the Hospital serve the patients in a better way.

i.e.   Min E

3.3.1 Composite Constraints for all six departments of the hospital LRH:

$WC1 + WP2 + WE3 + WEN4 + WG5 + WS6 = 1$

3.3.2 Mathematical form of Inputs Measures for C1 (Cardiology):

a.   Number of Consultants (Specialists): $08C1 + 15P2 + 04E3 + 04EN4 + 23G5 + 04S6 \geq 08$

b.   Number of Doctors (Medical officers): $03C1 + 01P2 + 01E3 + 02EN4 + 01G5 + 01S6 \geq 03$

c.   Number of Nurses: $12C1 + 68P2 + 14E3 + 10EN4 + 66G5 + 18S6 \geq 12$

d.   Number of Beds available: $43C1 + 204P2 + 20E3 + 22EN4 + 230G5 + 20S6 \geq 43$

3.3.4 Mathematical form of Outputs Measures for C1 (Cardiology):

a.   Number of Doctors Trained (TMO): $30C1 + 30P2 + 02E3 + 0EN4 + 38G5 + 10S6 \leq 30E$

b.   Patients served (monthly): $382C1 + 1069P2 + 454E3 + 119EN4 + 4401G5 + 82S6 \leq 382E$

3.3.5 Mathematical form of Inputs Measures for P2 (Pediatrics):

a.   Number of Consultants (Specialists): $08C1 + 15P2 + 04E3 + 04EN4 + 23G5 + 04S6 \geq 15$

b.   Number of Doctors (Medical officers): $03C1 + 01P2 + 01E3 + 02EN4 + 01G5 + 01S6 \geq 01$

c.   Number of Nurses: $12C1 + 68P2 + 14E3 + 10EN4 + 66G5 + 18S6 \geq 68$

d.   Number of Beds available: $43C1 + 204P2 + 20E3 + 22EN4 + 230G5 + 20S6 \geq 204$

3.3.6 Mathematical form of Outputs Measures for P2 (Pediatrics)**:**

a. Number of Doctors Trained (TMO): $30C_1 + 30P_2 + 02E_3 + 0EN_4 + 38G_5 + 10S_6 \leq 30E$

b. Patients served (monthly): $382C_1 + 1069P_2 + 454E_3 + 119EN_4 + 4401G_5 + 82S_6 \leq 1069E$

3.3.7 Mathematical form of Inputs Measures for E3 (ENT)**:**

a. Number of Consultants (Specialists): $08C_1 + 15P_2 + 04E_3 + 04EN_4 + 23G_5 + 04S_6 \geq 04$

b. Number of Doctors (Medical officers): $03C_1 + 01P_2 + 01E_3 + 02EN_4 + 01G_5 + 01S_6 \geq 01$

c. Number of Nurses: $12C_1 + 68P_2 + 14E_3 + 10EN_4 + 66G_5 + 18S_6 \geq 14$

d. Number of Beds available: $43C_1 + 204P_2 + 20E_3 + 22EN_4 + 230G_5 + 20S_6 \geq 20$

3.3.8 Mathematical form of Outputs Measures for X3 (ENT)**:**

a. Number of Doctors Trained (TMO): $30C_1 + 30P_2 + 02E_3 + 0EN_4 + 38G_5 + 10S_6 \leq 02E$

b. Patients served (monthly): $382C_1 + 1069P_2 + 454E_3 + 119EN_4 + 4401G_5 + 82S_6 \leq 119E$

3.3.9 Mathematical form of Inputs Measures for EN4 (Endocrinology)**:**

a. Number of Consultants (Specialists): $08C_1 + 15P_2 + 04E_3 + 04EN_4 + 23G_5 + 04S_6 \geq 04$

b. Number of Doctors (Medical officers): $03C_1 + 01P_2 + 01E_3 + 02EN_4 + 01G_5 + 01S_6 \geq 02$

c. Number of Nurses: $12C_1 + 68P_2 + 14E_3 + 10EN_4 + 66G_5 + 18S_6 \geq 10$

d. Number of Beds available: $43C_1 + 204P_2 + 20E_3 + 22EN_4 + 230G_5 + 20S_6 \geq 22$

3.3.10 Mathematical form of Outputs Measures for EN4 (Endocrinology)**:**

a. Number of Doctors Trained (TMO): $30C_1 + 30P_2 + 02E_3 + 0EN_4 + 38G_5 + 10S_6 \leq 0E$

b. Patients served (monthly): $382C_1 + 1069P_2 + 454E_3 + 119EN_4 + 4401G_5 + 82S_6 \leq 119E$

3.3.11 Mathematical form of Inputs Measures for G5 (Gynae)**:**

a. Number of Consultants (Specialists): $08C_1 + 15P_2 + 04E_3 + 04EN_4 + 23G_5 + 04S_6 \geq 23$

b. Number of Doctors (Medical officers): $03C_1 + 01P_2 + 01E_3 + 02EN_4 + 01G_5 + 01S_6 \geq 01$

c. Number of Nurses: $12C_1 + 68P_2 + 14E_3 + 10EN_4 + 66G_5 + 18S_6 \geq 66$

d. Number of Beds available: $43C_1 + 204P_2 + 20E_3 + 22EN_4 + 230G_5 + 20S_6 \geq 230$

3.3.12 Mathematical form of Outputs Measures for G5 (Gynae)**:**

a. Number of Doctors Trained (TMO): $30C_1 + 30P_2 + 02E_3 + 0EN_4 + 38G_5 + 10S_6 \leq 38E$

b. Patients served (monthly): $382C_1 + 1069P_2 + 454E_3 + 119EN_4 + 4401G_5 + 82S_6 \leq 4401E$

3.3.13 Mathematical form of Inputs Measures for S6 (Psychology):

a.   Number of Consultants (Specialists): $08C1 + 15P2 + 04E3 + 04EN4 + 23G5 + 04S6 \geq 04$

b.   Number of Doctors (Medical officers): $03C1 + 01P2 + 01E3 + 02EN4 + 01G5 + 01S6 \geq 01$

c.   Number of Nurses: $12C1 + 68P2 + 14E3 + 10EN4 + 66G5 + 18S6 \geq 18$

d.   Number of Beds available: $43C1 + 204P2 + 20E3 + 22EN4 + 230G5 + 20S6 \geq 20$

3.3.14 Mathematical form of Outputs Measures for S6 (Psychology):

a.   Number of Doctors Trained (TMO): $30C1 + 30P2 + 02E3 + 0EN4 + 38G5 + 10S6 \leq 10E$

b.   Patients served (monthly): $382C1 + 1069P2 + 454E3 + 119EN4 + 4401G5 + 82S6 \leq 82E$

The above linear program were entered in the TORA software to find out that the selected Department is inefficient or not. If the value of **E** in TORA software is 01, it means that the selected Department is efficient or otherwise. The results obtained from TORA software for all departments are summarized in table 01 below:

Table 01: TORA output for Efficiency of all Departments of Leady Reading Hospital, Peshawar

-	Departments						Slack - / Surplus + for all Departments
	C1	**P2**	**E3**	**EN4**	**G5**	**S6**	
Objective value (Min)	1.00	1.00	1.00	1.00	1.00	1.00	-
Constraints							
Number of Consultants	08	15	04	04	23	04	0
Number of Doctors	03	01	01	02	01	01	0
Nursing staff	12	68	14	10	66	18	0
Number of Beds	43	204	20	22	230	20	0
Doctors Trained	30	30	02	0	38	10	0
Patients served	382	1069	454	119	4401	82	0

4. Conclusion:

As shown in previous section, a total of six Departments were sampled from Leady Reading Hospital, Peshawar and were studied by using the technique of Data Envelopment Analysis. The results generated by the TORA software shows that all the six departments were found efficient, specifically, with the given inputs and outputs in the study. The data for all inputs and outputs were taken from Leady Reading Hospital's personal record through Right to Information Commission (RTI), Khyber Pakhtunkhwa. A unit is said to be efficient, when it is providing maximum level of output with the minimum number of inputs.

5. Policy and Recommendations:

Pakistan is a developing country and the population is increasing rapidly. Therefore there is always pressure on available resources such as health and education. It is imperative for the country to increase the available resources and introduction of reforms for optimum health services for the inhabitants of the country.

Lady Reading Hospital is the major hospital in the province of Khyber Pakhtunkhwa. The hospital is often under pressure because of heavy load of patients. Therefore it is necessary for the government to develop comprehensive policy for efficiency utilization of health resources for best outcome. By conducting this study, it was noticed that the efficient utilization of resources were result of recent health reforms introduced by the government to streamline health services in the province.

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