A SYSTEMATIC REVIEW OF HOSPITAL INPUTS AND OUTPUTS IN MEASURING TECHNICAL EFFICIENCY USING DATA ENVELOPMENT ANALYSIS

Azreena E.¹,², Muhamad Hanafiah Juni ³* & Rosliza A.M.³

¹DrPH candidates, Department of Community Health, Faculty of Medicine, Universiti Putra Malaysia
²Ministry of Health Malaysia
³Department of Community Health, Faculty of Medicine, University Putra Malaysia

*Corresponding author: Associate Professor Dr. Muhamad Hanafiah Juni
Department of Community Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia; Email: hanafiah_juni@upm.edu.my

ABSTRACT

There are many studies on technical efficiency conducted on various firms including hospitals in line with the demand to consume resources efficiently. In measuring technical efficiency of a hospital, there are many methods that can be applied and Data Envelopment Analysis is one of them. Even though Data Envelopment Analysis is widely used by the researchers, this method has its limitations. One of the limitations is that it is very model specific and the results may be influenced by the inputs and outputs selection. Hence, it is very important to identify the right hospitals’ inputs and outputs that are commonly used in measuring hospital’s technical efficiency using Data Envelopment Analysis to ensure accuracy of the results. Therefore, this study is aimed to identify the hospitals’ inputs and outputs commonly used in measuring hospital technical efficiency using Data Envelopment Analysis. Two databases, namely Pubmed and CINAHL were used for searching articles between 2007 to 2017. The search were based on the inclusion criteria and the search terms including hospitals’ inputs, hospitals’ outputs, hospitals’ technical efficiency, Data Envelopment Analysis and DEA were used. Twenty-four studies were reviewed and assessed in the final stage. In conclusion, the inputs that were commonly considered by researchers in analysing hospital technical efficiency using Data Envelopment Analysis include the number of doctors, number of nurses and number of beds. Other inputs include the number of other medical staffs, number of other non-medical staffs, number of total employed staffs, total expenditure, total non-labour cost, value of fixed capital and cost of drug supply. However, the hospitals’ outputs that were commonly considered by researchers in analysing hospital technical efficiency using Data Envelopment Analysis include the total inpatients, average daily admission, number of outpatients, number of surgeries, number of deliveries, the average length of stay, bed occupancy rate and total revenue. Even though this study has identified the commonly used inputs and outputs in measuring hospitals’ technical efficiency using Data Envelopment Analysis which can be used in conducting future research, the selection of inputs and outputs should take into account the objectives of the hospital itself.

Keywords: Hospital’s inputs, hospital’s output, technical efficiency, data envelopment analysis, DEA
1.0 Introduction

There are many studies on technical efficiency on various types of firms worldwide in line with the demand to consume resources efficiently. Technical efficiency can be defined as producing the maximum output from a given amount of input or producing a given output with minimum input (Farrell, 1957). Technical efficiency refers to the producers’ choices to allocate the resources to obtain the maximum possible output from given inputs, or to use the minimum possible inputs in the production of a given level of outputs and it can be defined as either output-oriented or input-oriented (Khumbakar & Lovell, 2000). Technical efficiency can be measured in any organisation including hospitals.

Over the years, hospital efficiency has been an issue of interest among the researchers. There are a number of methods that can be used in order to measure hospitals’ technical efficiency. Classically, there are two main approaches in measuring hospital efficiency namely; the non-parametric and parametric approach (Hollingsworth, 2003). One of the commonly used non-parametric approaches is the Data Envelopment Analysis (DEA) while the parametric approaches include the Stochastic Frontier Analysis (SFA), Cobb-Douglas functional form and the Translog formula (Katharakis, Katharakis & Katostaras, 2014). DEA has been one of the commonly used methods by many researchers in measuring hospital technical efficiency due to its advantages over the other methods.

1.1 Data Envelopment Analysis

DEA is a non-parametric approach that relies on mathematical programming and it is mainly the resolution of a set of problems via the maximisation or minimisation of a given objective subject to some constraints (Sarafidis, 2002). DEA was originally developed by Charnes, Cooper and Rhodes as a technique for measuring and comparing the relative efficiency of a set decision making units (DMUs) (Sengupta, 1989). The classical DEA model can be illustrated as below,

\[ \text{Efficiency} = \frac{\text{output}}{\text{input}} \]

DEA applies two frameworks namely the Constant Return to Scale (CRS) model and the Variable Returns to Scale (VRS) model (Aljunid, Moshiri & Ahmed, 2013). In CRS model, the producers are able to scale the inputs and outputs linearly without increasing or decreasing efficiency (Aljunid et al., 2013). In the VRS model developed by the Banker, Charnes and Cooper, it allows for varying returns to scale where as the organisation changes its scale of operations, its efficiency will either increase or decrease (Banker, Charnes & Cooper, 1984).

There are a number of DEA strengths that made it is popular among the researchers. One of the strengths is its’ ability to handle multiple inputs and multiple outputs and they can have different units of measurement (Kahraman & Toga, 1998). Besides that, the decision making units are directly compared against a peer or a combination of peers (Kahraman & Toga, 1998). However, there are also some limitations related to DEA, one of them is that it does not allow for error estimation and any distance from the efficiency frontier is interpreted as inefficiency (Bezat, 2009). DEA is also very model specific and the efficiency measurement can differ depending on the input-oriented versus output-oriented models and the variable specification (Bezat, 2009). Furthermore, measurements derived from DEA are only valid in a sample as DEA is good at estimating “relative” efficiency and they will only reflect the dispersion of efficiencies within each sample (Bezat, 2009).
As DEA is very model specific, the appropriate variables selections in the analysis is very crucial to ensure the accuracy of the results. This is because the selection and the number of inputs and outputs included in the model may affect the distribution of efficiency (Magnussen, 1996). There are many potential measurements of hospital’s inputs that can be classified as labour, capital and supplies (Zere et al., 2006). In most studies, labour input is represented by the number of staffs while the capital input is represented by the number of beds (Zere et al., 2006). Ideally, the ultimate hospital output measurement is the improvement in health which is difficult to be measured (Katharakis et al., 2014). Therefore, in many studies, hospital output is commonly measured by the intermediate output, such as number of cases treated, number of procedures performed and bed occupancy that supposedly improve health status (Moshiri et al., 2010). However, the selection of output to be studied depends on the objectives of the hospital and on the level of measurement activities (Moshiri et al., 2010). Therefore, this article is aimed to identify the inputs and outputs commonly used in measuring hospital technical efficiency using DEA.

2.0 Materials and Methods

2.1 Search Strategy and Selection Criteria

Hospitals’ inputs and outputs used in the hospitals technical efficiency measurement using DEA in the published literature as well as from the published hardcopies were searched. PubMed and CINAHL databases were searched for this systematic review. Bibliographies of retrieved articles were also searched for additional relevant publications. In order to be eligible for inclusion, a published study had to present information on the inputs and outputs used in measuring hospitals’ technical efficiency using DEA method. Studies using different methods in the hospitals’ technical efficiency measurement were excluded. The title and abstract of the studies were screened for relevance. The full articles for the relevant studies were analysed and those fulfilled the inclusion criteria were selected. The databases were searched to include studies between January 2007 and current date and limited to journals published in English language. Search terms included hospitals inputs, hospitals outputs, hospitals technical efficiency, Data Envelopment Analysis and DEA.

2.2 Quality Assessment and Extraction

The title, abstract and full text of each articles retrieved were screened by one reviewer. A review with a group of panel experts on the relevance of the articles was conducted to ensure an agreement on the articles included. The data were extracted by the main researcher. Duplicated publications were removed by comparing the author’s name, studies’ name and the year of publication.

2.3 Data Synthesis

The results were synthesised and summarised in a logic framework. The logic framework shows various findings obtained and narratively classified the studies by the number of hospitals and the hospitals types, inputs and outputs used, as well as the studies’ findings.
3.0 Results and Discussion

Initially the search returned a total of 279 articles from two databases and other resources. The search process involved the assessment of the title followed by the abstract. If the title or the abstract were not related to the study objective, the articles were excluded from further review. After screening for the eligible articles based on the inclusion criteria, only a total of 24 articles with full text were included in the final stage. Figure 1 describes the flow diagram on the search strategy. The assessments were made in terms of the articles’ content including the introduction, results and discussion. Table 1 shows the summary on the hospitals inputs and outputs in measuring hospital technical efficiency using DEA.

3.1 Study Location and Hospitals’ Description

The studies included those conducted in the United States, Italy, Greece, Iran, United Arab Emirates, Turkey, Uganda, Zambia, Republic of Botswana, Eastern Ethiopia, Eritrea, China, India and Malaysia. Most of the studies came from Iran with a total of five studies. There were a number of hospitals types that were selected as the DMUs in these studies, including the public hospitals, private hospitals, university hospitals, charity hospitals, church mission hospitals, military hospitals and the maternity and child health hospitals (MCHH). A total of twelve studies included the public hospitals as the DMUs, three studies included university hospitals, three studies included combination of private hospitals and public hospitals, one study included public and university hospitals, two studies included a combination of public, private and church mission hospitals, one study included public, private and university hospitals, one study included private, public, charity, military and teaching hospitals and only one study included the MCHH. The number of DMUs in these studies ranged between 12 DMUs, the minimum up to 3391 DMUs, the maximum.

3.2 Study Type

It was found that there was variation in the DEA model used for analysis in the studies, namely the CCR model also known as CRS model and the BCC also known as the VRS model. Majority of the studies, 13 studies used the BCC or VRS model, 2 studies used CCR or CRS model while another 9 studies used both CCR and BCC model in their analyses. The orientation of the DEA was also observed to be varied between studies, either the input-oriented DEA or output-oriented DEA or both which is based on the study objectives. Besides, there were also a mixture between one-stage DEA and two-stage DEA employed by the studies. In the one-stage DEA, only the efficiency score measurement was carried out while in the two-stage DEA, the determinants of the efficiency were also identified.
3.3 Flowchart of The Search Strategy

**IDENTIFICATION**

Articles identified through database (PUBMED and CINAHL) and through other sources: n=279

→ 30 duplicates removed

**SCREENING**

Articles retrieved and screened n=249

→ 209 articles excluded based on title and abstract

**ELIGIBILITY**

Full text articles assessed for eligibility n=40

→ 16 full articles excluded:
- Comparing DEA with other methods
- Different decision making units used instead of hospitals.
- Different type of efficiency instead of technical efficiency

**INCLUDED**

Total studies included n=24

---

**Figure 1: PRISMA Flow Diagram on The Process of Study Selection**
<table>
<thead>
<tr>
<th>Author Year Location</th>
<th>Number and Type of Hospitals</th>
<th>Inputs</th>
<th>Outputs</th>
<th>Findings on hospital technical efficiency (TE)</th>
<th>DEA model and other analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campanella et al. (2017) Italy</td>
<td>50 Italian public hospital trusts (PHTs) in 2010.</td>
<td>-Number of beds per patient admitted -Number of medical doctors per patient admitted -Number of nurses per patient admitted</td>
<td>-30-day risk-adjusted mortality for acute myocardial infarction -30-day risk-adjusted mortality for congestive heart failure -30-day risk-adjusted mortality for pneumonia</td>
<td>8% out of the 50 PHTs in Italy were efficient with average technical efficiency score of 77%.</td>
<td>This study employed input oriented CRS DEA. This study also employed Tobit regression to determine the determinants for inefficiency.</td>
</tr>
<tr>
<td>Farzianpour et al. (2017) Iran.</td>
<td>19 hospitals affiliated to Tabriz University of Medical Sciences in Iran.</td>
<td>- Specialist physician - General physician - Total staffs other than physicians - Number of active beds</td>
<td>- Number of outpatients - Bed occupancy rate (BOR)</td>
<td>In 2013, 6 (31%) out of the 19 hospitals were technically efficient. - In 2014, 7 (36.84%) hospitals were technically efficient.</td>
<td>This study employed input and output-oriented VRS DEA.</td>
</tr>
<tr>
<td>Flokou et al. (2017) Greece.</td>
<td>107 Greek National Health System (NHS) hospitals between 2009 to 2013.</td>
<td>- Number of full time equivalent (FTE) physicians - Number of FTE other</td>
<td>-Number of inpatient cases -Total number of surgeries -Number of outpatient visits</td>
<td>Year 2011 within window 2010–11 accommodates the highest number of fully efficient units for the hospital</td>
<td>This study employed input-oriented, VRS window DEA model.</td>
</tr>
<tr>
<td>Author</td>
<td>Year Location</td>
<td>Number and Type of Hospitals</td>
<td>Inputs</td>
<td>Outputs</td>
<td>Findings on hospital technical efficiency (TE)</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Jia &amp; Yuan.</td>
<td>(2017) China.</td>
<td>5 public hospitals in Shanghai, China in 7 years period (3 years before, during and 3 years after establishment of branched hospitals).</td>
<td>health professionals - Number of hospital beds</td>
<td>groups B with 85-190 beds, C with 190-400 beds and D with &gt;400 beds. There are 42.4%, 53.3% and 65.2% of the total number of units for groups B, C and D respectively. For group A with &lt;85 beds, the highest number of fully efficient units appears in year 2013 within windows 2012–13, accounting for 52.4%.</td>
<td>Results showed an overall upward tendency of TE in these five hospitals. Three years before establishing branched hospitals 40% of the hospitals achieved TE. During the establishment year, TE was lower than the year before for all these 5 hospitals. A year after the establishment, 40% of the hospitals had TE higher than the current year of establishment 2 years after the establishment, only 20% had a lower technical efficiency compared to the establishment year, while 3 years after the establishment, all these five hospitals had a higher TE than that in the establishment year.</td>
</tr>
<tr>
<td>Mahate, Hamidi &amp;</td>
<td>96 private and governmental hospitals in UAE.</td>
<td>- Number of FTE doctors - Number of FTE dentists - Number of FTE nurses - Number of inpatients within a year - Number of outpatients</td>
<td>- The actual number of beds - The actual number of staff - The number of discharged patients - The average days of hospitalisation</td>
<td>One third of the UAE hospitals were technically efficient.</td>
<td>- This study employed output-oriented CCR and BCC model.</td>
</tr>
<tr>
<td>Author Year Location</td>
<td>Number and Type of Hospitals</td>
<td>Inputs</td>
<td>Outputs</td>
<td>Findings on hospital technical efficiency (TE)</td>
<td>DEA model and other analysis</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------</td>
<td>--------</td>
<td>---------</td>
<td>-----------------------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>(2017) United Arab Emirates (UAE).</td>
<td>54 of Tehran public hospitals in Iran (with three ownership of university, private and social security).</td>
<td>and midwives - Number of FTE pharmacists and allied health professionals - Number of FTE administrators and other staff - Number of hospital beds</td>
<td>- Average length of stay (ALOS)</td>
<td>- This study employed input oriented VRS model - This study also examines the relationship between peripheral variables, background characteristics of hospitals, and the TE scores using the Mann–Whitney U-test and the Kruskal–Wallis test.</td>
<td>BCC models.</td>
</tr>
<tr>
<td>Kalhor et al. (2016). Iran.</td>
<td>17 hospitals including 14 public regional referral hospitals and 3 large private not for profit hospitals in Uganda.</td>
<td>- Total number of full time medical doctors - Total number of FTE nurses - Number of supporting medical personnel - Number of beds</td>
<td>- Number of patient days - Number of outpatient visits - Number of patients receiving surgery - Average length of stay</td>
<td>68.5% of the hospitals were inefficient. The average score of technical efficiency of the hospitals assuming variable return to scale was 81.9%.</td>
<td>- This study employed output-oriented with VRS model - This study also employed Tobit regression to determine the determinants for inefficiency.</td>
</tr>
<tr>
<td>Mujasi, Asbu &amp; Puig-Junoy. (2016). Uganda.</td>
<td>32 county-level</td>
<td>- Total expenditure</td>
<td>- Total revenue</td>
<td>Based on CRSTE, 16 out of 32</td>
<td>-This study employed</td>
</tr>
<tr>
<td>Author Year Location</td>
<td>Number and Type of Hospitals</td>
<td>Inputs</td>
<td>Outputs</td>
<td>Findings on hospital technical efficiency (TE)</td>
<td>DEA model and other analysis</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------------------</td>
<td>--------</td>
<td>---------</td>
<td>-----------------------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>(2016). China.</td>
<td>Maternal and Child Health Hospitals (MCHH) of Guangxi, China.</td>
<td>- Number of doctors - Number of nurses - Number of open beds</td>
<td>- Number of outpatients and emergency visits - Number of discharged patients</td>
<td>MCHHs were efficient in Guangxi, China while based on VRSTE, 19 out of 32 MCHHs were efficient.</td>
<td>both CRS and VRS model - Tobit model was used to analyse main factors affecting efficiency.</td>
</tr>
<tr>
<td>Cheng et al. (2015). China.</td>
<td>114 county hospitals in Henan province of China.</td>
<td>- Number of physicians - Number of nurses - Actual number of open beds</td>
<td>- Number of outpatient and emergency visits - Number of inpatient days</td>
<td>Based on CRSTE, in 2010, 2011 and 2012, out of the 114 hospitals, 2 (1.8%), 2 (1.8%) and 10 (8.8%) hospitals, respectively, were defined as technically efficient. Based on VRSTE, in 2010, 2011 and 2012, 6 (5.3%), 9 (7.9%) and 18 (15.8%) hospitals, were technically efficient respectively.</td>
<td>This study employed input-oriented CRS and VRS model. - Malmquist index was used to calculate productivity changes over time. - Tobit regression model was used to relate the TE to the explanatory variables.</td>
</tr>
<tr>
<td>Applanaidu et al. (2014). Malaysia.</td>
<td>9 Public district hospitals in Kedah.</td>
<td>- Number of doctors - Number of nurses - Number of beds</td>
<td>- Number Outpatient (OP) visits - Daily average number of inpatient admission, (IP) - Number of surgeries - Number of deliveries</td>
<td>74% of DMUs were technically efficient - TE score for the inefficient hospitals ranging between 0.780 to 0.991</td>
<td>This study employed input-oriented BCC model.</td>
</tr>
<tr>
<td>Harrison &amp; Meyer. (2014). United States.</td>
<td>165 federal hospitals in 2007 and 157 in 2011.</td>
<td>- Operating expenses - Hospital beds - Full-time employees</td>
<td>- Inpatient stays - Surgical procedures - Outpatient visits</td>
<td>In 2007, 25 (15.2%) out of 165 federal hospitals were technically efficient, with average TE score of 81%. In 2011, 21 (13.4%) out of 157 of the federal hospitals were technically efficient, with average TE score of 86%.</td>
<td>This study employed VRS input-oriented DEA model.</td>
</tr>
<tr>
<td>Samsudin et al. (2014).</td>
<td>25 Public hospitals in northern region of</td>
<td>- Number of doctors - Number of nurses</td>
<td>- Number Outpatient visits - Daily average number of</td>
<td>For specialist hospitals, in 2008, 2 out of 13 were found</td>
<td>This study employed input oriented model.</td>
</tr>
<tr>
<td>Author Year Location</td>
<td>Number and Type of Hospitals</td>
<td>Inputs</td>
<td>Outputs</td>
<td>Findings on hospital technical efficiency (TE)</td>
<td>DEA model and other analysis</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------------</td>
<td>--------</td>
<td>---------</td>
<td>-----------------------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Malaysia.</td>
<td>Malaysia (Specialist and non-specialist hospitals in Perlis, Kedah, Pulau Pinang and Perak)</td>
<td>- Number of beds</td>
<td>inpatient admission - Number of surgeries - Number of deliveries</td>
<td>to be technically inefficient. In 2009 and 2010, increased to 3 and 7 hospitals respectively.</td>
<td>oriented BCC model. - It employed Tobit regression model to identify determinants of inefficiency.</td>
</tr>
<tr>
<td>Jat &amp; San Sebastian. (2013). India.</td>
<td>40 district hospitals in Madhya Pradesh, India.</td>
<td>- Number of doctors - Number of nurses - Number of beds</td>
<td>- Number of women with three completed antenatal check-ups - Number of deliveries - Number of caesarean-section deliveries - Number of women receiving post-natal care within 48 hours of delivery (PNCs) - Number of medical terminations of pregnancy (MTPs) - Number of male and female sterilizations - Number of inpatient admissions - Number of outpatient consultation</td>
<td>50% of the hospitals were technically efficient, with mean TE score of 0.9.</td>
<td>- This study employed input oriented BCC model. - This study only focused on maternal health services.</td>
</tr>
<tr>
<td>Kirigia &amp; Asbu. (2013). Eritrea.</td>
<td>19 public community hospitals in Eritrea in 2007.</td>
<td>- Number of doctors - Number of nurses and midwives - Number of laboratory physicians</td>
<td>-Number of outpatient visits -Number of inpatient discharges</td>
<td>Based on the CRSTE, 8 (42%) hospitals were technically efficient. However, from the VRSTE, 13 (68%) hospitals were technically efficient.</td>
<td>-This study employed the output-oriented CRD and VRS DEA model. - Tobit model was used.</td>
</tr>
<tr>
<td>Author Year Location</td>
<td>Number and Type of Hospitals</td>
<td>Inputs</td>
<td>Outputs</td>
<td>Findings on hospital technical efficiency (TE)</td>
<td>DEA model and other analysis</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------------</td>
<td>--------</td>
<td>---------</td>
<td>-----------------------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Yusefzadeh et al. (2013). Iran.</td>
<td>23 hospitals affiliated to Urmia University of Medical Sciences in the West Azerbaijan province of Iran, conducted in 2009.</td>
<td>- Number of operational beds and cots - Number of doctors - Number of active beds - Number of other personnel</td>
<td>- Number of patients admission - Occupied day beds</td>
<td>- 4 (17.4%) out of 23 hospitals were technically efficient and the average TE was 0.584.</td>
<td>- This study employed VRS DEA model.</td>
</tr>
<tr>
<td>Farzianpour et al. (2012). Iran.</td>
<td>16 teaching hospitals (9 specialised hospitals and 7 general hospitals) under Tehran University of Medical Sciences.</td>
<td>- Number of physicians - Number of practising nurses - Number of active beds</td>
<td>- Number of inpatients bed days - Number of outpatients - ALOS</td>
<td>- 9 (56.29%) out of the 16 hospitals were technically efficient, with the average technical efficiency of 0.958.</td>
<td>- This study employed both input and output oriented CRS and VRS DEA model.</td>
</tr>
<tr>
<td>Hu, Qi, &amp; Yang. (2012). China.</td>
<td>30 regional hospitals in China 2002 to 2008</td>
<td>- Number of doctors - Number of technicians - Number of staffs - Number of beds - Total fixed assets</td>
<td>- Emergency room visits - Total number of outpatients - Total number of inpatient days</td>
<td>- 2 (6.7%) out of 30 regional hospitals were technically efficient, (similar hospitals) between 2002 to 2008.</td>
<td>- This study employed the output-oriented CCR - Tobit model was used to identify the determinants of hospital efficiency.</td>
</tr>
<tr>
<td>Shahhoseini et al. (2011). Iran.</td>
<td>12 public and private hospitals in Iran. ( 1 charity hospital, 1 military hospital, 4 teaching hospitals and 6 clinical hospitals.</td>
<td>- Number of physicians - Number of nurses - Number of other professional - Number of active beds</td>
<td>- Inpatient bed days - ALOS - BOR rate - Outpatient visits - Number of surgeries</td>
<td>- 7 (58%) out of 12 hospitals were technically efficient. - Average TE score for the inefficient hospitals was 78.5%.</td>
<td>- This study employed input oriented CRS and VRS DEA model.</td>
</tr>
<tr>
<td>Sulku. (2011).</td>
<td>Public hospitals in 81 provincial markets in</td>
<td>- Number of beds - Number of primary care</td>
<td>- Number inpatient cases (case-mix adjusted)</td>
<td>- Only 1% increase of the mean pure technical efficiency is</td>
<td>- This study employed output oriented BCC</td>
</tr>
<tr>
<td>Author</td>
<td>Year Location</td>
<td>Number and Type of Hospitals</td>
<td>Inputs</td>
<td>Outputs</td>
<td>Findings on hospital technical efficiency (TE)</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------</td>
</tr>
<tr>
<td>Turkey.</td>
<td>Turkey in years 2001 and 2006.</td>
<td>- Number of specialists</td>
<td>- Physician - Number of specialists</td>
<td>- Outpatient visits - Total number of surgeries.</td>
<td>observed between 2001 and 2006.</td>
</tr>
<tr>
<td>Dash, Vaishnavi &amp; Muraleedharan (2010) India.</td>
<td>29 district hospitals of Tamil Nadu, India.</td>
<td>- Number of beds - Number of nursing staff - Number of assistant surgeons - Number of civil surgeons</td>
<td>- Number of inpatients - Number of outpatient - Number of surgeries - Number of emergency cases handled - Number of deliveries</td>
<td>- 15 (52%) out of 29 hospitals were technically efficient. - Average TE score for the inefficient hospitals was 80%.</td>
<td>- This study employed input oriented BBC model.</td>
</tr>
<tr>
<td>Gai et al. (2010). China.</td>
<td>All county hospitals (2,696) in 1993, (3,391) in 2005 in 31 provinces of China between 1993 to 2005.</td>
<td>- Number of medical staff - Number of beds - Value of fixed capital - Hospital expenditure</td>
<td>- Outpatient and emergency visits - Number of inpatients - Hospital revenue</td>
<td>- County hospitals in the eastern region have a higher pure technical efficiency score than those in the middle and western regions.</td>
<td>- This study employed CCR model and BCC model.</td>
</tr>
<tr>
<td>Tiotlego et al. (2010). Republic of Botswana.</td>
<td>21 (public, private and mission) hospitals in the Republic of Botswana.</td>
<td>- Number of clinical staffs - Number of beds</td>
<td>- Number of outpatient visits - Number of inpatient days</td>
<td>5 (24%), 5 (24%) and 8 (38%) hospitals were technically efficient in 2008, 2009 and 2010 respectively.</td>
<td>- This study employed CCR model and BCC model.</td>
</tr>
<tr>
<td>Masiye. (2007). Zambia.</td>
<td>30 hospitals throughout Zambia. 18 government-owned hospitals, 8 church mission hospitals and 4 private hospitals.</td>
<td>- Total non-labour cost - Number of medical doctors - Number of nursing and other clinical staffs - Number of non-clinical staffs</td>
<td>- Number of ambulatory care visits - Number of bed-days - Number of deliveries - Number of tests or operation performed</td>
<td>11 (40%) of the 30 hospitals were technically efficient, with mean efficiency score of 0.67.</td>
<td>- This study employed input oriented VRS DEA model.</td>
</tr>
</tbody>
</table>
3.4 Hospitals’ Inputs In Measuring Technical Efficiency Using Data Envelopment Analysis

From the analysis, it was found that there are a number of hospitals’ inputs that were used in measuring hospital technical efficiency. There are many potential measurements of hospital’s inputs that were commonly used by the researchers including the number of staffs as a proxy to the labour input and the number of beds as a proxy to the capital input (Zere et al., 2006). This can be seen in the studies analysed where among the commonly used inputs were the number of doctors, number of nurses and number of bed. These inputs were used by studies in Malaysia conducted by Applanaidu et al., in determining technical efficiency of 9 public district hospitals in Kedah, Malaysia as well as in study conducted by Samsudin et al., in determining technical efficiency of 25 public hospitals in northern region of Malaysia between 2008 to 2010 (Applainaidu et al., 2014 & Samsudin et al., 2014).

Similarly, number of doctors, number of nurses and number of beds were also widely used in studies on determining hospitals technical efficiency using DEA conducted in other countries, such as in Italy, United Arab Emirates, Iran, Uganda, Eritrea, China, India and Botswana (Campanella et al., 2017, Mahate et al., 2017, Kalhor et al., 2016, Farzianpour et al., 2017, Shahhoseini et al., 2011, Mujasi et al., 2016, Wang et al., 2016, Cheng et al., 2015, Hu et al., 2012, Jat & San Sebastian, 2013, Kirigia & Asbu, 2013, Dash et al., 2010 & Ttotlego et al., 2010). A more recent study in Iran by Farzianpour et al., conducted between 2013 to 2014 used number of specialist physician and number of general physician as separate inputs and number of nurses was included in the number of total of staffs other than physicians in their analysis (Farzianpour et al., 2017). Similarly, a study in Iran conducted in 2009 also included number of nurses in the number of other personnel as an input (Yusefzadeh et al., 2013).

A study in Turkey conducted between 2001 and 2006 used number of specialist and number of primary care physician as part of the inputs (Sulku, 2011). The use of number of staffs in these studies are supported by the findings from a recent study in China that found a significant ($P<0.001$), proportional relationship between the number of health professionals to the technical efficiency (Wang et al., 2016). Besides, the selection of number of beds as an input is also supported by a study finding in China that hospitals beds groups was positively associated with technical inefficiency ($P<0.001$) (Cheng et al., 2015).

There were also other inputs used in analysing technical efficiency of hospitals using DEA, such as number of other staffs. Studies by Flokou et al., in Greece between 2009 to 2013, Mahate et al., in UAE in 2012, Kalhor et al., in 2014 and Shahhoseini et al., in 2008 in Iran used number of other health professionals, number of pharmacies and allied health staffs or other medical staffs as the inputs for DEA (Flokou et al., 2017, Mahate et al., 2017, Kalhor et al., 2016 & Shahhoseini et al., 2011). A study in Eritrea used number of laboratory technicians as one of the inputs in the analysis (Kirigia & Asbu, 2013). Besides that, some other inputs used in the research were the number of FTE administrators and other staff by Mahate et al., in 2017 and number of non-clinical staffs by Masiye in 2003 (Mahate et al., 2017 & Masiye, 2007). However, there were also studies that used total number of staffs as the input in determining hospital technical efficiency using DEA (Ali et al., 2017, Jia & Yuan, 2017, Hu et al., 2012 & Harrison & Meyer, 2014).

Apart from that, total expenses is another input that was used by some studies in analysing the hospital technical efficiency using DEA. A study in China by Wang et al., in 2014 used total expenditure as input of analysing technical efficiency of county hospitals (Wang et al., 2016).
Another study in China used value of fixed capital and hospital expenditure as part of the inputs (Gai et al., 2010). Similarly, a study in the United States used operating expenses as the input in analysing technical efficiency of federal hospitals using DEA (Harrison & Meyer, 2014). In contrary, a study conducted in Zambia in 2003 used total of non-labour cost as an input in analysing the hospitals technical efficiency (Masiye, 2007). However, a more recent study carried out in Eastern Ethiopia used the cost of drug supply as one of the inputs (Ali et al., 2017). It was observed that the expenses were included as one of the inputs in the analysis based on prior study. However, a recent study in China found that there is no significant association between total expenditure and technical efficiency (Wang et al., 2016).

3.5 Hospitals’ Outputs In Measuring Technical Efficiency Using Data Envelopment Analysis

Due to the difficulty in capturing the ultimate hospital output measurement which is the improvement in health, many researchers measured the intermediate output, such as number of cases treated, number of procedures performed and bed occupancy as proxies to indicate this (Moshiri et al., 2010). Some variations in the choice of outputs used between studies upon analysing technical efficiency of the hospitals using DEA were observed.

Studies in Malaysia by Applanaidu et al., and Samsudin et al., included the daily average number of inpatient admission, number of OP visits, number of surgeries and number of deliveries as the outputs for analysing technical efficiency using DEA (Applanaidu et al., 2014 & Samsudin et al., 2014). Studies in other countries such as Greece, UAE, China, India, Eritrea and Iran were also found to use the number of inpatient admission for the analysis of hospital technical efficiency using DEA (Flokou et al., 2017, Mahate et al., 2017, Jia & Huan, 2017, Wang et al., 2016, Dash et al., 2010, Jat & San Sebastian, 2013, Kirigia & Asbu, 2013, Yusefzadeh et al., 2013, Gai et al., 2010). However, a study in Turkey took the case mix into consideration by using case-mix adjusted inpatient cases as one of the outputs (Sulku, 2011). The use of inpatient admission is supported by the finding of significant association between daily average number of admission and hospital’s technical efficiency score (Samsudin et al., 2014). In addition, the use of inpatient days or bed day as the output of DEA were found in studies conducted in the Eastern Ethiopia, United States, China, Iran, Uganda, and Zambia (Ali et al., 2017, Harrison & Meyer, 2014, Cheng et al., 2015, Kalhor et al., 2016, Yuzefzadeh et al., 2013, Farzianpour et al., 2012, Shahhoseini et al., 2011, Mujasi et al., 2016 & Masiye, 2007).

Apart from that, researchers have also been commonly using number of outpatients as an output in the analysis of hospital technical efficiency using DEA. This can either be total outpatient visits including the emergency room visit or it can be a separate output for emergency room visit. Studies in Malaysia, Greece, Eastern Ethiopia, UAE, Iran, Uganda, China, India, United States, Eritrea, Turkey and Zambia were using total outpatient visits including the emergency room visits as the output of DEA (Applanaidu et al., 2014, Samsudin et al., 2014, Flokou et al., 2017, Ali et al., 2017, Mahate et al., 2017, Farzianpour et al., 2017, Farzianpour et al., 2012, Shahhoseini et al., 2011, Mujasi et al., 2016, Jia & Huan, 2017, Wang et al., 2016, Cheng et al., 2015, Harrison & Meyer, 2014, Jat & Sebastian, 2013, Kirigia & Asbu, 2013, Hu et al., 2012, Sulku, 2011, Dash et al., 2010 & Masiye, 2007). However, there are other studies that used emergency room visit as separate output in the analysis, such as studies done in China by Hu et al. (Hu et al., 2012). The selection of outpatient visits as an output in the DEA might be justified by the significant finding on the
outpatient to inpatient ratio as a determinant of hospital’s technical efficiency score conducted in Uganda, the increase in one unit of the ratio leads to lower inefficiency score of a hospital (Mujasi et al., 2016).

Another output that was used in analysing hospital technical efficiency using DEA by the researchers was the number of surgeries. In Malaysia, several studies were found to use the number of surgeries as an output to analyse technical efficiency of hospitals using DEA (Applanaidu et al., 2014 & Samsudin et al. 2014). Similarly, there are many studies in other countries, such as in Greece, Eastern Ethiopia, India, United States, Iran and Turkey, that also included number of surgeries as the output in the DEA (Flokou et al., 2017, Ali et al., 2017, Jat & Sebastian, 2013, Harrison & Meyer, 2014, Kalhor et al., 2016, Shahhoseini et al., 2011 and Sulku, 2011). A slightly different output was used by a study in Zambia as the number of tests or surgeries performed was used as an output for the technical efficiency analysis (Masiye, 2007). It seems the number of surgeries was selected as one of the outputs in these studies based on the prior studies.

In addition, number of deliveries was another output that was used in the analysis of hospital technical efficiency using DEA. In Malaysia, studies by Applanaidu et al., and Samsudin et al., were found to include the number of deliveries as the output in DEA (Applanaidu et al., 2014 & Samsudin et al. 2014). In other countries, studies in Zambia and India were found to use the number of deliveries as the output in DEA (Masiye, 2007, Jet & San Sebastian, 2013 & Dash et al., 2010).

Other outputs that were used in analysing technical efficiency of hospitals using DEA including the ALOS and total revenue. A study in China on hospital technical efficiency of the county maternal and child health hospitals used the total revenue as an output for the DEA (Wang et al., 2016). ALOS was found to be used as an output of DEA in studies in UAE, Iran and China in analysing the hospitals technical efficiency (Jia & Huan, 2017, Mahate et al., 2017, Kalhor et al., 2016, Farzianpour et al., 2012 & Shahhoseini et al., 2011). The selection of ALOS as the output in the analysis seems to be appropriate as it was supported by a study finding in China where ALOS was a statistically significant ($P=0.021$) determinant of hospital’s technical inefficiency with higher ALOS predicted higher hospital’s technical inefficiency (Cheng et al., 2015).

In addition to the above outputs, BOR was also observed to be used as an output in analysing the technical efficiency of hospitals. More recent studies in Iran by Farzianpour et al., conducted in between 2013 to 2014 and another study in Iran by Shahhoseini et al., in 2008 used the BOR in analysing the technical efficiency of hospitals (Farzianpour et al., 2017 & Shahhoseini et al., 2011). The selection of BOR seems to be appropriate as a recent study in China found BOR as a significant determinant ($P<0.001$) in technical inefficiency with increase in BOR predicted lower hospital’s technical inefficiency score (Cheng et al., 2015).

Slightly different outputs were used in a study conducted in Greece which included 30-day risk-adjusted mortality for acute myocardial infarction, 30-day risk-adjusted mortality for congestive heart failure and 30-day risk-adjusted mortality for pneumonia (Flokou et al., 2017). These outputs were used in the study as they were the available in-hospital quality indicators as proxies to health improvements.
4.0 Conclusion and recommendation

Based on the assessment of the articles, it was found that there were a number of hospital’s inputs and hospitals’ outputs that were commonly used in the studies. The selection of the inputs and outputs were mostly based on prior studies or based on the known determinants of hospital’s technical efficiency. Among the commonly used inputs in the hospitals’ technical efficiency measurement using DEA include the number of doctors, number of nurses and number of beds. Some other inputs being used are the number of other medical staffs, number of other non-medical staffs, number of total employed staffs, total expenditure, total non-labour cost, value of fixed capital and cost of drug supply. As for the outputs, some of the commonly used by the researchers including the total inpatients, average daily admission, number of outpatients, number of surgeries, number of deliveries, ALOS, BOR and total revenue. Even though this study has identified the commonly used inputs and outputs in measuring hospitals’ technical efficiency using DEA which can be used in conducting future research, the selection of inputs and outputs is should take into account the objectives of the hospital itself.

Declaration

No conflict of interest is declared.

Authors contribution

Author 1 : information gathering, preparation and editing of manuscript
Author 2 : final review of manuscript
Author 3 : final review of manuscript

References


