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# Performance Evaluation of Public Hospitals with Data Envelopment Analysis (DEA) Method

## VZA Yöntemi ile Kamu Hastanelerinin Performans Değerlendirmesi


**Abstract**

*In recent years, the importance of health services has been increasing due to the improvement in people's quality of life, technological developments in the field of medicine and the aging of the population around the world. Hospitals, which are one of the main institutions of the health care system, are expected to reduce their expenditure values and improve their service quality. For this reason, health systems, and especially hospitals, need to constantly control their performance and provide quality service in order to identify and eliminate their inefficient resources. Although there are different methods used in the evaluation of efficiency in the field of health, Data Envelopment Analysis (DEA) is known as the most frequently used method. This study, it is aimed to carry out efficiency measurements of public hospitals for 81 provinces in Turkiye. In the study, efficiency analyzes were performed using input-oriented CCR and CCR-super-efficiency (SE). According to the results of the CCR model, 33 DMUs are efficient. and 48 DMUs are inefficient. Using the CCR-SE model, the efficient provinces were ranked. As a results of the CCR model, it has been determined which DMUs should be taken as a reference for inefficient DMUs to be efficient.*

**Özet**

*Son yıllarda dünya genelinde insanların yaşam kalitelerinin artması, tıp alanındaki teknolojik gelişmeler ve nüfusun yaşlanması nedeniyle sağlık hizmetlerinin önemi giderek artmaktadır. Sağlık sisteminin temel kuruluşlarından biri olan hastanelerin harcama değerlerini düşürmesi ve hizmet kalitesini yükseltmesi beklenmektedir. Bu nedenle sağlık sistemlerinin ve özellikle hastanelerin verimsiz kaynaklarını tespit edip ortadan kaldırabilmeleri için performanslarını sürekli kontrol etmeleri ve kaliteli hizmet vermeleri gerekmektedir. Sağlık alanında etkinliğin değerlendirilmesinde kullanılan farklı yöntemler olmakla birlikte en sık kullanılan yöntem Veri Zarflama Analizi (VZA) olarak bilinmektedir. Bu çalışmada, Türkiye'de 81 ilde kamu hastanelerinin etkinlik ölçümlerinin yapılması amaçlanmaktadır. Çalışmada girdi odaklı CCR ve CCR-Süper Etkinlik (SE) kullanılarak etkinlik analizleri yapılmıştır. CCR modelinin sonuçlarına göre 33 Karar Verme Birimi (KVB) etkin ve 48 KVB etkin değildir. CCR-SE modeli kullanılarak etkin iller sıralanmıştır. CCR modeli sonucunda etkin olmayan KVB'lerin etkin olabilmesi için hangi KVB'lerin referans alınması gerektiği belirlenmiştir.*



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## Introduction

Health is a basic human right as well as a prerequisite for the economic and social development of nations (Chai et al., 2019). Health is one of the greatest wealth of societies (Yüksel, 2022a). Health expenditures have increased in developed countries and even in developing countries due to the advancement of health technology, economic developments and aging societies. In real-world data, higher-income countries generally have more health expenditures than lower-income countries (Wang, 2018).

The health services sector is a vital sector with its diverse dynamics that make significant contributions to the development of countries. Developments in health institutions contribute to the improvement of the welfare level of societies (Ersoy and Tehci, 2023).

Improving the health of a population depends on a fair and efficient health system. In economies with both a high and a medium development index, the only way for public health systems to overcome the spending pressure seems to be to increase spending efficiency. Identifying improvement areas in the health system requires evaluating the efficiency of the current system. Evaluation of the health system is a complex process due to limited data and methodological complications (Ibrahim and Daneshvar, 2018). Indeed, improving the efficiency of health systems has become one of the main concerns of all developed countries (Mourad et al., 2021). The implementation of management systems, management processes and resource management planning to increase efficiency in the health sector is an important element in reducing costs and increasing efficiency in health institutions (Lamovšek and Klun, 2020).

Equality in access to health services and fairness in the financing, as well as providing effective health care is among the main policy goals for decision-makers in health care. It is possible to say that there is an increase in health expenditures day by day and resources are limited. The limited resources allocated to health services jeopardize the sustainability and quality of health services. This situation raises the issue of efficiency in health services (Bagci and Konca, 2021). Improvements to be made in the field of health are possible by primarily identifying the deficiencies and making improvements according to the results achieved (Yüksel, 2022b).

Performance evaluation is the process of determining the efficiency or effectiveness of past actions, which is widely adopted to measure the performance of social organizations. Commonly used methods for performance measurement include ratio analysis, regression analysis, multi-criteria decision analysis, AHP, Delphi method, cost-benefit analysis, fuzzy comprehensive assessment and Data Envelopment Analysis (DEA). DEA is a simple and practical evaluation method applied in various categories. Government offices, transportation projects, educational institutions, etc. DEA is frequently used for the performance evaluation of an institution or unit (Shao et al., 2021). The efficiency of public service providers can be determined by different methods. However, the DEA method is one of the most widely used methods in the field of health (Lamovšek and Klun, 2020).

The hospital is one of the basic institutions of the health care system. Hospitals have a special place in the health economy and they bring higher costs to the health system compared to other health system components. Hospitals are the main consumers of resources in any healthcare industry. Therefore, increasing their effectiveness is the main way to reduce hospital costs (Torabipour et al., 2014). Since hospitals are the most basic and last component of health systems, it is vital to evaluate their performance (Rezaee and Karimdadi, 2015).

Hospitals are the most important cost factor for healthcare systems around the world and face constant pressure to increase their effectiveness. The health sector in general and hospitals in particular represent an important application area of the DEA method (Kohl et al., 2019).

It is very important to know the efficiency levels of hospitals operating as a business in the health sector. Since public hospitals use public resources, these resources should be used in the best way without wasting them (Karahan and Dinc, 2018). In this study, it is aimed to perform efficiency measurements for hospitals operating under the General Directorate of Public Hospitals of the Ministry of Health of the Republic of Turkiye.

The rest of the work is organized as follows. In the second part, the studies in the literature that used the DEA method to evaluate performance in the field of health were examined. In the third part, the method used and the data set are explained. In the fourth part, the findings are given. In the conclusion part, a general evaluation of the study was made, the limitations of the study were mentioned and some suggestions were made for future studies.

**2. Literature Review**

There are many studies in the literature using the DEA method in different fields (Mardani et al., 2017; Soeyoshi et al., 2017; Ibanez et al., 2021; Rostamzadeh et al., 2021; Cui and Yu, 2021; Izadikhah, 2022). It is possible to come across studies using the DEA method in the field of health, as in many other sectors. Some of the studies carried out in the field of health using the DEA method are given below.

It is known that the DEA method was first used in the field of health by Nunamaker (1983). Nunamaker (1983) used the DEA method to measure the efficiency of routine nursing services in Wisconsin hospital. Another important study using the DEA method in the health sector was carried out by Sherman (1984). Sherman (1984) used the DEA method to measure the efficiency of hospitals in his study and determine the efficient and inefficient hospitals.

There are many studies evaluating hospital efficiency using the DEA method (Aletras et al., 2007; Magnussen and Nylan, 2008; Kounetas and Papathanassopoulos, 2013; Chowdhury et al., 2014; Kang and Kaipornsak, 2014; Cheng et al., 2015; Gholami et al., 2015; Li and Dong, 2015; Narcı, 2015; Rezaee and Karimdadi, 2015; Kutlar and Salamov, 2016a; Jiang et al., 2016; Kutlar and Salamov, 2016b; Campanella et al., 2017; Hsiao et al., 2018; Gandhi and Sharma, 2018; Miguel et al., 2019; Liu et al., 2019; Saquetto and Araujo, 2019; Yang et al., 2020; Yeşilyurt and Selamzade, 2021; Yazıcı and Biçen, 2021; Selamzade and Yüksel, 2021; İlgün et al., 2022).

Different studies evaluate the efficiency of businesses providing services in the health sector by using the DEA technique (Yeşilyurt and Salamov, 2017; Kutlar and Salamov, 2018; Li et al., 2019; Kohl et al., 2019; Yeşilyurt and Selamzade, 2020; Pereira et al., 2021; Durur et al., 2022; Chiu et al., 2022). Some of the studies in which the performance evaluation of hospitals was carried out using DEA can be seen in Table 1.

**Table 1. Performance Measurement of Some Hospitals by Using the DEA Method**

| Author(s) | Year | Units | Inputs | Outputs |
|---|---|---|---|---|
| De Nicola et al., | 2013 | 390 hospitals in Italy | number of doctors, number of nurses, number of beds | number of treatment days of patients, number of outpatient treatments, number of surgeries, total medical examinations |
| Cheng et al., | 2016 | 48 hospitals in China | number of medical personnel, number of medical technicians, number of other personnel, number of beds | number of outpatients and emergency service visitors, number of inpatients, number of electronic medical records, number of patients with chronic diseases |
| Kalhor et al., | 2016 | 54 hospitals in Iran | number of full-time doctors, number of full-time nurses, number of other medical personnel, number of beds | average length of stay of patients, number of surgeries, number of outpatients, number of inpatient days |
| Mujasi et al., | 2016 | 17 hospitals in Uganda | number of beds, number of medical personnel | number of outpatients, number of inpatient days |
| Papadaki and Stankova | 2016 | 12 hospitals in the Chech Republic | operational (surgery) expenses | number of beds, number of inpatients, number of bed occupancy |
| Samsudin et al., | 2016 | 25 hospitals in Malaysia | number of doctors, number of nurses, number of beds | number of inpatients, number of outpatients, number of surgeries, number of births |
| Li et al., | 2017 | 12 hospitals in China | number of doctors, number of beds, number of nurses, total expenditure | number of emergency service visitors, number of discharged patients, number of inpatients |

| | | | | |
|---|---|---|---|---|
| Ali et al., | 2017 | 12 hospitals in Etiopia | number of health personnel, cost of medicine supply, number of beds | number of outpatient visits, number of inpatient days, number of surgeries |
| Flokou et al., | 2017 | 107 hospitals in Greece | number of beds, number of doctors, other professional staff | number of inpatient cases, number of surgeries, number of outpatient visits |
| Leleu et al., | 2018 | 1847 hospitals in the USA | case mix index, number of staff, number of beds | number of surgeries, number of visitors, 30-day readmission rate, 30-day death rate |
| Zhang et al., | 2018 | 218 hospitals in Japan | number of doctors, number of nurses, number of other personnel, number of beds, hospital area | number of beds in the emergency service, number of outpatient clinics per day, number of patients discharged annually |
| Ferreira and Nunes | 2019 | 27 hospitals in Portuqual | cost of health services, number of full-time health personnel, number of beds | number of inpatients, number of emergency room visitors, number of surgeries, number of patients with appointment |
| Cinaroglu et al., | 2019 | 688 hospitals in Turkiye | number of staff beds, number of full-time doctors, number of full-time midwives and nurses | the number of inpatients, the number of operations, the number of patients admitted to the hospital |
| Alatawi | 2020 | 91 hospitals in the United Arab Emirates | number of beds, number of doctors, number of nurses, number of assistant health personnel | the number of outpatient visits, the number of patients discharged, the number of surgical operations, the number of radiological examinations, the number of laboratory tests, the hospital mortality rate |
| Botega et al., | 2020 | 3504 hospitals in Brazil | human resources (doctor, nurse, nurse assistant and technicians), infrastructure (number of beds, number of medical equipment) | number of hospitalizations by circulation, respiration, pregnancy, delivery/postpartum procedures and others, number of hospitalizations by age under 60 and over age 60 |
| Nayer et al., | 2022 | 15 hospitals in Iran | Number of staff, number of beds | number of surgeries, the number of patients, and the average length of stay. |

From the studies above, that is, in Table 1, it is possible to say that the DEA method is widely used in the field of health, especially for the efficiency evaluation of hospitals. This study will contribute to the literature by evaluating the efficiency of public hospitals.

### 3. Methodology

In this study, efficiency measurements of DMUs were carried out using the input-oriented CCR-DEA model and the input-oriented Super-efficiency DEA model of this model. It investigated how much the input variables can be reduced without changing the number of output variables with the input-oriented DEA model. In the research, the data of input and output variables related to hospitals were handled on a provincial basis and used in the DEA analysis. Thus, it is aimed to determine the efficient and inefficient provinces, namely DMUs, according to the DEA analysis results. According to the results of the input-oriented CCR model, the efficiency score of the DMUs that were found to be efficient was "1", that is, 100%. Using the super efficiency DEA model, the

DMUs that were found efficient were ranked and the most efficient DMU was determined. DEA efficiency analyzes were carried out using the EMS 1.3.0 package program.

**3.1. Data Envelopment Analysis Method**

Data Envelopment Analysis (DEA) is a mathematical programming technique widely used to evaluate the relative efficiency of a set of homogeneous Decision Making Units (DMUs) consuming the same inputs (different quantities) to produce the same outputs (different quantities) (Benítez et al., 2021). DEA is a non-parametric and linear programming-based method. Generally, decision-making units are accepted as units that transform inputs into outputs and whose efficiencies will be evaluated (Asker, 2021; Yayla and Özer, 2022).

DEA method is an ideal method for efficiency evaluation in environments with multiple input and output variables (Bolayır and Keyifli, 2022). In the DEA method, it is expected that the decision-making units whose efficiencies will be measured will have similar characteristics, produce the same type of outputs using the same type of inputs, and have similar goals and objectives (Akgöbek et al., 2015; Asker, 2021).

Efficiency measurement is usually carried out with ratio analysis, non-parametric and parametric methods. The most easily applied and used method is the ratio analysis method. The ratio analysis method, which is based on the ratio of inputs and outputs, is insufficient in performance evaluation. Non-parametric DEA method is used when parametric methods are insufficient. The DEA method is also multidimensional and allows efficiency measurement with multiple inputs and outputs. With the DEA method, the relative efficiency of comparable decision-making units is measured (Künç, 2022).

DEA method is widely applied in many different fields such as education, health, banking, transportation, agriculture, service industries, engineering and science due to its strong features, as well as in the evaluation of regional and country performances (Rabar, 2017: 1774; Dinçer and Göral, 2017; Ersoy and Tehci, 2020 ; Ersoy, 2021a; Benítez et al., 2021; Ersoy, 2021b; Čiković and Lozić, 2022 ; Selamzade and Baghirov, 2022).

The DEA method was first introduced in 1957 by Farrel (1957) in his study titled "The Measurement of Productive Efficiency" (Othman et al., 2016; Kutlar and Salamov, 2018; Özkan, 2019). Charnes, Cooper, and Rhodes (1978) used the CCR model, known as the constant return to scale model, in their study called "Measuring The Efficiency of Decision Making Units", based on the study of Farrell (1957) (Othman et al., 2016; Gürbüz and Dumlu, 2018; Özkan, 2019; Bolayır and Keyifli, 2022). Banker, Charnes and Cooper (1984) examined the situation of variable returns to scale in their studies. Thus, the study of Banker Charnes Cooper has entered the literature as the BCC model (Kutlar and Salamov, 2018; Gürbüz and Dumlu, 2018; Acer, 2021).

The selection of inputs and outputs and DMUs used in DEA analysis is very important. Another issue to be considered in the selection of decision-making units is the number of decision-making units. Although there are different views on determining the number of decision-making units, according to one of these views, the number of decision-making units should be twice the sum of the number of inputs and outputs (Dyson et al., 2001; Gürbüz and Dumlu, 2018; Özkan, 2019). According to other studies in the literature; Considering the number of DMUs as "n", the number of inputs as "m" and the number of outputs as "s", it should be $n \geq \max\{m \times s,\ 3(m+s)\}$ (Cooper et al., 2001; Acer and Timor, 2017).

**3.1.1. Input-Oriented CCR DEA Model**

The input-oriented CCR model, it is aimed to reduce the amount of inputs to meet a certain number of output (Okursoy and Tezsürücü, 2014). In this model, it is investigated how much to reduce the inputs to achieve this output level most effectively without changing the output amount (Gürel, 2022). The input-oriented CCR model is defined as follows (Chen and Ali, 2002; Turşucu, 2017):

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

The constraints are expressed as shown below.

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1 \qquad j = 1,\ 2,\ ....,\ n$$

$$v_i,\ u_r \ge 0 \qquad r = 1,\ 2,\ ....,\ s \qquad i = 1,\ 2,\ ....,\ m \tag{3.1}$$

**3.1.2. Input-Oriented Super Efficiency CCR DEA Model**

The input-directed super-efficiency CCR model is defined as follows (Seiford and Zhu, 1999; Xu and Ouenniche, 2012; Çağlar and Keten, 2018).

$$\min\ \theta_k$$

$$s.t. \sum_{\substack{j=1 \\ j\neq k}}^{n} \lambda_j x_{ij} \le \theta_k x_{ik}, \qquad i = 1,\ ....,\ m$$

$$\sum_{\substack{j=1 \\ j\neq k}}^{n} \lambda_j y_{rj} \ge y_{rk} \qquad r = 1,\ ....,\ s$$

$$\lambda_j \ge 0 \qquad j = 1,\ ....,\ n \tag{3.2}$$

**3.2. Data Set of the Study**

The data of the study was obtained from the 2017 Public Hospitals statistical report published by the Republic of Turkiye Ministry of Health, General Directorate of Public Hospitals (KHGM, 2022). In the DEA analysis, it is primarily necessary to determine the decision-making units.

In this study, 81 provinces were used as decision-making units. DEA analysis was carried out by considering the input and output variables of public hospitals in 81 provinces. One of the important limitations of DEA analysis is that the number of DMUs must be at least two or three times the sum of the number of input and output variables. Since 4 input variables and 6 output variables are used in response to 81 DMUs in the research, an important limitation of DEA is fulfilled.

Since this study was carried out in the field of health and especially in hospitals, the input and output variables used in the DEA analysis should be related to the field of health. For the selection of input and output variables used in DEA analysis, previous studies in the literature were used. Information on the input and output variables used in the study is given in Table 2.

**Table 2. The Descriptions of Input and Output Variables Used in the Study**

| **Input Variables** | **Definition** | **Abbreviation** |
|---|---|---|
| Number of specialist doctors | It represents the total number of specialist doctors in all specialties. | SDN |
| Number of general practitioners | It represents the total number of general practitioners. | PDN |
| Number of nurses and midwives | It represents the total number of nurses and midwives. | NMN |
| Number of beds | It represents the total number of beds in which patients are hospitalized for their care and treatment. | NB |
| **Output Variables** | **Definition** | **Abbreviation** |
| Number of surgeries | It shows the total number of A-group, B-group and C-group surgeries. | TNS |

| | | |
|---|---|---|
| Number of applications | It refers to the number of applications made to all outpatient clinics in a year. | AN |
| Number of emergency applications | It refers to the number of applications made to the emergency department in a year. | NAES |
| Number of inpatients | It shows the number of patients hospitalized in a year. | NI |
| Bed occupancy rate | It shows what percentage of the beds are used in a year. | BOR |
| Average number of days of stay | It refers to the average number of days a patient stays in the hospital. | ADS |

Statistical data on inputs and outputs used in the study can be seen in Table 3.

**Table 3. Descriptive Statistics for Input and Output Variables**

| Input (s) | | |
|---|---|---|
| Number of specialist doctors | Maximum | 41873 |
| | Minimum | 517 |
| | Total | 54 |
| | Mean | 7796 |
| | Standard deviation | 1032 |
| Number of general practitioners | Maximum | 9623 |
| | Minimum | 119 |
| | Total | 14 |
| | Mean | 860 |
| | Standard deviation | 111,6 |
| Number of nurses and midwives | Maximum | 118.733 |
| | Minimum | 1466 |
| | Total | 154 |
| | Mean | 15545 |
| | Standard deviation | 2013,4 |
| Number of beds | Maximum | 134.682 |
| | Minimum | 1663 |
| | Total | 150 |
| | Mean | 17783 |
| | Standard deviation | 2332,3 |
| **Output (s)** | | |
| Number of surgeries | Maximum | 2.590.538 |
| | Minimum | 31982 |
| | Total | 1789 |
| | Mean | 433439 |
| | Standard deviation | 55908,1 |
| Number of applications | Maximum | 357.748.167 |
| | Minimum | 4416644 |
| | Total | 330428 |
| | Mean | 57536449 |
| | Standard deviation | 7194530,2 |
| Number of emergency applications | Maximum | 100.455.339 |
| | Minimum | 1240189 |
| | Total | 38014 |
| | Mean | 14352135 |
| | Standard deviation | 1775263,7 |
| Number of inpatients | Maximum | 7.721.584 |
| | Minimum | 95328 |
| | Total | 6624 |
| | Mean | 923853 |

| | | |
|---|---|---|
| | Standard deviation | 123793,6 |
| Bed occupancy rate | Maximum | 5435,1 |
| | Minimum | 67 |
| | Total | 46 |
| | Mean | 83 |
| | Standard deviation | 7,9 |
| Average number of days of stay | Maximum | 344,1 |
| | Minimum | 4 |
| | Total | 3 |
| | Mean | 7 |
| | Standard deviation | 0,9 |

The study findings that emerged as a result of DEA analyses using the input-oriented CCR model and the CCR-SE model are given below.

## 4. Results and Discussion

Efficiency measurement results according to the input-oriented CCR and CCR-SE models using the data in Table 3 are given in Table 4.

**Table 4. Efficiency Measurement Results of DMUs**

| NO | Provinces | CCR | Rank | CCR-SE | Rank |
|---|---|---|---|---|---|
| 1 | Adana | 0,91 | **41** | 0,91 | **31** |
| 2 | Adıyaman | 1,00 | **1** | 1,08 | **13** |
| 3 | Afyonkarahisar | 1,00 | **1** | 1,08 | **13** |
| 4 | Ağrı | 1,00 | **1** | 1,01 | **23** |
| 5 | Aksaray | 1,00 | **1** | 1,37 | **3** |
| 6 | Amasya | 0,89 | **43** | 0,89 | **33** |
| 7 | Ankara | 1,00 | **1** | 1,43 | **2** |
| 8 | Antalya | 1,00 | **1** | 1,03 | **21** |
| 9 | Ardahan | 0,99 | **34** | 0,99 | **24** |
| 10 | Artvin | 0,87 | **45** | 0,87 | **35** |
| 11 | Aydın | 0,88 | **44** | 0,88 | **34** |
| 12 | Balıkesir | 0,95 | **38** | 0,95 | **28** |
| 13 | Bartın | 1,00 | **1** | 1,18 | **7** |
| 14 | Batman | 1,00 | **1** | 1,10 | **11** |
| 15 | Bayburt | 1,00 | **1** | 1,50 | **1** |
| 16 | Bilecik | 1,00 | **1** | 1,09 | **12** |
| 17 | Bingöl | 0,83 | **49** | 0,83 | **39** |
| 18 | Bitlis | 0,99 | **34** | 0,99 | **24** |
| 19 | Bolu | 1,00 | **1** | 1,01 | **23** |
| 20 | Burdur | 0,89 | **43** | 0,89 | **33** |
| 21 | Bursa | 1,00 | **1** | 1,08 | **13** |
| 22 | Çanakkale | 0,81 | **52** | 0,81 | **42** |
| 23 | Çankırı | 0,93 | **40** | 0,93 | **30** |
| 24 | Çorum | 0,72 | **55** | 0,72 | **45** |
| 25 | Denizli | 0,96 | **37** | 0,96 | **27** |
| 26 | Diyarbakır | 0,84 | **48** | 0,84 | **38** |
| 27 | Düzce | 1,00 | **1** | 1,08 | **13** |
| 28 | Edirne | 0,93 | **40** | 0,93 | **30** |
| 29 | Elazığ | 0,64 | **56** | 0,64 | **46** |
| 30 | Erzincan | 0,87 | **45** | 0,87 | **35** |
| 31 | Erzurum | 0,84 | **48** | 0,84 | **38** |
| 32 | Eskişehir | 1,00 | **1** | 1,16 | **8** |
| 33 | Gaziantep | 1,00 | **1** | 1,07 | **14** |

| | | | | | |
|---|---|---|---|---|---|
| **34** | Giresun | 0,89 | **43** | 0,89 | **33** |
| **35** | Gümüşhane | 0,83 | **49** | 0,83 | **39** |
| **36** | Hakkâri | 0,94 | **39** | 0,94 | **29** |
| **37** | Hatay | 0,97 | **36** | 0,97 | **26** |
| **38** | Iğdır | 1,00 | **1** | 1,26 | **5** |
| **39** | Isparta | 0,85 | **47** | 0,85 | **37** |
| **40** | İstanbul | 1,00 | **1** | 1,11 | **10** |
| **41** | İzmir | 0,89 | **43** | 0,89 | **33** |
| **42** | Kahramanmaraş | 1,00 | **1** | 1,02 | **22** |
| **43** | Karabük | 0,80 | **52** | 0,80 | **42** |
| **44** | Karaman | 1,00 | **1** | 1,19 | **6** |
| **45** | Kars | 0,88 | **44** | 0,88 | **34** |
| **46** | Kastamonu | 0,88 | **44** | 0,88 | **34** |
| **47** | Kayseri | 0,93 | **40** | 0,93 | **30** |
| **48** | Kırıkkale | 1,00 | **1** | 1,28 | **4** |
| **49** | Kırklareli | 0,88 | **44** | 0,88 | **34** |
| **50** | Kırşehir | 0,84 | **48** | 0,84 | **38** |
| **51** | Kilis | 1,00 | **1** | 1,26 | **5** |
| **52** | Kocaeli | 1,00 | **1** | 1,04 | **20** |
| **53** | Konya | 0,85 | **47** | 0,85 | **37** |
| **54** | Kütahya | 0,89 | **43** | 0,89 | **33** |
| **55** | Malatya | 0,82 | **51** | 0,82 | **41** |
| **56** | Manisa | 0,90 | **42** | 0,90 | **32** |
| **57** | Mardin | 0,98 | **35** | 0,98 | **25** |
| **58** | Mersin | 0,90 | **42** | 0,90 | **32** |
| **59** | Muğla | 0,82 | **51** | 0,82 | **41** |
| **60** | Muş | 1,00 | **1** | 1,06 | **18** |
| **61** | Nevşehir | 0,95 | **38** | 0,95 | **28** |
| **62** | Niğde | 1,00 | **1** | 1,06 | **18** |
| **63** | Ordu | 1,00 | **1** | 1,01 | **23** |
| **64** | Osmaniye | 1,00 | **1** | 1,06 | **18** |
| **65** | Rize | 0,84 | **48** | 0,84 | **38** |
| **66** | Sakarya | 1,00 | **1** | 1,09 | **12** |
| **67** | Samsun | 0,93 | **40** | 0,93 | **30** |
| **68** | Siirt | 0,98 | **35** | 0,98 | **25** |
| **69** | Sinop | 0,86 | **46** | 0,86 | **36** |
| **70** | Sivas | 0,89 | **43** | 0,89 | **33** |
| **71** | Şanlıurfa | 1,00 | **1** | 1,13 | **9** |
| **72** | Şırnak | 1,00 | **1** | 1,04 | **20** |
| **73** | Tekirdağ | 0,97 | **36** | 0,97 | **26** |
| **74** | Tokat | 1,00 | **1** | 1,01 | **23** |
| **75** | Trabzon | 0,77 | **53** | 0,77 | **43** |
| **76** | Tunceli | 1,00 | **1** | 1,28 | **4** |
| **77** | Uşak | 0,86 | **46** | 0,86 | **36** |
| **78** | Van | 0,96 | **37** | 0,96 | **27** |
| **79** | Yalova | 1,00 | **1** | 1,28 | **4** |
| **80** | Yozgat | 0,73 | **54** | 0,73 | **44** |
| **81** | Zonguldak | 1,00 | **1** | 1,05 | **19** |
| **Mean** | | **0,93** | | **0,98** | |

When Table 4 is examined, the efficiency score of 33 provinces that are efficient according to the results of the CCR model is "1", that is, 100%. According to the CCR model, the remaining 48 provinces were not efficient. According to the results of the CCR model, the mean efficiency score was 0.93 and the standard deviation was 0.082. According to the CCR model, Elazig has the lowest

DMU with the lowest efficiency score of 0.64. To rank the efficient provinces, the super-efficiency scores should be evaluated.

According to the results of the CCR-SE model, the most efficient DMU is Bayburt. According to the results of the CCR-SE model, Bayburt is followed by Ankara and Aksaray, respectively. According to the results of the CCR-SE model, the provinces of Tunceli, Yalova and Kırıkkale are in fourth place. According to the results of the CCR model, the DMUs that need to be taken as reference for the inefficient provinces to become efficient can be seen in Table 5.

**Table 1. DMUs That Ineficient Provinces Should Take As Reference According to CCR Model Results**

| Provinces | DMU Number | Benchmarks (DMU to be Referenced) |
|---|---|---|
| Adana | 1 | 7 (0,03) 33 (0,84) 44 (0,39) 48 (0,19) |
| Amasya | 6 | 38 (0,26) 44 (0,60) 51 (0,27) 71 (0,08) |
| Ardahan | 9 | 15 (0,60) 79 (0,15) |
| Artvin | 10 | 15 (0,53) 27 (0,09) 38 (0,29) 71 (0,03) 79 (0,03) |
| Aydın | 11 | 5 (0,28) 38 (0,11) 42 (0,09) 62 (0,14) 79 (2,53) 81 (0,33) |
| Balıkesir | 12 | 38 (0,05) 42 (0,37) 44 (1,65) 71 (0,27) |
| Bingöl | 17 | 33 (0,01) 38 (0,33) 48 (0,12) 62 (0,41) 64 (0,04) |
| Bitlis | 18 | 3 (0,01) 38 (0,08) 44 (0,50) 48 (0,29) 71 (0,10) |
| Burdur | 20 | 13 (0,67) 33 (0,01) 44 (0,27) 48 (0,01) 64 (0,12) 79 (0,22) |
| Çanakkale | 22 | 44 (0,19) 51 (0,06) 71 (0,05) 79 (1,48) |
| Çankırı | 23 | 15 (0,48) 38 (0,47) 44 (0,06) 79 (0,09) |
| Çorum | 24 | 5 (0,10) 13 (0,26) 38 (0,73) 42 (0,22) 79 (0,01) 81 (0,12) |
| Denizli | 25 | 5 (0,66) 32 (0,09) 44 (0,47) 48 (0,54) 79 (1,17) |
| Diyarbakır | 26 | 5 (0,67) 48 (0,51) 64 (1,24) 79 (1,61) |
| Edirne | 28 | 5 (0,13) 42 (0,03) 79 (0,85) 81 (0,22) |
| Elazığ | 29 | 5 (0,05) 13 (0,63) 38 (0,00) 62 (0,02) 79 (0,59) 81 (0,23) |
| Erzincan | 30 | 14 (0,18) 15 (0,47) 16 (0,03) 27 (0,14) 51 (0,28) |
| Erzurum | 31 | 33 (0,26) 44 (1,90) |
| Giresun | 34 | 3 (0,36) 13 (0,16) 38 (0,76) 48 (0,14) 62 (0,09) |
| Gümüşhane | 35 | 15 (0,79) 38 (0,16) 76 (0,01) 79 (0,15) |
| Hakkâri | 36 | 5 (0,10) 14 (0,19) 15 (0,06) 38 (0,16) 79 (0,35) |
| Hatay | 37 | 5 (0,19) 14 (0,31) 44 (1,58) 51 (0,30) 64 (0,11) 71 (0,25) 79 (0,70) |
| Isparta | 39 | 32 (0,17) 44 (0,72) 48 (0,35) |
| İzmir | 41 | 40 (0,24) 79 (4,25) |
| Karabük | 43 | 14 (0,19) 15 (0,33) 16 (0,07) 38 (0,04) 79 (0,55) |
| Kars | 45 | 38 (0,71) 44 (0,22) 51 (0,12) 71 (0,00) 79 (0,22) |
| Kastamonu | 46 | 3 (0,01) 13 (0,07) 38 (1,38) 44 (0,32) |
| Kayseri | 47 | 5 (0,98) 40 (0,02) 79 (2,01) |
| Kırklareli | 49 | 33 (0,01) 38 (0,38) 48 (0,00) 62 (0,28) 64 (0,07) 79 (0,39) |
| Kırşehir | 50 | 5 (0,06) 14 (0,06) 15 (0,01) 79 (0,80) |
| Konya | 53 | 5 (0,60) 62 (0,02) 79 (4,85) 81 (0,48) |
| Kütahya | 54 | 5 (1,00) 13 (0,08) 32 (0,12) 44 (0,48) 79 (0,11) |
| Malatya | 55 | 5 (0,78) 14 (0,21) 38 (0,00) 71 (0,17) 79 (0,13) |
| Manisa | 56 | 71 (0,04) 79 (2,71) 81 (0,92) |
| Mardin | 57 | 33 (0,12) 44 (0,12) 71 (0,13) 72 (0,30) 79 (0,52) |
| Mersin | 58 | 5 (2,40) 8 (0,03) 32 (0,34) 44 (0,03) 79 (1,18) |

| | | |
|---|---|---|
| Muğla | 59 | 14 (0,35) 27 (0,06) 52 (0,04) 79 (2,08) |
| Nevşehir | 61 | 5 (0,10) 13 (0,06) 15 (0,32) 32 (0,03) 44 (0,26) 48 (0,08) 79 (0,25) |
| Rize | 65 | 33 (0,15) 38 (0,56) 44 (0,23) 48 (0,03) 62 (0,08) 64 (0,10) |
| Samsun | 67 | 5 (0,75) 33 (0,26) 44 (1,55) 66 (0,26) 71 (0,04) |
| Siirt | 68 | 3 (0,02) 38 (1,04) 48 (0,31) 71 (0,02) |
| Sinop | 69 | 3 (0,07) 13 (0,11) 38 (0,53) 44 (0,33) |
| Sivas | 70 | 5 (0,52) 38 (2,25) 81 (0,13) |
| Tekirdağ | 73 | 71 (0,19) 79 (0,67) 81 (0,43) |
| Trabzon | 75 | 5 (0,84) 42 (0,18) 79 (0,38) 81 (0,46) |
| Uşak | 77 | 5 (0,16) 33 (0,06) 38 (0,03) 48 (0,24) 62 (0,27) 79 (0,15) 81 (0,06) |
| Van | 78 | 5 (1,24) 33 (0,14) 66 (0,29) 71 (0,03) |
| Yozgat | 80 | 4 (0,31) 38 (0,50) 62 (0,37) 71 (0,01) |

The "DMU number" in the second column of Table 5 refers to the number of provinces. The DMUs in the second column constitute the inefficient provinces and the DMUs in the third column constitute the reference set of the inefficient provinces. For the inefficient DMUs to be efficient, it is necessary to reduce their inputs or increase their outputs compared to the reference DMUs. Therefore, target input variables and output variables values and potential improvement rates need to be determined.

In order to calculate the target input and output values, the input and output values of the referenced DMU should be multiplied by the coefficient of the reference DMU. The improvement rate is calculated with the following formula (Çalışkan, 2020):

$$improvement\ rate = (target\ value\ /\ actual\ value) - 1 \quad (4.1)$$

According to the results of the CCR model, for Burdur, which is among the inefficient provinces, to be efficient, Bartın 67%, Gaziantep 1%, Karaman 27%, Kırıkkale 1%, Osmaniye 12% and Yalova %. 22 percent reference is required.

For example; the efficiency score for the CCR model of Isparta province is 0.85. For the province of Isparta to be efficient, it should take 17% of Eskişehir, 72% of Karaman and 35% of Kırıkkale, which is included in the reference cluster, as a reference. Target values for Isparta province input and output variables were calculated as follows.

**Number of specialist doctors:**

$$(489*0{,}17)+(104*0{,}72)+(117*0{,}35)=199$$

**Number of general practitioners:**

$$(65*0{,}17)+(37*0{,}72)+(29*0{,}35)=48$$

**Number of nurses and midwives:**

$$(1695*0{,}17)+(449*0{,}72)+(513*0{,}35)=791$$

**Number of beds:**

$$(1846*0{,}17)+(500*0{,}72)+(725*0{,}35)=928$$

**Total number of surgeries:**

$$(39181*0{,}17)+(12200*0{,}72)+(12390*0{,}35)=19781$$

**Number of applications:**

$$(3931267*0{,}17)+(1143567*0{,}72)+(918160*0{,}35)=1813040$$

**Number of emergency service applications:**

$$(867761*0{,}17)+(331680*0{,}72)+(337456*0{,}35)=504439$$

**Number of inpatients:**

$$(101952*0{,}17)+(30264*0{,}72)+(40648*0{,}35)=53349$$

**Bed occupancy rate:**

$$(73{,}6*0{,}17)+(71*0{,}72)+(64{,}9*0{,}35)=86{,}3$$

**Average number of days of stay:**

$$(4{,}9*0{,}17)+(4{,}3*0{,}72)+(4{,}2*0{,}35)=5$$

According to the results of the input-oriented CCR model, which was carried out using the input and output variables targeted for Isparta province, Isparta province was found to be efficient. Since the input-oriented CCR model is used in the study, it is necessary to determine the required improvement rates for the input variables. According to the calculations made with the help of equation (4.1) for the province of Isparta, it has been concluded that an improvement of 15% in the number of specialist doctors, 14.6% in the number of general practitioners, 21% in the number of nurses and midwives and 15.7% in the number of beds is required. According to the results of the input-oriented CCR model, since the province of Isparta creates a surplus of inputs, the improvement rates reveal how much reduction should be made in the inputs.

**Conclusion**

Health services are of vital importance for all countries, as they are one of the measures of the development of a society. As a result of the acceleration of globalization, advances in technology increased awareness among health care consumers and increased healthcare prices, businesses operating in the health sector need to be more careful and examine their effectiveness while providing health services. The continuous increase in health expenditures in recent years, fluctuations in the disease structure, advances in medical research and expertise, and competition among facility suppliers have made it necessary to provide health services successfully and economically.

The use of human, financial and material resources in health institutions is very important. Uncontrolled use of health personnel, materials and beds causes a serious waste of resources. Therefore, it is important to optimize health resources so that primary health resources can reach the optimal output. The effectiveness of ineffective decision-making units is usually made possible by improving the resource management policy. Since hospitals are a critical part of the health system, they become the subject of analyzes aimed at defining, measuring and improving their performance. The DEA method is widely used in the efficiency evaluations of hospitals.

In this study, efficiency measurements on a provincial basis of the hospitals operating under the Ministry of Health of the Republic of Turkiye were carried out with the DEA method. In the study, 81 provinces were considered as Decision Making Units. In order to determine the input and output variables of the study, many studies in the literature were examined. In the study, number of specialist doctors, general practitioners, nurses and midwives, and beds were used as input variables, the number of surgeries, applications, emergency admissions, inpatients, the bed occupancy rate, the average number of days of stay were used as output variables. In the study, efficiency measurements were made in 81 provinces by using input-oriented CCR and CCR-SE models. According to the results of the CCR model, DMUs with an efficiency score of "1", ie 100%, were found to be efficient.

According to the results of the CCR model, 33 provinces were found to be efficient and the remaining 48 provinces were not efficient. According to the results of the CCR model, Elazig has the lowest DMU with an efficiency score of 0.64. Using the super-efficiency model, the the efficient provinces were ranked among themselves. According to the results of the CCR-SE model, Bayburt was found to be the most effective DMU with an efficiency score of 1.50.

According to the results of the CCR model in the study, the provinces that need to be taken as reference for the inefficient DMUs to become efficient were determined and shown in Table 5. According to the results of the CCR model, Yozgat, which is not efficient, should take Bartin 20%, Igdir 23%, Mus 15%, Nigde 35% and Sanliurfa 7% as a reference to be efficient.

According to the results of the CCR model, the efficiency score of the inactive province of Isparta is 0.85. For Isparta to be effective, it should take Eskisehir 17%, Karaman 72% and Kirikkale 35% as reference. Target values were calculated for the input and output variables of Isparta. The calculated values are, respectively, the number of specialist doctors: 199, the number of general practitioners: 48, the number of nurses and midwives: 791, the number of beds: 928, the total number of operations: 19781, the number of applications: 1813040, the number of emergency admissions: 504439, the number of inpatients: 53349 , bed occupancy rate: 86.3 and average length of stay: 5. Since the input-oriented CCR model was used in the study, the required improvement rates for the input variables for Isparta were found to be 15% in the number of specialist doctors, 14.6% in the number of general practitioners, 21% in the number of nurses and midwives, and 15.7% in the number of beds, respectively.

The results of the study may be useful for health policymakers to evaluate and compare health systems in provinces and to develop strategic regional health plans. As with many other studies, this study has some limitations. The fact that the study was conducted only in Turkiye and other countries were not included in the study is one of the important limitations of the study. The use of 4 inputs and 6 outputs in the study and the fact that the study is carried out with input-oriented DEA models is another limitation of the study. Another limitation of the study is that it was carried out using only the data of public hospitals without including private hospitals.

Çınaroglu et al. (2019) made an evaluation of the efficiency of 688 public hospitals in Turkey in their study, but did not make an evaluation on a provincial basis. This study differs from the literature in this aspect. In addition, the inputs and outputs used in this study are different.

In future studies, efficiency measurements can be carried out by using an output-oriented DEA model instead of an input-oriented one or using input and output-oriented DEA models together. It should be noted that in the DEA analysis, the relative efficiency measurement was made. Therefore, changes that can be made in the number or amount of inputs and outputs may affect the results of the analysis. Different input and output variables can be used in future studies on this subject. Since the study covers the provinces in Turkiye, future studies in which Turkiye's regions are compared or the efficiency comparisons of different countries where Turkiye will be located can be another subject of study. This study was carried out using the DEA method in the health sector. Making DEA efficiency measurements in different sectors such as education, tourism, textile and logistics can be considered as another study subject.

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