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EFFICIENCY ANALYSIS

IN

DIGITAL HOSPITALS

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Supervisor

Prof. Dr. Serap ULUSAM SEÇKİNER

by

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Ayşe SOFUOĞLU

ABSTRACT

EFFICIENCY ANALYSIS IN DIGITAL HOSPITALS

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Digitalization, introduced to our lives by technology, is pioneering the development of many sectors. The health sector is one of the sectors that has received a great amount of digitalization technology. Today, healthcare service delivery can be provided by different digital applications and digital hospitals. In recent years, the development of digital hospitals has been emphasized in Türkiye as well as on a global scale. Digital hospitals, which are increasing day by day in Türkiye, are graded according to international criteria, and sixth-stage and seventh-stage hospitals are accepted as digital hospitals. However, seventh-stage hospitals have a "zero paper" criterion, unlike sixth-stage hospitals. Accordingly, in this study the efficiency of sixth-stage and seventh-stage hospitals which are selected as samples is analyzed by data envelopment analysis technique under eight different scenarios with identified inputs and outputs based on stationery expenses. In this way, it is measured whether there is a difference in the efficiency of sixth-stage and seventh-stage hospitals due to the "zero paper" criterion. Then, the efficiency scores calculated by data envelopment analysis technique are tested statistically. As a result of data envelopment analysis and statistical analysis, in all scenarios, it has been concluded that the average efficiency of seventh-stage hospitals based on stationery expenses is higher than the average efficiency of sixth-stage hospitals based on stationery expenses. However, since sixth-stage hospitals also have high efficiency, there is no statistically significant difference observed between the hospital-based efficiency scores of sixth-stage and seventh-stage hospitals.

Key Words: Digital Hospital, HIMSS, EMRAM, Efficiency Analysis, Data Envelopment Analysis

ÖZET

DİJİTAL HASTANELERDE VERİMLİLİK ÖLÇÜMÜ

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Teknolojinin hayatımıza kazandırdığı dijitalleşme birçok sektörün gelişimine öncülük etmektedir. Sağlık sektörü de dijitalleşen teknolojiden payını büyük ölçüde alan sektörlerden biridir. Günümüzde sağlık hizmet sunumu, farklı dijital uygulamalar ve dijital hastaneler aracılığıyla sunulabilmektedir. Son yıllarda, küresel ölçekte olduğu gibi ülkemizde de dijital hastanelerin gelişimine önem verilmektedir. Türkiye'de sayıları her geçen gün artan dijital hastaneler uluslararası kriterlere göre derecelendirilmekte, altıncı seviye ve yedinci seviye hastaneler dijital hastane olarak kabul edilmektedir. Ancak yedinci seviye hastanelerde, altıncı seviye hastanelerden farklı olarak "sıfır kâğıt" kriteri bulunmaktadır. Bu nedenle çalışmada, örneklem olarak seçilmiş altıncı ve yedinci seviye hastanelerin verimliliği kırtasiye gideri bazında, belirlenen girdi ve çıktılar dâhilinde, sekiz farklı senaryo altında veri zarflama analizi tekniğiyle ölçülmüştür. Bu doğrultuda, "sıfır kâğıt" kriterinden kaynaklı olarak, altıncı ve yedinci seviye hastanelerin verimliliğinde bir fark olup olmadığı analiz edilmiş, daha sonra, veri zarflama analizi tekniğiyle hesaplanan verimlilik skorları istatistiksel olarak test edilmiştir. Veri zarflama analizi ve istatistiksel analizler neticesinde, tüm senaryolarda yedinci seviye hastanelerin kırtasiye gideri bazında ortalama verimliliği, altıncı seviye hastanelerin kırtasiye gideri bazında ortalama verimliliğinden yüksek çıkmıştır. Ancak altıncı seviye hastanelerin de yüksek verimliliğe sahip olması dolayısıyla altıncı ve yedinci seviye hastanelerin hastane bazında hesaplanan verimlilik skorları arasında istatistiki olarak anlamlı bir farklılık olmadığı gözlemlenmiştir.

Anahtar Kelimeler: Dijital Hastane, HIMSS, EMRAM, Verimlilik Analizi, Veri Zarflama Analizi

''Dedicated to my career and my family''

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LIST OFABBREVIATIONS

AE	Allocative Efficiency
BCC	Banker-Charnes-Cooper
CCR	Charnes-Cooper-Rhodes
CE	Cost Efficiency
CLMM	Closed-Loop Medication Management
CRS	Constant Returns to Scale
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DICOM	Digital Imaging and Communications in Medicine
DMU	Decision Making Units
DRS	Decreasing Returns to Scale
EE	Economic Efficiency
EHR	Electronic Health Records
eMAR	Electronic Medication Administration Record
EMR	Electronic Medical Records
EMRAM	Electronic Medical Record Adoption Model
GDP	Gross Domestic Product
HIMSS	Healthcare Information and Management Systems Society
HIS	Hospital Information System
IPS	Intrusion Prevention System
IRS	Increasing Returns to Scale
LIMS	Laboratory Information Management System
MEG	Model of EHR Grading
MHRS	Central Hospital Appointment System
MoH	Republic of Türkiye Ministry of Health
ODHC	Oral and Dental Health Clinic
OECD	Organization for Economic Co-operation and Development

PACS	Picture Archiving and Communication Systems
PTE	Pure Technical Efficiency
RBAC	Role-Based Access Control
RFID	Radio Frequency Identification Devices
RIS	Radiology Information System
SE	Scale Efficiency
SİNA	Statistics and Causal Analyses in Health
TE	Technical Efficiency
TTE	Total Technical Efficiency
VRS	Variable Returns to Scale
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

Digitalization is becoming widespread all over the world at an increasing pace and becoming more involved in everyday life and making it easier. As well as reducing the cost of the services, digital technologies integrated in sectors such as industry, education, health, and many others allow to save time.

The health sector is one of the sectors that adapt the most to the digitalizing world. Since healthy individuals and healthy societies are one of the main objectives of the countries, the health sector is one of the basic components of a country. Therefore, it is substantial that the health sector develops day by day and keeps pace with the developing technology. Based on this need, it is possible to say that technology exists in every field of the health sector. For instance, patients receive health services easily via digital health applications which are accessible to both doctors and patients. By storing medical records digitally, patients' health information can be accessed quickly and easily, and health services can be carried out more effectively in the digitalized health sector. E-health, mobile health, telemedicine, wearable technology, 3D printers, artificial intelligence, and digital hospital applications are some techniques in digital health.

As in the rest of the world, Türkiye is adapting to the developing technology and using digital technologies in many sectors. In the health sector, many digital health applications are being used and expanded in Türkiye. With Article 56/1 of the Constitution; "*Everyone has the right to live in a healthy and balanced environment.*" the right to health is guaranteed in Türkiye. Therefore, providing quality and easily accessible healthcare services is one of Türkiye's most fundamental objectives. Based on this aim, Türkiye benefits from the innovations and advantages of digitalization in the health sector.

Türkiye is among the countries that use digitalization instruments extensively in the healthcare sector. In Türkiye, there are some digital applications for individuals to receive health services and monitor their health such as Sağlık.NET, Central Hospital Appointment System (MHRS), E-Nabız, Tele-Medicine, National Health Data Standards, Hayat Eve Sığar, Vaccine Tracking System, RUHSAD Mental Health Support System, 112 Emergency Help Button, Unimpeded Audio Book, SİNA (Statistics and Causal Analyses in Health). In addition to above mentioned applications, the digital hospital is one of the most comprehensive instruments of the digitalized health sector and it is among the most successful implementations in Türkiye on a global scale. Digital hospitals use technology to improve patient safety and healthcare quality. Hospital information system (HIS), electronic health record, picture archiving and communication systems (PACS), laboratory information management system (LIMS), radiology information system (RIS), electronic prescription, electronic order, appointment systems, etc. systems are used in digital hospitals.

The Healthcare Information and Management Systems Society (HIMSS) uses EMRAM, a globally accepted accreditation and standard model, to assess and grade the digital processes of hospitals. HIMSS 7 and HIMSS 6 stage hospitals are accepted as digital hospitals. As of September 2023, Türkiye has 57 HIMSS 6 stage hospitals and 7 HIMSS 7 stage hospitals by HIMSS EMRAM criteria. On the other hand, there are 18 HIMSS 6 stage and 3 HIMSS 7 stage health centers by HIMSS O-EMRAM criteria [1]. In Türkiye, the issue of digital hospitals is among the top priorities and studies are being carried out to increase their number.

Studies indicate that digital hospitals save time and cost in service delivery. When compared to conventional hospitals, stationery costs as well as medication and medical consumables are reduced in digital hospitals. According to the HIMSS EMRAM criteria, both HIMSS 7 and 6 stage hospitals are considered as digital hospitals, but unlike HIMSS 6 stage hospitals, there is no paper use in HIMSS 7 stage hospitals. It means that HIMSS 7 stage hospitals have zero paper use criteria. Accordingly, it is unclear whether there is an efficiency difference between HIMSS 7 and HIMSS 6 stage hospitals based on stationery expenses. Thus, the efficiency of HIMSS 7 and HIMSS 6 stage hospitals was calculated and compared based on stationery expenses.

In the efficiency calculation, Data Envelopment Analysis (DEA) technique, which is frequently used in the health sector but has not yet been used in the efficiency measurement of digital hospitals, is used. When quantitative studies about digital hospitals in the literature are examined, it is seen that there are studies using hospital-based observational data. For this reason, in this study, the efficiency analysis of digital hospitals is conducted with DEA technique.

The rest of the study is designed within the framework of the following topics.

In Chapter II, detailed explanations about the digitalizing health sector, digital hospitals and the HIMSS organization are given. Moreover, information about HIMSS-certified hospital practices in the world and Türkiye is presented.

Chapter III is concerned with efficiency analysis. Types of efficiency, efficiency measurement and methods used in efficiency analysis are explained in this section. The DEA method, which is frequently used in efficiency measurement in many sectors besides health sectors, is also discussed in detail.

Chapter IV presents the literature reviews on digital hospitals and data envelopment method in the health sector.

In Chapter V, the efficiency of 4 HIMSS 7 and 16 HIMSS 6 stage hospitals included as a sample in the study is analyzed by DEA technique based on stationery expenses. Then, the efficiency scores calculated by DEA are statistically analyzed under different hypotheses.

Finally, in Chapter VI, conclusions and recommendations are presented considering the findings regarding digital hospitals. The results of the efficiency analysis of HIMSS 6 and HIMSS 7 stage digital hospitals on the basis of stationery expenses are evaluated and recommendations for hospital efficiency are presented.

CHAPTER 2

DIGITAL HOSPITALS

2.1 Digitalization of the Health Sector

Today, digitalization and technology have an important place in our lives. The rapid advancement of technology has forced all sectors into digital transformation. As the place of computers and the internet in our lives has increased, digitalization has accelerated for the business world and gained an important dimension in the economies of countries. Especially with internet services becoming accessible, globalization has also accelerated and distances have disappeared. Technological developments have brought innovations, while digitalization processes have reduced costs and increased health service quality and efficiency as well as customer satisfaction. Transitioning from traditional production and service systems to digital and smart systems is highly efficient for the business world.

As the health sector is a vital field, the health sector has also become one of the most important digitalized sectors within the other sectors adapting to the digitalized world. In this sense, the digitalization of the health sector is so important concerning both the quality of the service provided and time. Digital health technologies and applications are defined as systems that enable individuals to control their own health status, promote preventive health activities, and enable communication between individuals and healthcare personnel.

Digital health enables a change in the healthcare system by redefining and expanding the boundaries between patients, consumers, citizens, healthcare professionals, investors, organizations and similar structures. At the same time, digital technologies are leading to the creation of an integrated healthcare system to improve digital connectivity between patients, healthcare professionals, stakeholders and companies within the healthcare system [2].

The digital health world includes some techniques such as e-health, mobile health, telemedicine, wearable technology, 3D printers, artificial intelligence, digital hospitals applications. All these techniques play an active role in digital healthcare and also these digital transformations will contribute to increasing organizational efficiency and improving the quality of healthcare. In this study, digital hospitals, whose applications are increasing day by day and have an important place in digital health, will be examined in detail. Implementation methods, technologies used, advantages, and productivity of digital hospitals are included in the following chapters. In addition to the digital hospital, the other techniques of digital health are briefly mentioned below.

- **E-Health:** E-health is health services delivered through the internet and related technologies. It also characterizes a state of mind, a way of thinking, an attitude and a commitment to networked, global thinking to improve healthcare locally, regionally and worldwide using information and communication technology [3]. E-health enables the cost-effective and secure use of information and communication technologies during the health service delivery [4].
- **Mobile Health:** According to the Global Observatory for eHealth, mobile health is the medical and public health practice. Mobile health is supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices [5].
- **Telemedicine:** Telemedicine refers to the provision of remote medical support to the patient by the physician through mobile connections when the physician and the patient are not in the same place. [6].According to WHO, there are five specific categories of telemedicine practices. These are teleradiology, teledermatology, telepathology, telepsychiatry, remote patient monitoring (Monitorization) [7].
- **Wearable Technology:** Wearable technology or wearable devices are defined as electronic devices and computers that can be easily worn on the body and integrated into clothing and other accessories. The main feature of these wearable devices is that they can perform the basic functions of cell phones and laptops, sometimes even outperforming them. With this technology, people can access information instantly using the internet, as well as devices with built-in memory. Examples of wearable devices include watches, glasses,

contact lenses, e-textiles and smart fabrics, headbands, beanies, and caps, hearing aid devices that look like rings, bracelets and earrings [6].

- **3D printers:** 3D printing is a technological process in which a three-dimensional model is solidly printed on a 3D printer. The most widespread use of 3D printing technologies has been in the engineering and medical fields. The last 30 years have seen major advances in medical technology, from open surgeries to minimally invasive surgery to the use of high-tech simulators in education. Considering the domestic and foreign widespread use in the field of health;
    - Anatomical models
    - Use in surgical planning and radiology
    - Orthosis-prosthesis-implant production
    - Pharmacological applications
    - Surgical instrument manufacturing
    - Simulation and education

  usage is widespread [8].
- **Artificial Intelligence:** Bioethics Briefing Note [9] describes artificial intelligence as computing technologies that are similar to processes associated with human intelligence, such as reasoning, learning and adaptation, sensory understanding, and interaction in general. Artificial intelligence applications are used for a range of health service delivery and research purposes, such as disease detection, chronic disease management, and health service delivery. However, in addition to its significant benefits, artificial intelligence raises some ethical issues such as the potential for erroneous decision-making, who is responsible for decision-making situations, some difficulties in verifying artificial intelligence outputs, protection of sensitive data, and the potential to be used for malicious purposes [6].

2.2 Definition of Digital Hospitals

Digital hospitals are defined as where all information systems within the hospital are fully integrated with all kinds of medical and non-medical technologies, reliable data flow standards are determined, and mobile access to hospital and patient data and information from anywhere by spending less time and energy on physicians, nurses, etc. personnel within the framework of their authorization; moreover hospitals where no manual operations are performed, paperless and filmless, effective business processes of healthcare professionals, correct medication and medical treatment applications are controlled, and all transactions are fully automated and managed in real terms are called digital hospitals [10]. According to the Republic of Türkiye Ministry of Health (MoH), a digital hospital is a fully integrated hospital with management elements such as hospital information management system, digital medical records, PACS (Picture Archiving and Communication Systems), digital medical archive, barcode, RFID (Radio Frequency Identification Devices) technologies, drug and material tracking, mobile and tablet computers, medical technologies, building, energy, lighting technologies and information systems, communication systems, data, audio, video and multimedia technologies, tele-medicine, tele-education, virtual autopsy, virtual surgery, virtualization, management services, consultancy, guidance, garden, parking and all kinds of integrated services [11].

Digital hospitals hospital systems use technology to improve patient safety and healthcare quality. HIS, electronic health record, PACS, Laboratory Information Management System (LIMS), Radiology Information System (RIS), electronic prescription, electronic order, appointment systems, etc. systems used in hospitals provide doctors, nurses, and other healthcare personnel with easy access to patient information by integrating developing technologies into hospital information systems. Thus, the physician and the patient can access all health records of the patient electronically. Nurses providing care services contribute to minimizing errors in the treatment process by handling the treatment processes of patients as a whole without wasting time. In addition, there will be various administrative and financial gains for decision-makers who will eliminate the paperwork [12]. According to "Digital Hospital Guide" which is published by MoH, the general requirements for becoming a digital hospital are as follows;

-- Electronic ordering system should be used

-- Physician and nurse clinical decision support systems should be available

-- Closed-Loop Medication Management should be done

-- Medication Decision Support Systems should be available

-- Clinical Data Repository should be established

-- Data warehouse and business intelligence should be available

-- Data sharing between health institutions should be possible

-- Data should be exchanged to ensure the clinical care process

-- Paper documents should not be used in service delivery.

Determining the stage of digitalization of a hospital at the international level is measured by EMRAM (Electronic Medical Record Compliance Model), developed by HIMSS (Health Information and Management Systems Society).

2.3 HIMSS and HIMSS Stage of Digital Hospitals

HIMSS was founded in 1961 and has 600 companies and 450 associations/foundations and covers more than 70,000 people in the field of health worldwide. The aim of HIMSS, which is headquartered in Chicago and has offices in America, Europe, and Asia, is to provide the most appropriate level of use of information technologies in the delivery and development of health services [13]. HIMSS is a global community of advisors, thought leaders, and members dedicated to reforming the global health ecosystem using information and technology. As a not-for-profit society, HIMSS advises global healthcare leaders and stakeholders on best practices and provides in-depth expertise in healthcare innovation, public policy, workforce development, research, and digital health transformation. HIMSS also provides important information, education, and events to healthcare providers, payers, governments, startups, and other healthcare organizations. [14].

In the digitalization process, the level of use the information systems in the functioning of healthcare organizations is audited and hospitals are accredited. HIMSS uses the universally accepted accreditation and standard model EMRAM to assess the digitalization levels of applicant hospitals. In this way, hospitals are rated from HIMSS 1 to HIMSS 7, and if the hospitals' digitalization level reaches to the HIMSS 6 and HIMSS 7 stage, they are rewarded with a digital hospital certificate [15].

EMRAM measures, patient participation, clinical outcomes, and use of Electronic Medical Records (EMR) technology by physicians to strengthen organizational performance and health outcomes across patient populations. Internationally applicable EMRAM includes methodology and algorithms to grade an entire hospital, including inpatient, outpatient, and daycare services provided in a hospital. EMRAM grades hospitals around the world according to their digital maturity, providing a detailed roadmap for adoption and embarking on digital transformation toward targeted results. By measuring evidence-based data at every stage, organizations use EMRAM to optimize their digital work environment, build a sustainable workforce, improve performance and financial sustainability, and support a remarkable patient experience. Increasing information digitally improves patient safety and physician satisfaction by reducing care errors, patient length of stay and repetitive care instructions, and by facilitating access and use of data to inform care delivery [14].

On the other hand, the EMRAM for Outpatient Care Providers referred to as O-EMRAM specifies methodologies that include electronic health records-based delivery of outpatient services and is mostly used to determine the HIMSS measurement criteria for “Oral And Dental Health Clinics (ODHC)” [16].

Considering the guide prepared by the General Directorate of Health Information Systems of the MoH, the functions of HIMSS stages are summarized below [17].

Stage 0

It states that even the most basic support applications such as laboratory, pharmacy, and radiology are not integrated into the digital environment.

Stage 1

The hospitals where pharmacy, laboratory, and radiology information systems are all located together. PACS systems, which are complete complement to radiology and cardiology, provide medical images to physicians via the intranet. Images delivered through PACS systems have replaced all film-based images. Patient-centered storage is also available for non-DICOM (Digital Imaging and Communications in Medicine) images.

Stage 2

The hospitals where the main ancillary clinical systems are activated with data fed from a single clinical data store or with fully integrated data stores for all orders, results, radiology, and cardiology images examined, and where the clinician can access these data from a single user interface without any problems.

Stage 3

50% of the nursing documents such as vital signs, flowcharts, caregiver notes, caregiver duties, and care schedules within the hospital (including documents determined by the hospital) should be created and integrated into the clinical data pool. 50% of the integration of nursing documents with the repository should be provided through electronic data, but all electronic data within the hospital should be recorded in the clinical data repository. An Electronic Medication Administration Record (eMAR) application must be performed. Role-based access control (RBAC) should be implemented.

Stage 4

50% of all medical orders must be made through the electronic ordering system (Computerized Physician Order Entry –CPOE) by any clinician authorized to create the order. The CPOE should be supported by a clinical decision support system for basic dispute control and orders added to the nursing and clinical repository environment. At least 90% of clinical documents used by nurses and allied health personnel should be in electronic form. Unless restricted in terms of privacy, physicians can access a national or regional patient database to support decision-making (such as drug therapy, imaging, vaccination, and laboratory results). Through the use of an electronic medication administration record, clinicians can access patient allergies, diagnosis lists, medication, and laboratory results. A potential network attack detection system (Intrusion Detection System-IDS) must be in place to detect network attacks.

Stage 5

All physician documentation with structured templates (such as progress reports, opinion reports, discharge summaries, problem/diagnosis lists) and discrete data should be implemented in at least 50% of the hospital. Physician documentation should be operated under the 50% rule. However, the process of recording electronic data is considered outside the 50% rule. Nursing work plans should be editable; completion time with task time should be trackable and reportable. Intrusion Prevention System (IPS) must be available and used not only to detect possible attacks but also to prevent attacks. In case of loss or theft of portable devices that are defined and authorized to work in the hospital's network, the information in the device should be remotely erased to ensure data security.

Stage 6

Implementation of closed loop systems and utilization of emerging technology in the management of medicines, blood products, and breast milk should be utilized. Closed loop systems should be fully implemented in 50% of hospitals. However, electronic recording of data is considered outside the 50% rule. The electronic medicines management record and other technologies used in the hospital should be integrated with electronic ordering, pharmacy and laboratory systems to maximize safe point of care processes and outcomes. A clinical decision support system should be developed and elaborated by the "5 right rules (Right patient, right drug, right dose, right route and right time)". In addition, the "5 right rules" should provide higher levels of rules for medication, blood products, breast milk management and blood sample processing. A clinical decision support system that can guide physicians by processing the data obtained from electronic documentation organized by physicians in accordance with existing protocols should be prepared. A safe use document for mobile device security policy and applications should be prepared. In order for the hospital to be stage 6 must submit an annual security risk assessment report to management to take action. In order for the hospital to take action to become stage 6, it must provide an annual safety risk assessment report to management.

Stage 7

Paper should not be used to provide and manage patient care within the hospital. All patient data, medical imaging and other documents should be included in the patient's electronic health record. Databases should be used to analyze clinical data models to increase healthcare quality and efficiency as well as to ensure patient safety. Clinical information should be easily shared with all units authorized to treat patients using standardized electronic processes. The hospital should be able to make at least three case study analyses for all hospital services. Physician documentation and electronic ordering should be used at a rate of 90% (excluding all electronic data recorded within the hospital) and closed-loop processes at a rate of 95% (excluding all electronic data recorded within the hospital).

In HIMSS 6 and HIMSS 7 stage hospitals, the Closed Loop Medication Management System (CLMM), which simplifies and facilitates treatment processes, becomes visible. In this system, digital technologies (barcode reader, finger reader, vein reader, etc.) should be used for patient verification and each unit dose in the package should also be scanned with a barcode to check the warnings given by the system about the right patient, the right drug, the right dose, the right time of administration and the right route of administration [18]. The expectation with CLMM is to standardize the flow of the medication management system, identify unnecessary steps that may lead to errors and remove these steps from the process. The medication use process involves many levels, from the physician's prescribing the medication to the patient's use of the medication. Operational errors are possible in all these steps and CLMM can be considered as the most effective way to eliminate these errors. What is meant by the closed loop expression here is that each step provides information for the next step and that these steps can also be used as control points. The basics of CLMM's application can be described as follows [17]:

- Immediately before the drug is administered to the patient, the drug should be compared with the order made by the physician in terms of the characteristics of the drug (name, form, dose, etc.) and the time of administration.
- At the same time, it should also be verified at this point whether the drug has been given to the right person.
- After these checks, the type of drug, the patient the drug was administered to, the time it should be applied, the time it was applied and the person who applied it can be documented so that it can be accessed again when needed.

With these steps mentioned above, it will be ensured that the patient receives the correct medication during the treatment process and no mistakes are observed. In addition, healthcare providers will have evidence that all steps in the treatment process have been carried out at the expected time and quality, which they can present in legal cases.

2.4 HIMSS in the World

The EMRAM model started to attract worldwide attention after 2005. It varies according to the socio-political structure of the countries, although it is taken as a basis in the process of digitalization in health by countries all over the world. The basis of the EMRAM model, which differs among countries, can be explained as follows [17].

- A study conducted in Paris examined the digitalization process on the basis of two different hospitals, "Hospital Italiano de Buenos Aires" and "Hospital Europeen Georges Pompidou", and stated that both hospitals can be considered EMRAM Stage 6.
- In China, the MEG (Model of EHR Grading) model, which was built in 2010 based on HIMSS EMRAM criteria, was used in the scoring of many different hospitals in the country as of 2011 with the authorization of the Chinese Ministry of Health. The difference of the new MEG model from the HIMSS EMRAM standards is that hospitals have 9 roles and 37 functions. The number

of hospitals participating in the scoring was 848 in total, of which the number of hospitals that could reach Stage 6 according to HIMSS EMRAM criteria was 1%, while it was also stated that there were no hospitals that could achieve Stage 7.

- The United Kingdom, Canada, and Australia have adopted the HIMSS EMRAM scoring system for the digitalization of their hospitals and the development of information technologies. In the studies carried out, it was emphasized that hospital personnel should be trained especially on the integration of hospitals, information security, and integrated systems to make digitalization sustainable in healthcare service delivery, and the necessary studies on personnel training, which HIMSS especially draws attention to, have been continued.
- As a result of a study conducted in 2016, it was determined that the recognition of the EMRAM model in Iran is quite low, three hospitals were evaluated according to EMRAM criteria in the field study, and it was observed that all three hospitals identified only corresponded to EMRAM Stage 1. At this point, the country realized that digitalization in healthcare is an important roadmap and designed to prioritize the improvements to be made to expand digitalization in hospitals.

According to the HIMSS analytics website as of September 2023, respectively Stage 6 and Stage 7 hospital numbers in the countries according to EMRAM criteria, Argentina 0-1, Australia 4-0, Brazil 4-4, Canada 10-8, Germany 1-0, Indonesia 3-0, Ireland 1-0, Italy 6-0, Norway 1-0, Portugal 0-3, Russia 1-1, Saudi Arabia 18-19, Spain 2-0, Türkiye 57-7, United Arab Emirates 8-0, United Kingdom 3-4, United States 85-293 [1] [19].

In the direction of this information, it is seen that EMRAM criteria are taken into consideration in many countries of the world today. The dissemination of digitalized hospitals has gained global importance to provide quality and effective health service delivery in a shorter time and at a lower cost.

2.5 HIMSS Experience in Türkiye

As the elderly population increases along with all population groups, there is a need to increase health service delivery capacity. For this reason, it is becoming increasingly difficult to meet health service delivery with traditional methods with the existing number of personnel, beds, and equipment. In this context, while trying to increase the number of health personnel, equipment, and beds in the health sector, it is also aimed to provide more accurate health services to more people in a shorter time with the existing capacity. At this point, the Eighth Five-Year Development Plan in Türkiye states that "All levels of health service delivery will be improved in terms of workforce, infrastructure, management and technology and a health information system will be established." [20]. In line with the principles set out in the Development Plan, the "E-Transformation Türkiye Project" and the "Health Transformation Project" were launched in 2003, and within the scope of this project, the statement "*In order to provide a sustainable structure for health services, the system's workforce, financing, organization, management, supervision, technology and physical infrastructure will be improved*" was included [21].

In parallel with all these objectives, studies have started to be carried out for the establishment of digitalization infrastructure in health practices and health facilities to achieve the targets. With the circular on "Information and Communication Technologies" issued by the Ministry of Health in 2013, it was decided that by the end of 2015, all services provided in the healthcare sector would be implemented through web-based applications [22]. The General Directorate of Health Information Systems of the Ministry of Health, which carries out studies for the transition to the digital hospital and closely follows the developments in the world, implemented the digital/paperless hospital project called "Digital Transformation Project in Our Hospitals" in 2012 [23]. In this direction, the "Ministry of Health 2013-2017 Strategic Plan" published in 2012 aims to increase the digital hospital infrastructure in Türkiye with the statement "To create and expand the concept of "digital hospital" in the facilities affiliated to the Ministry and its subsidiaries" [24]. The Ministry of Health has closely monitored digitalization in hospitals to include healthcare service delivery in the digitalization process supported by high-level policy documents. It has collaborated with the HIMSS organization to register the digital maturity levels of hospitals within the framework of globally accepted standards. The HIMSS organization and the Ministry of Health started to work together in line with their common goals to register the quality of healthcare services within the framework of a globally accepted standard and to continue the digitalization process without stopping by the requirements of these standards [17].

In Türkiye, HIMSS EMRAM is carried out in cooperation with the Ministry of Health and HIMSS Europe. In 2013, the first 5-year protocol was signed between HIMSS Europe and the Ministry of Health to ensure that the information technology levels of health institutions in Türkiye comply with international standards and to measure and document the digitalization levels of health institutions [17]. Then, in February 2019, a new 5-year protocol was signed and the agreement period was extended [13]. Accordingly, the agreement between HIMSS and Türkiye will continue until 2024.

HIMSS made a name for itself when Ankara Gazi Mustafa Kemal Hospital, which was selected as a pilot in Türkiye in May 2013, received a Stage 6 certificate in 2013. Since the validity period of the certificate is 3 years and the hospital did not request any validity for re-rating in 2016, it lost its Stage 6 rating. While the number of hospitals that reached Stage 6 at the HIMSS Exhibition held in Istanbul in 2014 was 3, it increased to 6 at the exhibition held in Antalya in March 2015. In the event held in Istanbul in May 2016, the number of hospitals with Stage 6 increased from 6 to 7 and 1 hospital was awarded Stage 7. At the "*HIMSS 2017 Health Informatics Conference and Exhibition*" event, the Minister of Health of the time set a target for 100 hospitals to reach HIMSS Stage 6 and for all remaining hospitals to reach HIMSS Stage 5. Following this target, 771 hospitals and 81 provincial health managers were informed on HIMSS EMRAM criteria and digital hospital practices through 10 regional workshops held between May 25 and July 31, 2017. As a result of the workshops, 153 hospitals were validated as Stage 6. As of January 1, 2018, the HIMSS EMRAM Criteria were updated. Since the change of criteria, regional workshops have started to be conducted to explain the current HIMSS EMRAM criteria [17].

Along with all these developments, there is an incentive for digitalization in traditional hospitals as a result of advances in digitalized hospitals such as achieving cost and time optimization in health service delivery, reducing misdiagnosis and incorrect medication applications, and serving more patients in a shorter time with the use of digital applications by healthcare personnel. As a result of the announcement and presentation of digital hospitals at the HIMSS exhibitions organized every year and the explanation of the contributions of digitalization infrastructure to health service delivery, more hospitals want to undergo the digitalization process and the number of digitalized hospitals in Türkiye is increasing day by day.

Figure 2.1, which is reproduced from "*HIMSS-EMRAM Çalıştay Sunumu* by Dr. İlker KÖSE", shows the digital hospital progress in Türkiye chronologically [23] [17] [1].

The figure clearly shows that Türkiye has been continuously working and updating digital hospitals over the years. When looking at the figure, 2017 and 2020 were the years with the highest number of hospitals. When the number of digital hospitals in the countries, under the title of "*HIMSS in the World*", is compared with Türkiye, it can be easily said that Türkiye is considered the most developed country in terms of digital hospitals.

The Deputy Minister of the MoH is the co-chair of HIMSS Eurasia and the majority of HIMSS Eurasia Steering Committee members are Turkish physicians and scientists [13]. "HIMSS Eurasia Health Informatics Conference and Exhibition" event is organized annually. The last "HIMSS Health Informatics Conference and Exhibition" event was organized on November 10-12, 2022 in Antalya.

As of September, 2023, Türkiye have 57 Stage 6 hospitals and 7 Stage 7 hospitals on HIMSS EMRAM criteria. On the other hand, there are 18 Stage 6 and 3 Stage 7 health centers on HIMSS O-EMRAM criteria [1].

2012

MoH General Directorate of Health Information Systems "Digital Transformation Project in Our Hospitals" was carried out in 2012.

2013

The first 5-year protocol was signed. Ankara Gazi Mustafa Kemal State Hospital was selected as a pilot. It was the first hospital to be validated as Stage 6 in April 2013.

2016

EMRAM: 7 Hospitals Stage-6, 1 Hospital Stage-7

2017

EMRAM: 153 Hospitals Stage-6

2018

As of January 2018, HIMSS EMRAM Criteria have been updated.

2019

The second 5-year protocol was signed. HIMSS O-EMRAM model started to be implemented.
EMRAM: 19 Hospitals Stage-6, 2 Hospitals Stage-7
O-EMRAM: 11 ODHCs Stage-6

2020

EMRAM: 172 Hospitals Stage-6, 3 Hospitals Stage-7
O-EMRAM: 10 ODHCs Stage-6, 2 ODHCs Stage-7

2021

EMRAM: 63 Hospitals Stage-6, 5 Hospitals Stage-7
O-EMRAM: 11 ODHCs Stage-6, 2 ODHCs Stage-7

2022

EMRAM: 56 Hospitals Stage-6, 7 Hospitals Stage-7
O-EMRAM: 20 ODHCs Stage-6, 3 ODHCs Stage-7

2023

EMRAM: 57 Hospitals Stage-6, 7 Hospitals Stage-7
O-EMRAM: 18 ODHCs Stage-6, 3 ODHCs Stage-7

Figure 2.1 Digital Hospital Progress in Türkiye

CHAPTER 3

EFFICIENCY ANALYSIS

3.1 The Concepts of Productivity Efficiency and Effectiveness

“Productivity”, “Efficiency”, and “*Effectiveness”* are the technical performance indicators of enterprises. Technical performance indicators allow the measurement of performance in all its dimensions. Technical indicators are used to measure the performance of activities, factors of production and employees. However, there is confusion in the literature about the definitions of productivity, efficiency, and effectiveness [25].

In basic terms, “***Productivity****”* examines the relationship between input and output in a given production process. Productivity is therefore expressed in terms of a formula for measuring production activities, which is a ratio of output to input as shown below [26].

$$\text{Productivity} = \frac{\text{Output(s)}}{\text{İnput(s)}} \tag{3.1}$$

Productivity measurements can be realized as “*Partial Productivity”* for a single input; “*Multi-Factor Productivity*” for more than one input; and “*Total Productivity*” for all inputs [25].

Which of these productivity measures is used depends mainly on the reason for the measurement. If the reason is to follow developments in labor productivity, labor will be used as the input measure. Partial Productivity calculation can be used to determine the appropriate degree of intervention in each of the factors. Partial Productivity measures such as labor productivity (output/labor) or machine productivity (output/machine) are often used by enterprises. The criterion to be used to measure the overall performance of an enterprise, therefore, should be the Total Productivity value, which takes into account all inputs and outputs [25]. The table in the below provides a clear explanation of the calculation of different productivity types.

Table 3.1 Types of Productivity

Productivity	Formula	Example
Partial Productivity	Output/One Input	Output/Labor
Multi-Factor Productivity	Output/More than One Input	Output/Labor + Machinery
Total Productivity	Output/All Input	Output/Labor + Machinery + Capital + Raw Materials + Energy

Note: The table is from Yükçü & Atağan (2009)

The concept of productivity is closely related to the concept of efficiency. Although the terms efficiency and productivity are used instead of each other, efficiency does not have the same definite meaning as productivity [27]. "***Efficiency***" is also defined as the comparison of two components (inputs and outputs), with the highest level of productivity obtained from each level of inputs is considered as the efficient case. Coelli et al. [26] claim that efficiency is the ability of a firm to maximize output from a given set of inputs. A firm is said to be efficient if it maximizes output from a set of inputs [28]. Pritchard et al. [29] state that if an organization's productivity growth is higher than its competitors or other firms, that firm is regarded as a better performer and more efficient [27].

According to Chorafas [30], efficiency is the performance of an activity in the shortest possible time and at the lowest possible cost, taking into account quality. According to another approach, efficiency is the comparison of optimal values of inputs and outputs with their observed values. In this approach, the optimal value is expressed in terms of production possibilities or behavioral objectives of the producer [31].

In the most general terms, "Efficiency" is the highest level of performance that uses the minimum amount of inputs to produce the maximum amount of output. Efficiency is the requirement to decrease the number of unnecessary resources used to produce a given output [32]. Efficiency strives to realize the macro-plan objectives of the economy in the micro-plan. In this respect, efficiency plays the role of a tool in the way of the goal that the economy wishes to realize [33].

When we look at the definition of "***Effectiveness***", which is the ability to produce a desired outcome or the ability to produce a desired output. Efficiency and effectiveness can sometimes be confused with each other. Efficiency is actually a measure that determines the relationship between inputs and outputs and is the achievement of objectives using the minimum resources. Efficiency is the ability to do things in the most appropriate way and at the least cost, while effectiveness is the ability to achieve the goals and objectives of an institution and to do the right work. While efficiency focuses on inputs and outputs, effectiveness is concerned with outputs, outcomes, and impacts. *Efficiency measures the extent to which factors of production are used appropriately, while effectiveness measures the extent to which objectives are achieved.* In this context, an institution may be efficient but not effective, or an effective institution may not use its resources efficiently [34].

3.2 Types of Efficiency

There can be different factors that determine whether an enterprise is considered efficient or not. In other words, efficiency measurement depends on the different issues. Therefore, there are different types of efficiency studied in the literature. Technical, allocative, cost, scale, dynamic, social, and X-efficiency are efficiency types in the literature. In this study, technical, allocation, cost and scale efficiencies are discussed in detail, while other types of efficiencies are briefly explained below.

3.2.1 Technical Efficiency

Technical efficiency (TE) is the success of an enterprise in producing the maximum possible output by using the inputs appropriately [35]. A firm is said to be technically efficient if a firm produces the maximum output from the minimum inputs, such as labor and capital.

The production frontier represents the maximum output that can be obtained from each level of input. Firms operate above this frontier if they are technically efficient. If they are not technically efficient, they operate below the frontier.

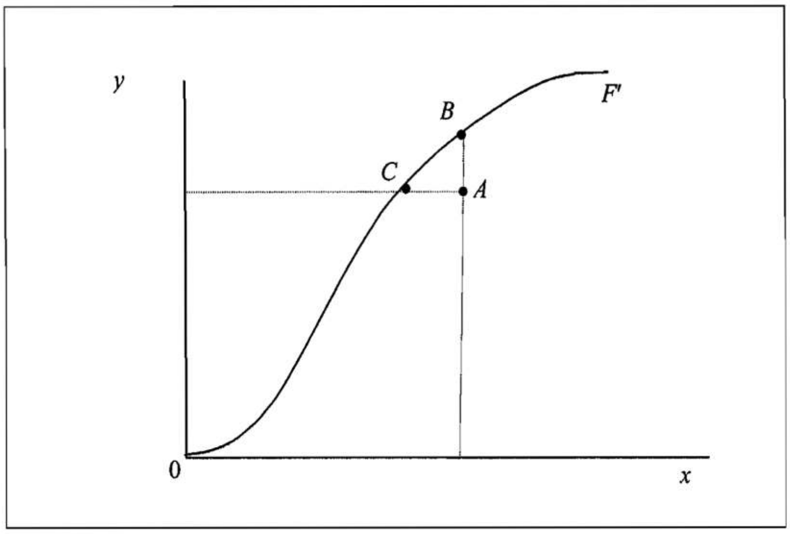

Figure 3.1 Production Frontiers and Technical Efficiency

According to the graph in Figure 3.1, quoted from Coelli et al. [26], point A represents an inefficient point, while points B and C represent efficient points. A firm operating at point A is inefficient because it can technically increase its output to point B without requiring more input.

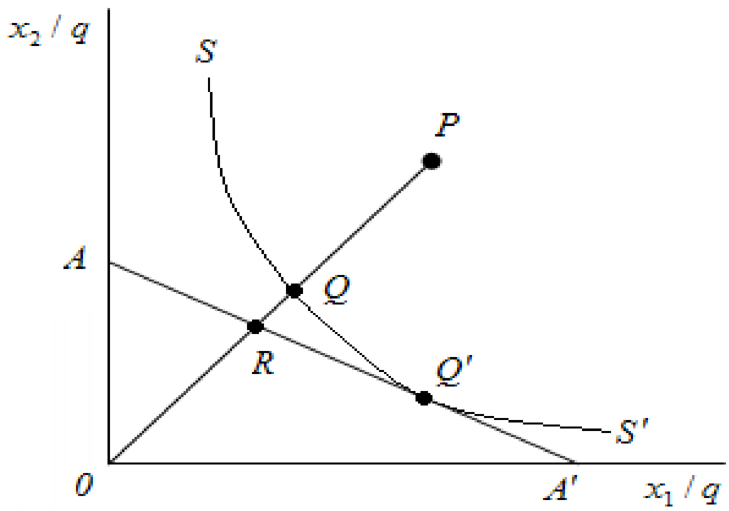

Figure 3.2 Technical and Allocative Efficiency

Coelli et al. [26] considered a set of inputs (such as labor and capital) with two input components (x_1, x_2) and one output component (q) and presented it on a graph in Figure 3.2. The vertical axis shows the quantity x_2 that needs to be used to obtain per unit of output and the horizontal axis shows the quantity x_1 that needs to be used to obtain per unit of output. It is assumed that the efficient frontier (SS') is determined in some way and the input price ratios are also represented by the line AA'. In Figure 3.2, point P represents the input combination to produce per unit of output for decision a firm. Since point P is located above the efficient frontier, it can be said that the firm is inefficient. For the firm to be efficient, it needs to reduce the amount of inputs up to point Q without reducing the amount of output [26]. The rate of reduction in inputs is QP/OP and the technical efficiency of this firm is measured by 1- (QP/OP) [36] [28]. In this way, the technical efficiency of a firm operating at point P is calculated as follows.;

$$TE = OQ/OP \tag{3.2}$$

3.2.2 Allocative Efficiency

When information on prices is available and a behavioral assumption such as cost minimization or profit maximization is appropriate, performance measures can be developed accordingly. In this case, allocation efficiency (AE) can be measured in addition to technical efficiency. Input-oriented allocative efficiency involves selecting the combination of inputs (e.g. labor and capital) that produces a given quantity of output at minimum cost given current input prices [26].

Allocative efficiency can only be determined based on input prices. Going back to Figure 3.2, line AA'' shows the input price ratio. Given this ratio, production at point Q is not efficient and the firm should be located at point Q'. A firm operating at point Q' is technically efficient but does not have allocative efficiency. Thus, the allocative efficiency of the producer at point P is calculated by the ratio OR and OQ ratio as shown below [28].

$$AE = OR/OQ \tag{3.3}$$

3.2.3 Economic (Cost) Efficiency

The success of an enterprise in selecting the most appropriate input by considering input cost and output prices is called economic/cost efficiency [35]. In other words, economic efficiency is decreasing the production/service cost without reducing production/service quantity and quality. Along with the concepts of technical efficiency and allocative efficiency, Farrell [37] defined a measure of what he called overall efficiency, renamed in the literature as “Economic Efficiency (EE)”. Economic efficiency is also called as cost efficiency in the literature. Economic efficiency is obtained by multiplying technical and allocative efficiency as shown below [38].

Coelli et al. [26] also argue that allocative and technical efficiency are combined to produce an overall economic efficiency.

$$EE = TE \times AE \tag{3.4}$$

In Figure 3.2, the RQ distance shows the reduction in costs that would occur if the firm produced at point Q', which is both technically efficient and allocative efficient, instead of producing at point Q, which is technically efficient but not allocative inefficient. Considering the explanation of Coelli et al. [26] and Farell [37] above, since total economic efficiency is calculated as the multiplication of technical efficiency and allocative efficiency, the formula for economic efficiency is shown as follows [36].

$$\frac{OR}{OP} = \frac{OQ}{OP} \times \frac{OR}{OQ} \tag{3.5}$$

3.2.4 Scale Efficiency

The success of an organization in producing at an appropriate scale by using the input combination most appropriately is called "Scale Efficiency (SE)" [35].

The efficiency results of an organization under different scale assumptions are shown in Figure 3.3, which is quoted from Zamorano. The explanation of the figure is detailed below [38].

The line with points J and B represents the frontier technology associated with the Constant Returns to Scale (CRS) assumption. Under this assumption, only units J and B are considered technically efficient. The efficiency scores of other non-efficient units such as A and D are calculated as Xh/Xa and Xj/Xd, respectively. The efficiency scores of the inefficient points A and D are accordingly less than 1.

Under Variable Returns to Scale, efficiency scores are obtained from the efficient frontier defined by the line Xa, A, B, C, and the horizontal section to the right of C. Since TE_{CRS} is less restrictive than TE_{VRS} (no convexity constraint), lower efficiency scores are obtained under the CRS assumption. Under the TE_{VRS} assumption, the VRS line is considered efficient over the VRS line. Accordingly, since the VRS line has a larger surface area, the VRS efficiency score can be higher. For instance, points A, B, and C on the VRS line are efficient points.

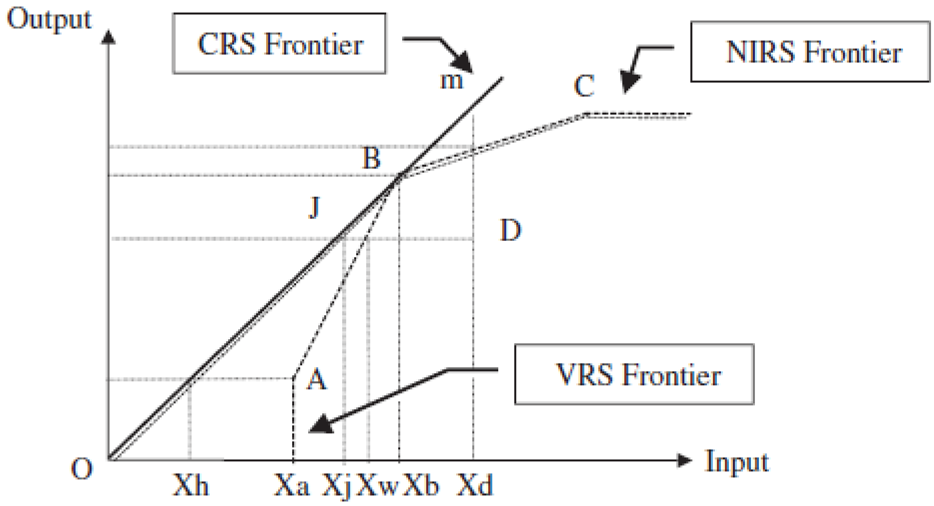

Figure 3.3 Constant-Variable-Non-Increasing Returns to Scale

Point D is inefficient. The efficiency score of point D under the CRS assumption is calculated from the ratio Xj/Xd, while the efficiency score under the VRS assumption is calculated from the ratio Xw/Xd. Therefore, the efficiency scores of a point under CRS and VRS assumptions can be calculated differently. On the other hand, point B is technically efficient under both CRS and VRS assumptions. In contrast, points A and C are efficient under the VRS assumption but not under the CRS assumption. This implies that the size of these points deviates from the optimal scale.

Scale efficiency is calculated as the ratio of the technical efficiency scores, calculated under the CRS and VRS assumptions as shown in the formulation below.

$$SE = \frac{\text{TE (CRS)}}{\text{TE (VRS)}} \tag{3.6}$$

The efficiency score obtained from the CRS assumption is called Total Technical Efficiency (TTE) and the score obtained from the VRS assumption is called Pure Technical Efficiency (PTE). If both the CRS and VRS efficiency scores are 100%, DMU is efficient. These DMUs are considered to be in the most efficient scale size. If the VRS score is efficient and the CRS score is less than 100%, the DMU is pure technical efficient but not total technical efficient with respect to scale size. The ratio of these two scores is used to calculate the scale efficiency of the DMU. In this case, the scale efficiency is less than one. The scale efficiency formula can be shown below considering the total technical efficiency and pure technical efficiency expressions [39].

$$SE = \frac{TE\ (CRS)}{\mathrm{TE\ (VRS)}} = \frac{TTE}{\mathrm{PTE}} \tag{3.7}$$

According to Banker et al. [40], output can also be affected by changes in the quantity of inputs in an organization. In order to determine the returns to scale, the amount of increase in output caused by a one-unit increase in input components is taken into account on the efficient frontier. Under this condition, the following three situations occur [36]:

***Increasing Returns to Scale (IRS)*:** This occurs when an equal increase in input components leads to a higher increase in output components. According to Figure 3.3, under the VRS assumption, point AB on the efficient frontier shows the case of increasing returns to scale.

***Constant Returns to Scale (CRS)*:** If the rate of increase in input components is equal to the rate of increase in output components, there is a constant return to scale. According to Figure 3.3, point OJB on the efficient frontier shows the case of constant returns to scale.

***Decreasing Returns to Scale (DRS)*:** If an equal rate of increase in input components leads to a lower rate of increase in output components, there is a decreasing return to scale. According to Figure 3.3, under the VRS assumption, the point BC on the efficient frontier shows the case of decreasing returns to scale.

3.2.5 Dynamic Efficiency

In general, the concept of efficiency is used to describe two different situations. In the first case, which is called "*Static Efficiency*", efficiency refers to the ability to produce the highest possible amount of production by utilizing the components such as labor, capital, and resources available in an economy. In this sense, economies that can produce the most with the available labor and physical resources are high-efficiency economies. The second concept, called "*Dynamic Efficiency*", represents the ability to produce higher quality production by achieving change and transformation in economic and social structures and behavioral patterns. Concepts such as technological innovation, development of new products and production methods, research and development, invention, and patents are concepts that are related to the objectives, processes, or results of dynamic efficiency [41].

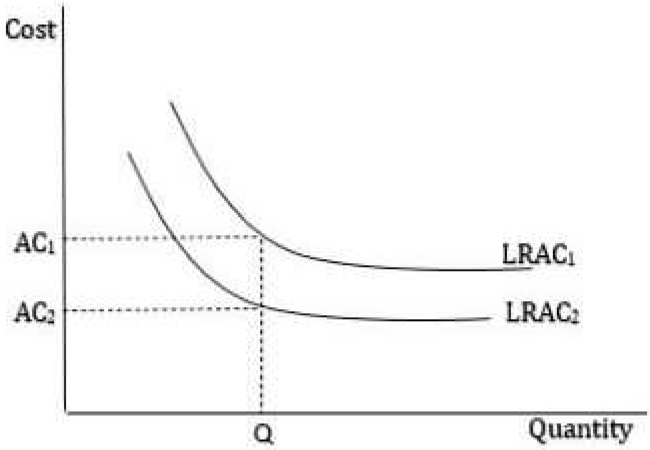

Figure 3.4 Dynamic Efficiency

As illustrated in Figure 3.3, which is quoted from WallStreetMojo, cost decreases as the amount of inputs increases in a dynamically efficient organization due to innovation, new technologies, etc [42]. The long-run average cost curve $LRAC_1$ is shifted down to $LRAC_2$, thus dynamic efficiency is achieved. Dynamic efficiency involves improving allocation and productive efficiency over time. Dynamic efficiency can imply developing new or better products, and finding better ways of producing goods and services. It is central to the ability of an organization, sector, or economy to adapt to changing conditions [43].

3.2.6 Social Efficiency

Social Efficiency is the optimal allocation of goods and services, taking into account externalities. In a socially efficient environment, marginal social cost is equal to social benefit [44]. All activities are inherently social and these activities determine the need for social impacts to be measurable. Any action or social event, and hence social efficiency, is characterized quantitatively and qualitatively. However, unlike economic efficiency, social efficiency is a more complex efficiency type and is not easy to express in one dimension [45].

To summarize, social efficiency is the optimal allocation of resources in society, considering all internal and external costs and benefits [46].

3.2.7 X-Efficiency

X-efficiency is defined as the maximum output a firm can produce with a given amount of input, taking into account the management incentive.

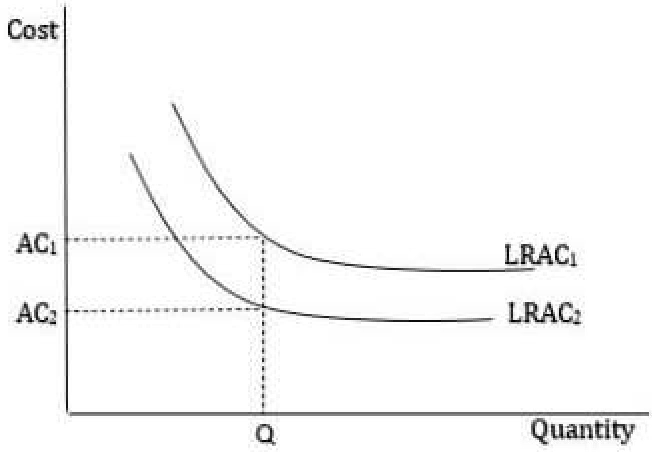

Figure 3.5 X-Efficiency

As seen in Figure 3.4, which is quoted from WallStreetMojo, the graph is no different from the dynamic efficiency graph (Figure 3.3) [42]. However, in this graph, the $LRAC_1$ curve has shifted to $LRAC_2$ only due to managerial factors and not due to factors such as innovation and technology. This means that the firm can shift its average total costs to $LRAC_2$ from the beginning, and it can be efficient in terms of x-efficiency. X-efficiency is most commonly observed in markets where competition is intense. In a competitive market, an organization aims to produce the maximum possible output at the lowest possible cost to remain competitive. On the other hand, when looking at a monopoly organization, it is observed that x-efficiency is generally not achieved very much. This is because the monopoly does not need to maximize output to increase its profits [44]. From another point of view, with the decrease in cost x-efficiency increases, shifting from a monopoly market to a competitive market and thus achieving a welfare gain [47].

3.3 Measurement of Efficiency

Efficiency measurement can be classified under three headings methodologically. These methods are Ratio Analysis, Parametric Methods, and Non-parametric Methods. Details of these methods are explained below [35].

a. Ratio Analysis

Ratio analysis is the most common method used in performance measurement because it is easy to apply and requires less data than other methods. With this method, a single input and output can be analyzed, but the method is inadequate for the analysis of multiple inputs and outputs. It is not appropriate to use ratio analysis in economic efficiency measurements that involve the use of a large number of inputs and outputs [48].

Ratio analysis is one-dimensional and cannot provide sufficient information about different dimensions of the performance of the enterprise due to the selection of a single ratio. Because this analysis is a one-dimensional method, it cannot derive a single measure by weighting different ratios. As a result of the evaluation of each ratio separately in ratio analysis, the enterprise can be characterized as efficient for some ratios and inefficient for some ratios. Therefore, it can be difficult to interpret and decide on the effectiveness of the business.

b. Parametric Methods

In parametric methods, it is assumed that the production function of the organization to be measured has an analytical structure and the parameters of this function are identified. Determination of the parameters of the "Cobb-Douglas" type production function is an example of parametric methods. In efficiency measurement with parametric methods, regression techniques are generally used for forecasting. The stochastic frontier analysis is also a parametric method used to measure the efficiency of decision-making units. The production function is usually defined by relating a single output to many inputs. However, there are also parametric methods that include many inputs and many outputs.

c. Non-Parametric Methods

Non-parametric methods, which emerged as an alternative to parametric methods, generally use mathematical programming as a solution technique. The efficiency frontier is tried to be measured in these methods. Non-parametric methods do not specify any analytical form about the structure of the production function. In this respect, they are more flexible than parametric methods. They are also very convenient to use for productivity measurement in enterprises with many inputs and many outputs.

The non-parametric method is a method that uses linear programming to measure the relative efficiency of decision-making units by optimally determining inputs and outputs grouped according to their actual performance. Zamorano states that the majority of efficiency studies are concerned with estimating the frontier production function and measuring economic efficiency using parametric or non-parametric frontier methods [38]. If all parameters of an econometric model are contained in a finite-dimensional parameter space, the model is "parametric"; if all its parameters are in the infinite-dimensional parameter space, the model is called "non-parametric". Parametric methods include the stochastic frontier production function, while nonparametric methods include Data Envelopment Analysis (DEA) [49].

As non-parametric methods, DEA is the most common method used by enterprises to measure relative efficiency. By DEA, the inputs and outputs of decision making units (DMU) are analyzed, the ones with the best performance are selected and the efficient frontier is obtained using these DMUs [50].

3.4 Data Envelopment Analysis

Data Envelopment Analysis (DEA) is one of the most widely used efficiency measurement techniques in the literature. In this method which was developed by Charnes, Cooper, and Rhodes, the relationship between input(s) and output(s) is analyzed and relative efficiency values are determined for decision-making units.

In DEA, the inputs and outputs of the DMUs are analyzed, the ones with the best performance are selected and the efficient frontier is formed using these DMUs. The degree of inefficiency of the units that are not located on this efficient frontier is determined according to this efficient frontier [50]. This theoretical frontier, which is formed by the highest production quantities that can be obtained with the optimal input combination, is called the efficient production frontier [48].

DEA is a nonparametric method for measuring the efficiency of a DMU with multiple inputs and outputs. Nonparametric methods use linear programming to measure the relative efficiency of a set of DMUs by determining the optimal mix of inputs and outputs grouped according to their actual performance. DEA is thus obtained by the ratio of the weighted sum of outputs to the weighted sum of inputs [49].

DEA was first introduced in 1978 by Charnes, Cooper, and Rhodes based on Farrell's [37] "Production Frontier" concept to measure the relative efficiency of DMU with a large number of inputs and outputs. The first model analyzed by using linear programming is the CCR (Charnes, Cooper, Rhodes- consisting of the initials of their surnames) model. The CCR model is based on the assumption of constant returns to scale. Afterward, in 1984, Banker, Charnes, and Cooper developed the BCC (Banker, Charnes, Cooper) model, which separates technical efficiency and scale efficiency. With the BCC model, since the assumption of constant returns to scale in the CCR model was eliminated, this model enabled efficiency analysis in cases of increasing, decreasing, or constant returns to scale. With the studies conducted in the following years, different DEA models were put forward and many applications were modeled [51].

3.4.1 Advantages and Disadvantages of Data Envelopment Analysis

Data envelopment analysis is one of the most common methods used to measure efficiency when there are multiple inputs and outputs. However, this model has disadvantages as well as advantages. The advantages and disadvantages of the DEA model are stated below [52].

Advantages:

- Since the efficiency analysis by DEA is performed according to the frontier function generated by the best observations instead of the average function generated by statistical frontier estimation methods, the targets set are based on the best performing units. This strengthens the meaning and validity of efficiency analysis with DEA.
- DEA is capable of handling multiple inputs and multiple outputs.
- DEA does not need a functional form that relates inputs and outputs except in linear form.
- Decision units whose efficiency is calculated by DEA are compared with relatively fully efficient ones.
- Inputs and outputs may have very different units. In this case, there is no need to use various assumptions and transformations to measure them in the same way.

- A detailed database can be created to contain the data needed for DEA and the results of the analysis. This will strengthen the documentation on the subject.

Disadvantages:

- The ability of the related inputs and outputs to accurately represent the production process is crucial for the method to provide reliable results. When a critical input or output is excluded, the results of the method may be misleading and biased.
- Since DEA is considered as an extreme point technique, the measurement is very sensitive to error.
- DEA is adequate for measuring the performance of decision-making units, but it does not provide clues about the interpretation of this assessment in terms of absolute efficiency.
- The relative superiority of the decision-making units included in the reference group over the others makes it difficult to comment on whether these units are really efficient when evaluated on their own. Therefore, DEA efficiency results should be evaluated within the framework of relativity.
- Since DEA is a nonparametric technique, it is difficult to apply statistical hypothesis tests to the results.
- DEA is a static analysis, it performs a cross-sectional analysis between decision unit data in a single period.
- Since a separate linear programming model needs to be solved for each decision unit, solving large-sized problems by DEA can be computationally time-consuming.

3.4.2 Stages of Data Envelopment Analysis

Several stages need to be followed while applying DEA. According to the quotation from Kılınç [53], the stages to be followed in DEA are as follows [54].

1. Selection of DMUs
2. Selection of Input and Output Sets
3. Testing the Reliability of Data
4. Relative Efficiency Measurement
5. Determination of Activity Values and Activity Limits
6. Detail Analysis for Each Decision Making Unit

7. Determining the Reference Set
8. Setting Targets for Inefficient CVBs
9. Evaluation of Results

The initial step of the DEA method is the selection of the DMUs. When selecting the DMUs, units with the same characteristics and operating in similar sectors should be selected. For example, measuring the efficiency of a hospital cluster and a bank cluster together using DEA is not the correct approach. The correct approach is to analyze the efficiency of bank or hospital clusters individually using DEA method.

Another important issue is the number of DMUs included in the analysis. There are different approaches in the literature regarding the number of DMUs required for a reliable DEA application. Some of these approaches are as follows [55]. When the number of input and output variables are represented by (m) and (n) respectively, the number of DMUs should be at least $(n \times m)$ according to Boussofiane et al. [56]; $2(n+m)$ according to Golany & Roll [57]; $3(n+m)$ according to Bowlin [58]; $2(n \times m)$ according to Dyson et al. [59]. As can be seen, there is no single and precise approach to the minimum number of DMUs. Therefore, the studies in the literature, the minimum number of DMUs may comply with one or all of these approaches.

3.4.3 Data Envelopment Analysis Models

In this section, general information about the methods popularly used in the Data Envelopment Analysis literature will be given. DEA models basically have constant returns to scale (CCR) and variable returns to scale (BCC) characteristics. The issues of constant returns to scale and variable returns to scale are discussed in the previous section. These two models can be constructed in two directions: input-oriented and output-oriented. Input-oriented DEA models investigate the level of inputs to be used to produce a fixed amount of output in the most efficient way. Output-oriented DEA models investigate the amount of output that can be obtained using a fixed amount of input.

The ratio method is the most commonly used method for measuring efficiency. The pitfall of this method is that only a few of the factors are used when measuring the impact on the overall efficiency of a production unit. Suppose there is an organization consisting of n decision-making units, DMU1, DMU2,. ..., DMUn. Each unit consumes "*m*" inputs and produces "*s*" outputs [60].

In this case,

Input matrix:

X = [xij, i = 1, 2, ..., m, j = 1, 2, ..., n]

Output matrix:

Y = [yij, i = 1, 2, ..., s, j = 1, 2, ..., n].

These matrices at line q, i.e. Xq and Yq, represent the quantized inputs and outputs of DMUq. The efficiency ratio of such a unit can generally be calculated expressed as follows:

$$\frac{\text{Weighted sum of outputs}}{\text{Weighted sum of inputs}} = \frac{\sum_{i=1}^{s}(u_i y_{iq})}{\sum_{j=1}^{m}(v_j x_{jq})} \tag{3.8}$$

where:

vj, j = 1, 2, …, m, are weights assigned to jth input,

ui, i = 1, 2, …, s, are weights assigned to ith output

DEA models aim to maximize the efficiency ratio while measuring the efficiency of n productive units, in which each DMU receives m different inputs to produce s different outputs. However, the efficiency ratio of any DMU should not be greater than 1 and this should be added as a constraint to the model. Input and output weights should be greater than zero. The models should include all the considered objectives and constraints. Such a model is defined as a linear divisive programming model and is shown below [60].

$$\text{Maximize} \quad \frac{\sum_{i=1}(u_i y_{iq})}{\sum_{j=1}(v_j x_{jq})} \tag{3.9}$$

$$\text{Subject to} \quad \frac{\sum_{i=1}(u_i y_{ik})}{\sum_{j=1}(v_j x_{jk})} \leq 1 \qquad k= 1, 2, \ldots, n \tag{3.10}$$

$$u_i \geq \in \quad i = 1, 2, ..., s$$

$$v_j \geq \in \quad j = 1, 2, ..., m$$

U_i: weight of i^{th} output

V_j: weight of j^{th} input

Y_{iq}: ith output quantity of q^{th} decision unit

X_{jq}: jth input quantity of q^{th} decision unit

Y_{ik}: output quantities of decision units

X_{jk}: input quantities of decision units

Fractional programming models are more difficult to solve than linear programming. The transformation of the above model into linear programming is expressed by the following formulas.

$$\text{Max} \quad \sum_{i=1} \left(u_i y_{iq}\right) \tag{3.11}$$

$$\sum_{j=1} \left(v_j x_{jq}\right) = 1 \tag{3.12}$$

$$\sum_{i=1} \left(u_i y_{ik}\right) - \sum_{j=1} \left(v_j x_{jk}\right) \leq 0 \tag{3.13}$$

$$u_i, v_j \geq 0$$

The explanations of the CCR model and BCC model, which are the most frequently used models in DEA, are given below.

a) CCR Method (Charnes-Cooper-Rhodes)

The CCR model analyzes efficiency under the assumption of "constant returns to scale" and makes a general assessment of overall efficiency. It identifies resources and estimates the inadequate ones. It was developed by Charnes, Cooper, and Rhodes in 1978 to measure the relative efficiency of systems producing similar goods or services. With CCR models, the TTE value of the CVBs is obtained. CCR models can be constructed in two different ways, input-oriented and output-oriented. In the case of inefficiency, in the input-oriented model, outputs are constant and inputs are reduced; in the output-oriented model, inputs are constant and outputs are increased. The output-oriented DEA model differs from the input-oriented model in that the ratio of weighted input to weighted output is minimized. Input-oriented and output-oriented CCR primal and linear models are shown in Table 3.2 [52] [61].

Table 3.2 CCR Primal and Linear Model

CCR Input Oriented Model	**CCR Output Oriented Model**
Primal Model	**Primal Model**
Max $\dfrac{\sum_{i=1} u_i y_{iq}}{\sum_{j=1} v_j x_{jq}}$ Subject to $\dfrac{\sum_{i=1} u_i y_{ik}}{\sum_{j=1} v_j x_{jk}} \leq 1$ k= 1,., n $u_i \geq \in$ i = 1, 2, ..., s $v_j \geq \in$ j = 1, 2, ..., m	Min $\dfrac{\sum_{i=1} v_j x_{jq}}{\sum_{j=1} u_i y_{iq}}$ Subject to $\dfrac{\sum_{i=1} v_j x_{jk}}{\sum_{j=1} u_i y_{ik}} \geq 1$ k= 1,., n $u_i \geq \in$ i = 1, 2, ..., s $v_j \geq \in$ j = 1, 2, ..., m
Linear Model	**Linear Model**
Max $\sum_{i=1} u_i y_{iq}$ $\sum_{j=1} v_j x_{jq} = 1$ $\sum_{i=1} u_i y_{ik} - \sum_{j=1} v_j x_{jk} \leq 0$ $u_i, v_j \geq 0$	Min $\sum_{i=1} v_j x_{jq}$ $\sum_{j=1} u_i y_{iq} = 1$ $\sum_{j=1} u_i y_{ik} - \sum_{j=1} v_j x_{jk} \leq 0$ $u_i, v_j \geq 0$

b) BCC Method (Banker-Charnes-Cooper)

Unlike CCR, the BCC model examines efficiency under the assumption of "variable returns to scale". When inputs are increased at the same rate, if the increase in output level is greater than the increase in inputs, there is increasing returns to scale, and if less, there is decreasing returns to scale. It was developed by Banker, Charnes, and Cooper in 1984. Similar to the CCR model, the BCC model can also be constructed as input and output oriented. On the other hand, in the BCC model, different from the

CCR model, a variable free in sign, which belongs to the "oth DMU" is considered as "u_o, v_o,..".

Input-oriented and output-oriented BCC primal and linear models are shown in Table 3.3 [52] [61].

Table 3.3 BCC Primal and Linear Model

BCC Input Oriented Model	BCC Output Oriented Model
Primal Model	**Primal Model**
Max $\frac{\sum_{i=1} u_i y_{iq} - u_o}{\sum_{j=1} v_j x_{jq}}$ Subject to $\frac{\sum_{i=1} u_i y_{ik} - u_o}{\sum_{j=1} v_j x_{jk}} \leq 1$ k= 1,., n $u_i \geq \in$ i = 1, 2, ..., s $v_j \geq \in$ j = 1, 2, ..., m u_o: Free in sign	Min $\frac{\sum_{i=1} v_j x_{jq} - v_o}{\sum_{j=1} u_i y_{iq}}$ Subject to $\frac{\sum_{i=1} v_j x_{jk} - v_o}{\sum_{j=1} u_i y_{ik}} \geq 1$ k= 1,., n $u_i \geq \in$ i = 1, 2, ..., s $v_j \geq \in$ j = 1, 2, ..., m v_o: Free in sign
Linear Model	**Linear Model**
Max $\sum_{i=1} u_i y_{iq} - u_o$ $\sum_{j=1} v_j x_{jq} = 1$ $\sum_{i=1} u_i y_{ik} - u_o - \sum_{j=1} v_j x_{jk} \leq 0$ $u_i, v_j \geq 0$ u_o: Free in sign	Min $\sum_{i=1} v_j x_{jq} - v_o$ $\sum_{j=1} u_i y_{iq} = 1$ $\sum_{j=1} u_i y_{ik} - \sum_{j=1} v_j x_{jk} - v_o \leq 0$ $u_i, v_j \geq 0$ v_o: Free in sign

CHAPTER 4

LITERATURE REVIEW

In this section, digital hospital studies and DEA studies adapted to the health sector in the literature are reviewed. The studies in the literature on both subjects are presented in separate sub-headings below, 4.1 and 4.2.

4.1 Literature Review of Digital Hospitals

When the literature on the digital hospital is analyzed, it can be seen that many studies are related to digital healthcare applications such as e-health, mobile health, telemedicine, wearable technology, 3D printers, and artificial intelligence. The digital hospital issue also has an important place in the literature, but there are not many studies on the efficiency benefits of HIMSS/EMRAM processes in digital hospitals. When studies in the literature are examined, it is seen that the perspective and adoption of healthcare professionals in the digitalization process are widely researched. In this section, different studies in the literature on digital hospitals will be revealed.

Sulkers et al. [62] explain the effect of EMRAM/HIMSS criterias, which are used to increase medication safety in the Mental Health Hospital in Toronto. In the study, it is observed that medication safety improvement is achieved as a result of applying these criteria in the hospital.

Bülbül and Medeni [63] measure the adoption of the HIMSS system in Türkiye. In the study, the adoption of the HIMSS criteria and the level of use of the system by the healthcare professionals in the first public city hospitals in Türkiye, which has received the stage 6 and stage 7 hospital awards, are analyzed.

There is another study which is the about expectations of healthcare professionals in the digitalization process of the hospital. The knowledge, attitudes, and expectations about the E-Health Systems used by the managers and healthcare professionals of a hospital that has been certified EMRAM-6 in the digitalization process in Türkiye are studied. According to the results of the study, the adoption of efficiency and quality by healthcare professionals in the digitalization process leads to positive results in hospitals. It demonstrates that digital hospital models also benefit by working in harmony with health information systems [18].

Bayer et al. [64] conduct interviews with users of digital hospital applications to determine the advantages and disadvantages of the digital hospital system compared to the previous system and the interviews are evaluated. As a result of the research; increasing the prestige and reliability of the hospital in terms of health service delivery with digital hospital applications, performing fast and reliable transactions, increasing accessibility to patient records, providing patient monitoring systematically and quickly, preventing misuse of medication and contributing to patient safety, preventing medication loss and reducing general administration costs are the main advantages of the system.

Tüfekçi et al. [65] explain the opportunities and threats caused by digital hospitals, the HIMSS organization that grades digital hospitals and the EMRAM model, and describe Türkiye's general situation in the digital hospital journey.

Digital hospital, mobile health, telemedicine, and robotic health are defined as the sub-components of e-Health by Khan and Mir [66]. In the study, features of digital hospitals and Electronic Health Records (EHR) are discussed.

Kılıç [15] analyzes two digital hospitals that provide service in Türkiye. In his study, the concept of a "Digital Hospital" in theoretical and practical aspects is discussed. According to the conclusion of the study, digital hospitals increase speed and efficiency in business processes and reduce costs such as paper and documents to zero.

Öztürk [67] investigates the impact of the CLMM system on return to pharmacy rates. According to the study, there is a 10.74% increase in the rate of medication returns with the implementation of the CLMM. In addition, it is observed that the CLMM helps to record the reasons for medication returns in a more disciplined manner.

Previously, returns are usually made due to "change in treatment", but after the implementation of the CLMM, returns are also made for other reasons.

Volkan [68] analyzes the impact of the digital hospital, which is graded according to HIMSS criteria, on paper savings and nursing care services time. The study reveals that the widespread use of electronic systems in health services will result in significant savings in paper and toner costs. On the other hand, it is also revealed that significant savings will be achieved in the nursing workforce and the time to be allocated to patient care will increase.

The impact of digitalization of medical records stored on paper forms in intensive care units on business processes is measured by Yılmaztürk [69]. With this measurement, the effect of digitalization on form filling times and the amount of paper and toner consumed is measured and savings are observed in the digital hospital which is graded according to HIMSS criteria.

4.2 Literature Review of Data Envelopment Analysis in the Health Sector

As in all sectors, efficiency is a very important issue for the health sector. Hospitals are the most important component and the most resource consuming facility in the health sector. In other words, the majority of health expenditures are spent on health services originating from hospitals. Therefore, ensuring hospital efficiency is very important both in terms of the country's resource management and health service delivery. Hospital inefficiencies are one of the most important causes of inefficiency in the health system and budget of the country.

DEA is one of the most commonly used techniques for efficiency measurement in the health sector. In the literature, there are studies in which DEA is applied in the health sector as well as in many other sectors. When these studies are examined, it is seen that health service providers are selected as the DMU and inputs/outputs of DMUs are used in different combinations. In this section, the studies in the literature where the DEA model is applied in the health sector will be reviewed.

Kirigia et al. [70] carry out an efficiency analysis to measure 32 health centers in Kenya. Technical efficiency score and scale efficiency score are measured. 11 inputs and 4 outputs are used in the study. The inputs are clinical officers, nurses, physiotherapists, occupational therapists, laboratory technologists, laboratory technicians, administrative-general staff, dental technologists, public health officers, beds, and nonwage recurrent expenditures; the outputs are diarrhoeal-malaria-STI-urinary tract infections-intestinal worms-respiratory disease visits, antenatal-family planning visits, immunizations, other general outpatient visits.

Steinmann et al. [71] study the efficiency of hospitals in Germany and Switzerland by using the DEA technique. In the study, number of academic staff, number of nurses, number of administrative staff, expenses and number of beds are considered as inputs and number of patient days are considered as outputs in the analysis.

Hollingsworth and Spinks [72] conduct a cross-country comparison by measuring technical efficiency in health service delivery for OECD countries. In the study, OECD and WHO health indicators are used as data sets and analyzed separately. The output-oriented model is adopted to analysis under the VRS assumption. From the 1995 and 2000 years OECD dataset, general socioeconomic determinants such as gross domestic product (GDP) per capita (US$), average years of education, total health expenditure per capita (US$), and unemployment rate (%) are used as input variables and life expectancy at birth is used as output variable. The same four input variables are used from the WHO dataset for 1993 and 1997 years, but the output variable is used as disease-adjusted life expectancy.

Nayar and Ozcan [73] analyze the acute care hospitals efficiency by using DEA. The aim of the study is to learn how the inclusion of quality indicators as outputs in DEA models changes the results of hospital efficiency analysis. For this reason, quality indicators are added to the technical inputs and outputs in the study and quality indicators are included in the analysis as outputs. The analysis is conducted under the CRS model in two scenarios and with 53 DMUs. The first scenario has four inputs and three outputs while the second scenario has four inputs, three outputs, and three quality outputs. In the analysis, the technical inputs are bed size, non-labor/capital expenses, total assets, and staffing full-time equivalents; technical outputs are total adjusted discharges, total outpatient visits and training full-time equivalents; the quality outputs are the percent of patients given initial antibiotic timing, percent of patients given oxygenation assessment and percent of patients given pneumococcal vaccination. According to the results of the study, technical outputs and quality outputs have an impact on efficiency. Evidence from the study demonstrates that the efficient hospitals in the study don’t compromise on quality outcomes.

Çakmak et al. [74] measure the technical efficiency of 41 maternity hospitals based on 2004 year data by using the DEA. Input and output oriented models are used in the analysis. In the study, the number of beds, other expenses (excluding investment, drug, and material procurement expenses), drug expenses, and medical material procurement expenses are considered as inputs; and the number of outpatient clinics, number of small surgeries, number of medium surgeries, number of large surgeries, number of births, average days of stay and total revenue are considered as outputs.

Ayanoğlu et al. [75] use the DEA technique to measure the efficiency of 16 hospitals based on the 2007 year data. In the study, 5 financial inputs and 1 financial output variables are used and the study is carried out as input oriented. Raw materials and supplies, personnel wages and expenses, outsourced benefits and services, other miscellaneous expenses, depreciation and amortization are considered as inputs and service revenues is considered as output.

Bal and Bilge [76] measure the total, technical and scale efficiencies of 35 training and research hospitals. Input oriented model under VRS is used in the study. Number of specialist physicians, number of assistant physicians, number of beds, number of nurses, total expenditure as input; number of examinations, number of surgeries, number of hospitalized days, total revenue as output are considered in the study.

Asanduluia et al. [77] evaluate the efficiency of public healthcare systems in Europe with DEA. 30 countries are included in the study. Life expectancy at birth, health adjusted life expectancy, and infant mortality rate are considered output variables while number of doctors, number of hospital beds and public health expenditures as a percentage of GDP are considered input variables. CRS and VRS models are used in the analyse.

Yiğit [78] analyzes the technical efficiency of Public Hospital Unions. In the analysis conducted according to the CCR and BCC model, all hospitals selected on the basis of 81 provinces are included in the research. 2013 year data are used in the study. The study consists of six outputs (number of outpatients, number of inpatients, number of group A operations, number of group B operations, number of group C operations, bed occupancy rate) and three inputs (number of specialist physicians, number of general practitioners, number of beds).

Using the DEA method, Cetin and Bahce [55] measure the efficiency of 34 OECD countries with input oriented model under both CRS and VRS. In the analysis, the number of patient beds, number of doctors, and per capita health expenditure are used as input variables, while life expectancy at birth and infant mortality rate are used as outputs.

Bardakçı and Filiz [79] measure the efficiency of public hospitals in the Artvin province of Türkiye by using the DEA method. Input-oriented model under CCR is used in the analysis. The 6 hospitals data in 2016 and 2017 years are taken into consideration and three inputs and three outputs variables are used. In the study, number of beds, number of physicians, number of nurse-midwives are input variables while weighted number of surgeries, number of outpatients and number of inpatients are output variables.

Antunes et al. [80] analyze efficiency of 93 intensive care units in order to benchmark by DEA. The study is based on three models, in terms of staffing, structure, and capacity, which considered different combinations of inputs and outputs. In addition, input and output oriented models under VRS are used in the analyse. Inputs are number of nursing technicians per 10 beds, number of physiotherapists per 10 beds, number of intensive care unit beds, total physicians' hours per week, total nurses' hours per week, bed occupancy rate in the study. Two performance measures, Standardized Mortality Rate and Standardized Resource Utilization, are considered as outputs.

When DEA studies in the health sector are reviewed in the literature, it is seen that countries or hospitals are generally compared with each other. In these studies, inputs and outputs are included in the study in a different way. While indicators such as number of physicians, number of nurses, number of personnel, health expenditures are mostly considered as inputs, indicators such as number of inpatients, number of outpatients, life expectancy at birth, health adjusted life expectancy and infant mortality rate are considered as outputs. However, the combination of inputs and outputs of each study can vary depending on the data provided during the study and the ability of these data to produce a reliable analysis. Therefore, it is not right to make a definitive statement that these indicators should be considered as inputs and these indicators as outputs. It is possible that inputs and outputs can vary depending on the study.

On the other hand, when looking at the DEA models constructed, it is seen that both "*Constant Returns to Scale*" and "*Variable Returns to Scale*" are used. While some studies utilize both VRS and CRS, some studies utilize only one of them. In terms of orientation, both input and output orientations can be used. In the studies, DEA model is constructed as input oriented, output oriented or both together according to the indicators that may vary.

CHAPTER 5

EFFICIENCY ANALYSIS OF DIGITAL HOSPITALS

5.1 Purpose of the Study

Health is one of the areas that is universally important and needs to be continuously developed and improved. The right to health is guaranteed in Türkiye with the Constitution; stating that "Everyone has the right to live in a healthy and balanced environment.” As a matter of fact, with this statement, it is understood how important health and health service provision is for the state and citizens.

Digitalization, which is an inevitable reality in all areas of life, is becoming universally popular and one of the areas where it is becoming popular is health technologies. Health technologies are developing more and more every day, enabling important steps to be taken in health service delivery. Digital hospitals, which are described in detail in the first chapter, are one of the best examples of digital health. However, although the concept of digital hospital is being tried to be popularized in our country as well as all over the world, the awareness of digital hospitals is unfortunately not at the desired level. When looking at the literature, it is seen that although digital hospital studies have been included both at international and national levels, the diversity of studies is limited.

It is observed that the studies in the literature on the health sector include efficiency analysis with DEA method, but this method is not applied to digital hospitals. In digital hospital studies, generally time and cost analyses are carried out over a hospital and these analyses are formed as a result of the information obtained based on observation. Therefore, this study aims to apply DEA method to digital hospitals and to measure the efficiency of digital hospitals in this direction.

In the research on digital hospitals, it is seen that hospitals with HIMSS 7 and HIMSS 6 stages are accepted as digital hospitals. Since the first chapter explains the details of technologies these hospitals have, in this chapter technologies will not be explained in detail. Looking at the technologies the hospitals have, it is noticed that there is a difference between HIMSS 7 and HIMSS 6 regarding the use of paper. Although the use of paper is less in HIMSS 6 hospitals compared to traditional non-digital hospitals, "zero paper" is required to be certified as a HIMSS 7 hospital. In other words, while “zero paper” is required in the hospital to meet the HIMSS 7 requirement, there is no “zero paper” requirement in HIMSS 6. In this direction, it is thought that there may be a difference in the amount of paper used in hospitals with HIMSS 7 and HIMSS 6 stages. Accordingly, during the study, it is aimed to measure and compare the efficiency of hospitals with HIMSS 6 and HIMSS 7 stages on the basis of ***stationery expenses***. In practice, the fact that zero paper is used in HIMSS 7 stage hospitals leads to the expectation that the efficiency of HIMSS 7 stage hospitals on the basis of stationery expenses will be higher than HIMSS 6 stage hospitals. As mentioned above, although DEA has been frequently used in the area of healthcare, it has not yet been applied to digital hospitals, therefore, the efficiency analysis of digital hospitals in this study is carried out by DEA method. The analysis is applied to the hospitals with HIMSS 6 and HIMSS 7 by considering the same inputs and outputs based on ***stationery expenses***.

5.2 Methodology of Analysis

The purpose of the study is to analyze and compare the efficiency of HIMSS 6 and HIMSS 7 hospitals on the basis of stationery expenses since there is a difference in practice in terms of paper usage. For this reason, the hospitals selected as a sample were first analyzed by data envelopment analysis. In order to carry out DEA method, DEAP 2.1 software was used. Then, the statistical significance of the results obtained by data envelopment analysis was analyzed by SPSS software.

A total of 20 hospitals, which are affiliated to the MoH, and their data for 2021 year were used in the analysis. Since 2021 data was included in the analysis, the HIMSS certificates of the hospitals in 2021 were considered. For this reason, 4 HIMSS 7 stage and 16 HIMSS 6 stage hospitals in 2021 were included in the study in accordance with the sample selection criteria. In fact, as stated in the "HIMSS Experience in Türkiye" section in the first chapter, there were a total of 5 hospitals with HIMSS 7 stage in 2021. However, since one of these hospitals was accepted as HIMSS 7 stage in November 2021, it was not included in the analysis under HIMSS 7 hospitals. Therefore, the number of HIMSS 7 hospitals included in the analysis is 4.

Selected hospitals data were provided by the MoH General Directorate of Public Hospitals. Data on the number of inpatients, number of outpatients (including dental and emergency), number of surgeries, number of hospital beds, number of specialists and dentists, number of nurses and midwives, and stationery costs were used in the analysis.

5.3 Application of Data Envelopment Analysis to the Digital Hospitals

In this section, the efficiency of 20 hospitals selected as a sample is analyzed by data envelopment analysis method. The steps followed in the analysis and the results of the analysis are presented in detail in the following sub-headings.

5.3.1 Selection of Decision Making Units

The aim of the study is to analyze HIMSS 6 and HIMSS 7 stage hospitals efficiency on the basis of stationery expense by DEA method and compare the analysis results. The fact that zero paper is used in HIMSS 7 stage hospitals in practice creates an expectation that the efficiency of HIMSS 7 stage hospitals will be higher than HIMSS 6 stage hospitals on the basis of stationery expenses. For this reason, HIMSS 6 and HIMSS 7 stage hospitals were included in the analysis as ***decision-making units***.

A total of 20 hospitals in Türkiye were included in the analysis. Since only the hospitals affiliated to the MoH have HIMSS 6 and HIMSS 7 certificates, all of the hospitals selected as the sample are affiliated to the MoH. While selecting 20 hospitals as a sample, certain criteria were taken into consideration. First of all, hospitals were selected from A and B role hospital groups and hospitals with over 200 hospital beds were included in the analysis. Digital hospitals in provincial centers were taken into consideration especially. If there is no digital hospital in the provincial center, hospitals in relatively large districts were accepted as the sample. Since the analysis data year is based on 2021, the digitalization year of the hospital was taken into account, and hospitals that were digitalized/entitled to receive HIMSS certification at the beginning of 2021 or earlier were included in the analysis. Especially considering the digitalization year being close to the present, hospitals digitalized after 2018 were selected as a sample. However, since the hospitals selected as the sample of Ankara province were digitalized in 2017, the digitalization year of the hospitals of Ankara province is 2017. In this framework, since the number of HIMSS 7 stage hospitals is very few, 4 HIMSS 7 stage and 16 HIMSS 6 stage hospitals were included in the study within the scope of the criteria above.

5.3.2 The DEA Models Applied in the Study

When the DEA studies for hospitals in the literature are examined, it is seen that only the CCR model is used in some studies, only the BCC model in some studies, and both the CCR model and BCC model in some studies. In addition, these models have been carried out as input-oriented in some studies, output-oriented in some studies, and both input and output-oriented in some studies.

In this study, the efficiency of digital hospitals was analyzed using both CCR and BCC models. Because it is aimed to compare and interpret the efficiency results of the hospitals under both constant returns to scale and variable returns to scale assumptions. On the other hand, CCR and BCC assumptions were studied both input-oriented and output-oriented. In fact, when examining the studies in the literature, input-oriented models are more preferred in hospital efficiency analyses. Since it is easier to plan and control inputs in hospitals compared to hospital outputs, studies in the literature are generally input-oriented. However, there are also studies that focus on both inputs and outputs. In this study, both input- and output-oriented assumptions were considered, assuming that both inputs and outputs can be controlled.

As a result, in this study, digital hospital efficiencies were analyzed using DEA technique under input and output oriented assumptions of CCR and BCC models.

5.3.3 Identifying of Inputs and Outputs

In DEA technique, the step of determining inputs and outputs is very important in order for the analysis to be concluded correctly. Because inputs and outputs directly influence the result of the analysis.

In this study, various variables of 20 digital hospitals were included in the analysis as inputs and outputs. While identifying inputs and outputs, the studies in the literature were also taken into consideration. When the studies conducted with DEA were examined, it was observed that a wide variety of variables were used. Therefore, considering the studies in the literature and the purpose of this study, generally accepted variables were defined as inputs and outputs.

Because the main purpose of the study is to measure and compare the efficiency of HIMSS 6 and HIMSS 7 certificated hospitals on the basis of **stationery expenses**, "stationery expenses" was included as the main input variable in this study. On the other hand, the number of beds, number of specialists, number of dentists, number of nurses and midwives, which play an important role in the efficiency of hospitals, were also included in the analysis as input variables. The number of inpatients, the number of outpatients (including dental and emergency) and the number of surgeries were included in the analysis as outputs. All of these inputs and outputs are factors affecting the stationery expenses of a hospital. These inputs and outputs were analyzed by DEA method in different combinations as well as in a single analysis at the same time. The scenarios created by these combinations will be presented in the next section. All input and output variables included in the study are presented in Table 5.1.

Table 5.1 Input and Output Variables in the DEA

Input	Output
Stationery Expenses	Number of Inpatient
Number of Hospital Bed	Number of Outpatient (Including Dental and Emergency)
Number of Specialist and Dentist	Number of Surgery
Number of Nurse and Midwife	

In DEA, the relationship between the number of inputs-outputs and the number of DMUs is important. As stated in Chapter 2 of the study, it is important for the analysis to give accurate results that the number of DMUs is above a certain number in line with the number of inputs-outputs. For this reason, in all scenarios, the consistency between the number of DMUs and the number of inputs-outputs was taken into account. As mentioned in Chapter 2; "*When the number of input and output variables are represented by (m) and (n) respectively, the number of DMUs should be at least* *(n x m) according to Boussofiane et al.* [56]*; 2(n+m) according to Golany & Roll* [57].” Under these assumptions, even if all four inputs and three outputs are included in the analysis at the same time, 20 DMUs are adequate for the accuracy of the analysis results.

In addition, the significant relationship between the variables is also important to conduct a reliable DEA. For this reason, the variables identified as input and output were first statistically analyzed by the “IBM SPSS Statistics 22” software using the "Correlation Test". Then, the efficiency of input and output variables was analyzed with the DEA technique using the "DEAP 2.1" software. The correlation analysis of input and output variables is presented in Table 5.2. The results of the data envelopment analysis will be presented in the next section.

As shown in Table 5.2, the sigma value is less than 0.001 for all variables and it is clear that there is a positive and significant relationship between the variables used as input and output. This positive and significant relationship between the variables is important in terms of increasing the reliability of DEA results. Therefore, there is no obstacle in conducting the DEA with these variables. As a result of the correlation analysis, it is seen that the significant relationship between some variables is much higher. For instance, the correlation between the number of nurses and midwives, the number of inpatients and the number of beds is quite high. However, as stated, the correlation relationship between the other variables is also acceptable and very high.

Table 5.2 Correlation Analysis of Variables in the Study

		Inpatient	Outpatient	Surgery	Specialist and Dentist	Nurse and Midwife	Hospital Bed	Stationery Expenses
Inpatient	Pearson Correlation	1	,876**	,894**	,887**	,952**	,929**	,757**
	Sig. (2-tailed)		,000	,000	,000	,000	,000	,000
	N	20	20	20	20	20	20	20
Outpatient	Pearson Correlation	,876**	1	,907**	,894**	,912**	,918**	,805**
	Sig. (2-tailed)	,000		,000	,000	,000	,000	,000
	N	20	20	20	20	20	20	20
Surgery	Pearson Correlation	,894**	,907**	1	,862**	,875**	,861**	,684**
	Sig. (2-tailed)	,000	,000		,000	,000	,000	,001
	N	20	20	20	20	20	20	20
Specialist and Dentist	Pearson Correlation	,887**	,894**	,862**	1	,931**	,874**	,844**
	Sig. (2-tailed)	,000	,000	,000		,000	,000	,000
	N	20	20	20	20	20	20	20
Nurse and Midwife	Pearson Correlation	,952**	,912**	,875**	,931**	1	,982**	,865**
	Sig. (2-tailed)	,000	,000	,000	,000		,000	,000
	N	20	20	20	20	20	20	20
Hospital Bed	Pearson Correlation	,929**	,918**	,861**	,874**	,982**	1	,867**
	Sig. (2-tailed)	,000	,000	,000	,000	,000		,000
	N	20	20	20	20	20	20	20
Stationery Expenses	Pearson Correlation	,757**	,805**	,684**	,844**	,865**	,867**	1
	Sig. (2-tailed)	,000	,000	,001	,000	,000	,000	
	N	20	20	20	20	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

5.3.4 Implementation of DEA under the Different Scenarios

In this section, HIMSS 6 and HIMSS 7 stage digital hospital efficiencies will be analyzed under different scenarios with DEA technique on the basis of stationery expenses. Different scenarios are created with the DMUs, DEA models, inputs and outputs that are mentioned in the previous sections and to be considered in the study. Therefore, the study analyzes the efficiency of HIMSS 6 and HIMSS 7 stage hospitals under multiple scenarios on the basis of stationery expenses.

The study was conducted under a total of 5 different scenarios. However, in 3 of the 5 scenarios, both basic DEA and cost efficiency were structured. Cost efficiency analyses were also included in the study as separate sub-scenarios. In other words, for example, Scenario 1 was structured as Scenario 1.1 and Scenario 1.2. Here, while Scenario 1.1 is the basic DEA, Scenario 1.2 is included in the study as cost efficiency analysis. Therefore, in fact, the study was carried out with a total of 5+3, 8 scenarios together with the sub-scenarios.

In the study, output variables were the same in all scenarios, while input variables varied from scenario to scenario. All output variables in the study were used in each scenario. Since the main purpose of the study is to compare the efficiency of digital hospitals on the basis of stationery expenses, the stationery expense variable was included in all scenarios. Stationery expense was included as an input variable in the basic DEA and as a cost variable in the cost efficiency analysis. In cost efficiency analysis, cost variables are included in the analysis as much as the number of inputs. How many inputs there are, as many cost variables should be included in the analysis. For this reason, since there is one cost variable (stationery expense) in the cost efficiency analysis, one input is included in the analysis. The scenarios where input variables vary are detailed in Table 5.3.

In 5 of these 8 scenarios, technical efficiency and scale efficiency were calculated; in 3 scenarios, technical efficiency, cost efficiency and allocation efficiency were calculated. In the efficiency calculations, both Constant Return to Scale (CRS) and Variable Returns to Scale (VRS) assumptions were taken into account and therefore both CCR and BCC models were used. Both models were analyzed as input and output.

The names of 20 digital hospitals affiliated to the Ministry of Health, which were used as DMUs in the study, were coded in the study. The 4 hospitals with HIMSS 7 certification are coded as X_1, X_2, X_3, X_4; the 16 hospitals with HIMSS 6 certification are coded as Y_1, Y_2, Y_3, Y_4, Y_5, Y_6, Y_7, Y_8, Y_9, Y_{10}, Y_{11}, Y_{12}, Y_{13}, Y_{14}, Y_{15}, Y_{16}. Therefore, hospitals with HIMSS 7 certification are defined as X, while hospitals with HIMSS 6 certification are defined as Y.

Table 5.3 includes assumptions for all scenarios. Then the analysis results for each 8 scenarios are detailed below.

Table 5.3 The Scenarios in the Analysis

Scenario	Type of Efficiency	Output	Input	Cost*	DEA Model	Input-Output Oriented
Scenario 1.1	Technical Efficiency Scale Efficiency	Number of Inpatient Number of Outpatient Number of Surgery	Stationery Expenses Number of Hospital Bed	-	CCR BCC	Input Output
Scenario 1.2	Cost Efficiency Technical Efficiency Allocative Efficiency	Number of Inpatient Number of Outpatient Number of Surgery	Number of Hospital Bed	Stationery Expenses	CCR BCC	The orientation has been set to "input" Because “output” orientation is not applicable in a cost efficiency DEA.
Scenario 2.1	Technical Efficiency Scale Efficiency	Number of Inpatient Number of Outpatient Number of Surgery	Stationery Expenses Number of Specialist/Dentist	-	CCR BCC	Input Output
Scenario 2.2	Cost Efficiency Technical Efficiency Allocative Efficiency	Number of Inpatient Number of Outpatient Number of Surgery	Number of Specialist/Dentist	Stationery Expenses	CCR BCC	The orientation has been set to "input" Because “output” orientation is not applicable in a cost efficiency DEA.
Scenario 3.1	Technical Efficiency Scale Efficiency	Number of Inpatient Number of Outpatient Number of Surgery	Stationery Expenses Number of Nurse/Midwife	-	CCR BCC	Input Output
Scenario 3.2	Cost Efficiency Technical Efficiency Allocative Efficiency	Number of Inpatient Number of Outpatient Number of Surgery	Number of Nurse/Midwife	Stationery Expenses	CCR BCC	The orientation has been set to "input" Because “output” orientation is not applicable in a cost efficiency DEA.
Scenario 4	Technical Efficiency Scale Efficiency	Number of Inpatient Number of Outpatient Number of Surgery	Stationery Expenses Number of Hospital Bed Number of Specialist/Dentist	-	CCR BCC	Input Output
Scenario 5	Technical Efficiency Scale Efficiency	Number of Inpatient Number of Outpatient Number of Surgery	Stationery Expenses Number of Hospital Bed Number of Specialist/Dentist Number of Nurse/Midwife	-	CCR BCC	Input Output

* If the efficiency analysis is to be calculated as “***Cost Efficiency***”, in addition to the input, "***Stationery Cost***" is included in the analysis as a cost.

5.3.4.1 Scenario 1 - Number of Hospital Bed as an Input Besides Stationery Expenses

Under this scenario, “Basic DEA” and “Cost Efficiency” analyses were carried out by considering the number of hospital bed as an input besides stationery expenses. These analyses are detailed below under two separate scenarios as Scenario 1.1 and Scenario 1.2.

Scenario 1.1 Basic DEA (Technical Efficiency)

In the analyses, outputs are total number of inpatients, total number of outpatients, total number of surgeries; inputs are total number of hospital beds and stationery costs. The aim of the analysis is to calculate the technical efficiency scores of HIMSS 6 and HIMSS 7 stage hospitals in terms of stationery expenses by using these inputs and outputs. In this direction, the efficiency scores that emerge considering the stationery expenses and number of beds as inputs are shown in Table 5.4 and Table 5.5. In order to compare the results of variable returns to scale and constant returns to scale, scores were calculated according to both CCR and BCC models. Scale efficiency was also calculated by the ratio of CCR and BCC results. The analysis was modeled as input and output oriented which are demonstrated in the tables separately. All of the results are shown in Table 5.4 and Table 5.5.

Table 5.4 Analysis of Scenario 1.1 Results-Input Oriented

Basic DEA (Technical Efficiency)-Input Oriented					
Digital Hospitals (DMU)		**CCR**	**BCC**	**Scale Efficiency**	
X1	**HIMSS 7**	0,976	1,000	0,976	irs
X2		0,704	0,923	0,763	irs
X3		0,927	1,000	0,927	irs
X4		1,000	1,000	1,000	-
Average		**0,902**	**0,981**	**0,917**	
Y1	**HIMSS 6**	0,826	1,000	0,826	drs
Y2		0,891	1,000	0,891	drs
Y3		0,607	0,883	0,688	irs

Cont. Table 5.4 Analysis of Scenario 1.1 Results-Input Oriented

Y4	HIMSS 6	**0,963**	**1,000**	**0,963**	**irs**
Y5		0,680	0,802	0,848	drs
Y6		0,597	0,633	0,943	irs
Y7		0,645	0,708	0,912	irs
Y8		1,000	1,000	1,000	-
Y9		0,737	1,000	0,737	irs
Y10		1,000	1,000	1,000	-
Y11		0,885	1,000	0,885	drs
Y12		0,923	1,000	0,923	drs
Y13		0,500	0,820	0,609	drs
Y14		0,710	1,000	0,710	irs
Y15		0,811	0,977	0,830	drs
Y16		0,548	0,602	0,909	irs
Average		**0,770**	**0,902**	**0,855**	

Table 5.5 Analysis of Scenario 1.1 Results-Output Oriented

Basic DEA (Technical Efficiency)-Output Oriented					
Digital Hospitals (DMU)		**CCR**	**BCC**	**Scale Efficiency**	
X1	**HIMSS 7**	0,976	1,000	0,976	irs
X2		0,704	0,865	0,814	irs
X3		0,927	1,000	0,927	irs
X4		1,000	1,000	1,000	-
Average		**0,902**	**0,966**	**0,929**	
Y1	**HIMSS 6**	0,826	1,000	0,826	drs
Y2		0,891	1,000	0,891	drs
Y3		0,607	0,726	0,836	irs
Y4		0,963	1,000	0,963	irs
Y5		0,680	0,849	0,801	drs

Cont. Table 5.5 Analysis of Scenario 1.1 Results-Output Oriented

Y6	HIMSS 6	**0,597**	**0,631**	**0,946**	**drs**
Y7		0,645	0,660	0,978	drs
Y8		1,000	1,000	1,000	-
Y9		0,737	1,000	0,737	irs
Y10		1,000	1,000	1,000	-
Y11		0,885	1,000	0,885	drs
Y12		0,923	1,000	0,923	drs
Y13		0,500	0,946	0,528	drs
Y14		0,710	1,000	0,710	irs
Y15		0,811	0,980	0,827	drs
Y16		0,548	0,572	0,958	drs
Average		**0,770**	**0,898**	**0,863**	

Scenario 1.2 Cost Efficiency

In Scenario 1.2, cost efficiency analysis was conducted. Here, the outputs were determined as total number of inpatients, total number of outpatients and number of surgeries as in scenario 1.1. However, since the analysis is a cost efficiency analysis, stationery expenses was included as a cost variable and the number of beds was included as an input variable. The aim here is to compare the cost efficiency of HIMSS 6 and HIMSS 7 stage hospitals on the basis of stationery expenses by accepting stationery expenses as a cost variable. The all efficiency scores for the cost efficiency analysis are shown in Table 5.6 and Table 5.7. In this analysis, by considering stationery expenses as a cost variable not an input variable; technical efficiency, allocative efficiency and cost efficiency scores were calculated for both CCR and BCC models to compare the results of variable returns to scale and constant returns to scale. Allocative efficiency was calculated by the ratio of cost efficiency and technical efficiency scores. Since output orientation is not applicable in a cost efficiency DEA, the orientation has thus been set to "input". Therefore, the cost efficiency analysis was analyzed only as input oriented. The results of the analysis are shown in Table 5.6 and Table 5.7.

Table 5.6 Analysis of Scenario 1.2 Results CCR Model

Cost Efficiency-CCR Model				
Digital Hospitals (DMU)		**Technical Efficiency**	**Allocative Efficiency**	**Cost Efficiency**
X1	**HIMSS 7**	0,976	1,000	0,976
X2		0,704	1,000	0,704
X3		0,927	1,000	0,927
X4		0,709	1,000	0,709
Average		**0,829**	**1,000**	**0,829**
Y1	**HIMSS 6**	0,796	1,000	0,796
Y2		0,891	1,000	0,891
Y3		0,607	1,000	0,607
Y4		0,963	1,000	0,963
Y5		0,680	1,000	0,680
Y6		0,597	1,000	0,597
Y7		0,645	1,000	0,645
Y8		1,000	1,000	1,000
Y9		0,673	1,000	0,673
Y10		1,000	1,000	1,000
Y11		0,879	1,000	0,879
Y12		0,923	1,000	0,923
Y13		0,500	1,000	0,500
Y14		0,666	1,000	0,666
Y15		0,721	1,000	0,721
Y16		0,548	1,000	0,548
Average		**0,756**	**1,000**	**0,756**

Table 5.7 Analysis of Scenario 1.2 Results BCC Model

Cost Efficiency-BCC Model				
Digital Hospitals		**Technical Efficiency**	**Allocative Efficiency**	**Cost Efficiency**
X1	**HIMSS 7**	1,000	1,000	1,000
X2		0,923	1,000	0,923
X3		1,000	1,000	1,000
X4		0,733	1,000	0,733
Average		**0,914**	**1,000**	**0,914**
Y1	**HIMSS 6**	1,000	1,000	1,000
Y2		1,000	1,000	1,000
Y3		0,883	1,000	0,883
Y4		1,000	1,000	1,000
Y5		0,802	1,000	0,802
Y6		0,633	1,000	0,633
Y7		0,708	1,000	0,708
Y8		1,000	1,000	1,000
Y9		0,892	1,000	0,892
Y10		1,000	1,000	1,000
Y11		1,000	1,000	1,000
Y12		1,000	1,000	1,000
Y13		0,820	1,000	0,820
Y14		1,000	1,000	1,000
Y15		0,974	1,000	0,974
Y16		0,602	1,000	0,602
Average		**0,895**	**1,000**	**0,895**

5.3.4.2 Scenario 2 - Number of Specialist and Dentist as an Input Besides Stationery Expenses

Under this scenario, “Basic DEA” and “Cost Efficiency” analysis were carried out by considering the number of specialist and dentist as an input besides stationery expenses. These analyses are detailed below under two separate scenarios as Scenario 2.1. and Scenario 2.2.

Scenario 2.1 Basic DEA (Technical Efficiency)

Table 5.8 Analysis of Scenario 2.1. Results-Input Oriented

Basic DEA (Technical Efficiency)-Input Oriented					
Digital Hospitals (DMU)		**CCR**	**BCC**	**Scale Efficiency**	
X1	**HIMSS 7**	1,000	1,000	1,000	-
X2		0,740	0,788	0,939	drs
X3		1,000	1,000	1,000	-
X4		1,000	1,000	1,000	-
Average		**0,935**	**0,947**	**0,985**	
Y1	**HIMSS 6**	0,741	1,000	0,741	drs
Y2		0,607	0,645	0,942	drs
Y3		0,553	0,565	0,978	drs
Y4		0,457	0,467	0,978	drs
Y5		0,447	0,515	0,868	drs
Y6		0,788	0,842	0,936	drs
Y7		0,894	0,937	0,954	drs
Y8		0,778	0,781	0,996	irs
Y9		0,921	1,000	0,921	irs
Y10		1,000	1,000	1,000	-
Y11		0,930	1,000	0,930	drs
Y12		0,647	1,000	0,647	drs
Y13		0,629	1,000	0,629	drs
Y14		1,000	1,000	1,000	-
Y15		1,000	1,000	1,000	-
Y16		0,749	0,853	0,878	drs
Average		**0,759**	**0,850**	**0,900**	

Table 5.9 Analysis of Scenario 2.1. Results-Output Oriented

Basic DEA (Technical Efficiency)-Output Oriented					
Digital Hospitals (DMU)		**CCR**	**BCC**	**Scale Efficiency**	
X1	**HIMSS 7**	1,000	1,000	1,000	-
X2		0,740	0,818	0,905	drs
X3		1,000	1,000	1,000	-
X4		1,000	1,000	1,000	-
Average		**0,935**	**0,955**	**0,976**	
Y1	**HIMSS 6**	0,741	1,000	0,741	drs
Y2		0,607	0,713	0,852	drs
Y3		0,553	0,582	0,950	drs
Y4		0,457	0,568	0,804	drs
Y5		0,447	0,766	0,583	drs
Y6		0,788	0,856	0,920	drs
Y7		0,894	0,944	0,947	drs
Y8		0,778	0,779	0,999	irs
Y9		0,921	1,000	0,921	irs
Y10		1,000	1,000	1,000	-
Y11		0,930	1,000	0,930	drs
Y12		0,647	1,000	0,647	drs
Y13		0,629	1,000	0,629	drs
Y14		1,000	1,000	1,000	-
Y15		1,000	1,000	1,000	-
Y16		0,749	0,868	0,863	drs
Average		**0,759**	**0,880**	**0,862**	

In the analysis, outputs are total number of inpatients, total number of outpatients, total number of surgeries; inputs are total number of specialists and dentists and stationery expenses. The purpose of the analysis is to calculate the technical efficiency scores of HIMSS 6 and HIMSS 7 hospitals in terms of stationery expenses using these inputs and outputs. Accordingly, the efficiency scores that emerge when stationery expenses and the number of specialists and dentists are considered as inputs are shown in Table 5.8 and Table 5.9. In order to compare the results of variable returns to scale and constant returns to scale, scores are calculated according to both CCR and BCC models. Scale efficiency is also calculated by ratio of CCR and BCC results. Input and output oriented models were used in the analysis. Both of them are demonstrated on the tables separately. All of the results are shown in Table 5.8 and Table 5.9.

Scenario 2.2 Cost Efficiency

In Scenario 2.2, cost efficiency analysis was conducted. Here, the outputs were determined as total number of inpatients, total number of outpatients and number of surgeries as in scenario 2.1. However, since the analysis is a cost efficiency analysis, stationery expenses was included as a cost variable and number of specialists and dentists was included as an input variable. The aim here is to compare the cost efficiency of HIMSS 6 and HIMSS 7 stage hospitals on the basis of stationery expenses by accepting stationery expenses as a cost variable. The efficiency scores for the cost efficiency analysis are shown in Table 5.10 and Table 5.11. In this analysis, by considering stationery expenses as a cost variable not an input variable; technical efficiency, allocative efficiency and cost efficiency scores were calculated for both CCR and BCC models in order to compare the results of variable returns to scale and constant returns to scale. Allocative efficiency was calculated by the ratio of cost efficiency and technical efficiency scores. Since output orientation is not applicable in a cost efficiency DEA, the orientation has thus been set to "input". Therefore, the cost efficiency analysis was analyzed only as input oriented. The results of the analysis are shown in Table 5.10 and Table 5.11.

Table 5.10 Analysis of Scenario 2.2 Results CCR Model

Cost Efficiency-CCR Model				
Digital Hospital (DMU)		**Technical Efficiency**	**Allocative Efficiency**	**Cost Efficiency**
X1	**HIMSS 7**	1,000	1,000	1,000
X2		0,740	1,000	0,740
X3		1,000	1,000	1,000
X4		0,877	1,000	0,877
Average		**0,904**	**1,000**	**0,904**
Y1	**HIMSS 6**	0,628	1,000	0,628
Y2		0,594	1,000	0,594
Y3		0,528	1,000	0,528
Y4		0,404	1,000	0,404
Y5		0,444	1,000	0,444
Y6		0,788	1,000	0,788
Y7		0,894	1,000	0,894
Y8		0,738	1,000	0,738
Y9		0,777	1,000	0,777
Y10		0,852	1,000	0,852
Y11		0,858	1,000	0,858
Y12		0,598	1,000	0,598
Y13		0,629	1,000	0,629
Y14		1,000	1,000	1,000
Y15		1,000	1,000	1,000
Y16		0,749	1,000	0,749
Average		**0,718**	**1,000**	**0,718**

Table 5.11 Analysis of Scenario 2.2 Results BCC Model

Cost Efficiency-BCC Model				
Digital Hospital (DMU)		**Technical Efficiency**	**Allocative Efficiency**	**Cost Efficiency**
X1	**HIMSS 7**	1,000	1,000	1,000
X2		0,788	1,000	0,788
X3		1,000	1,000	1,000
X4		0,883	1,000	0,883
Average		**0,918**	**1,000**	**0,918**
Y1	**HIMSS 6**	1,000	1,000	1,000
Y2		0,631	1,000	0,631
Y3		0,539	1,000	0,539
Y4		0,406	1,000	0,406
Y5		0,515	1,000	0,515
Y6		0,842	1,000	0,842
Y7		0,937	1,000	0,937
Y8		0,745	1,000	0,745
Y9		0,807	1,000	0,807
Y10		0,994	1,000	0,994
Y11		1,000	1,000	1,000
Y12		0,918	1,000	0,918
Y13		1,000	1,000	1,000
Y14		1,000	1,000	1,000
Y15		1,000	1,000	1,000
Y16		0,853	1,000	0,853
Average		**0,824**	**1,000**	**0,824**

5.3.4.3 Scenario 3 - Number of Nurse and Midwife as an Input Besides Stationery Expenses

Under this scenario, "Basic DEA" and "Cost Efficiency" analysis were carried out by considering the number of nurse and midwife as an input besides stationery expenses.

These analyses are detailed below under two separate scenarios as Scenario 3.1. and Scenario 3.2.

Scenario 3.1 Basic DEA (Technical Efficiency)

In Scenario 3.1, outputs are total number of inpatients, total number of outpatients, total number of surgeries; inputs are total number of nurse and midwife and stationery expenses. The purpose of the analysis is to calculate the technical efficiency scores of HIMSS 6 and HIMSS 7 hospitals in terms of stationery expenses using these inputs and outputs. Accordingly, the efficiency scores that emerge when stationery expenses and the number of nurse and midwife are considered as inputs are shown in Table 5.12 and Table 5.13. In order to compare the results of variable returns to scale and constant returns to scale, scores are calculated according to both CCR and BCC models. Scale efficiency is also calculated by ratio CCR and BCC results. Input and output oriented models were used in the analysis. Both of them are demonstrated on the tables separately. All of the results are shown in Table 5.12 and Table 5.13.

Table 5.12 Analysis of Scenario 3.1 Results-Input Oriented

Basic DEA (Technical Efficiency)-Input Oriented					
Digital Hospitals (DMU)		**CCR**	**BCC**	**Scale Efficiency**	
X1	**HIMSS 7**	1,000	1,000	1,000	-
X2		0,740	0,892	0,830	irs
X3		1,000	1,000	1,000	-
X4		1,000	1,000	1,000	-
Average		**0,935**	**0,973**	**0,958**	
Y1	**HIMSS 6**	0,824	1,000	0,824	drs
Y2		0,782	0,784	0,998	drs
Y3		0,625	0,853	0,732	irs
Y4		0,727	0,778	0,934	irs
Y5		0,665	0,671	0,991	drs
Y6		0,710	0,743	0,955	irs
Y7		0,675	0,701	0,964	irs

Cont. Table 5.12 Analysis of Scenario 3.1 Results-Input Oriented

Y8	**HIMSS 6**	**1,000**	**1,000**	**1,000**	**-**
Y9		0,797	1,000	0,797	irs
Y10		1,000	1,000	1,000	-
Y11		1,000	1,000	1,000	-
Y12		1,000	1,000	1,000	-
Y13		0,619	1,000	0,619	drs
Y14		0,801	1,000	0,801	irs
Y15		0,879	1,000	0,879	drs
Y16		0,632	0,665	0,950	irs
Average		**0,796**	**0,887**	**0,903**	

Table 5.13 Analysis of Scenario 3.1 Results-Output Oriented

Basic DEA (Technical Efficiency)-Output Oriented					
Digital Hospitals (DMU)		**CCR**	**BCC**	**Scale Efficiency**	
X1	**HIMSS 7**	1,000	1,000	1,000	-
X2		0,740	0,826	0,896	irs
X3		1,000	1,000	1,000	-
X4		1,000	1,000	1,000	-
Average		**0,935**	**0,957**	**0,974**	
Y1	**HIMSS 6**	0,824	1,000	0,824	drs
Y2		0,782	0,785	0,996	drs
Y3		0,625	0,708	0,883	irs
Y4		0,727	0,738	0,985	drs
Y5		0,665	0,822	0,809	drs
Y6		0,710	0,720	0,986	irs
Y7		0,675	0,678	0,996	drs
Y8		1,000	1,000	1,000	-
Y9		0,797	1,000	0,797	irs
Y10		1,000	1,000	1,000	-

Cont. Table 5.13 Analysis of Scenario 3.1 Results-Output Oriented

Y11	**HIMSS 6**	**1,000**	**1,000**	**1,000**	**-**
Y12		1,000	1,000	1,000	-
Y13		0,619	1,000	0,619	drs
Y14		0,801	1,000	0,801	irs
Y15		0,879	1,000	0,879	drs
Y16		0,632	0,634	0,996	irs
Average		**0,796**	**0,880**	**0,911**	

Scenario 3.2 Cost Efficiency

Cost efficiency analysis was conducted in Scenario 3.2. Here, the outputs were determined as total number of inpatients, total number of outpatients and number of surgeries as in scenario 3.1. However, since the analysis is a cost efficiency analysis, stationery expenses was included as a cost variable and number of nurse and midwife was included as an input variable. Here, the aim is to compare the cost efficiency of HIMSS 6 and HIMSS 7 stage hospitals on the basis of stationery expenses by accepting stationery expenses as a cost variable. The efficiency scores for the cost efficiency analysis are shown in Table 5.14 and Table 5.15. In this analysis, by considering stationery expenses as a cost variable not an input variable; technical efficiency, allocative efficiency and cost efficiency scores were calculated for both CCR and BCC models in order to compare the results of variable returns to scale and constant returns to scale. Allocative efficiency was calculated by the ratio of cost efficiency and technical efficiency scores. Since output orientation is not applicable in a cost efficiency DEA, the orientation has thus been set to "input". Therefore, the cost efficiency analysis was analyzed only as input oriented. The results of the analysis are shown in Table 5.14 and Table 5.15.

Table 5.14 Analysis of Scenario 3.2 Results CCR Model

Cost Efficiency-CCR Model				
Digital Hospital (DMU)		**Technical Efficiency**	**Allocative Efficiency**	**Cost Efficiency**
X1	**HIMSS 7**	1,000	1,000	1,000
X2		0,740	1,000	0,740
X3		0,996	1,000	0,996
X4		0,767	1,000	0,767
Average		**0,876**	**1,000**	**0,876**
Y1	**HIMSS 6**	0,747	1,000	0,747
Y2		0,777	1,000	0,777
Y3		0,553	1,000	0,553
Y4		0,659	1,000	0,659
Y5		0,664	1,000	0,664
Y6		0,705	1,000	0,705
Y7		0,675	1,000	0,675
Y8		1,000	1,000	1,000
Y9		0,687	1,000	0,687
Y10		0,864	1,000	0,864
Y11		1,000	1,000	1,000
Y12		0,986	1,000	0,986
Y13		0,614	1,000	0,614
Y14		0,731	1,000	0,731
Y15		0,821	1,000	0,821
Y16		0,628	1,000	0,628
Average		**0,757**	**1,000**	**0,757**

Table 5.15 Analysis of Scenario 3.2 Results BCC Model

Cost Efficiency-BCC Model				
Digital Hospital (DMU)		**Technical Efficiency**	**Allocative Efficiency**	**Cost Efficiency**
X1	**HIMSS 7**	1,000	1,000	1,000
X2		0,892	1,000	0,892
X3		1,000	1,000	1,000
X4		0,773	1,000	0,773
Average		**0,916**	**1,000**	**0,916**
Y1	**HIMSS 6**	1,000	1,000	1,000
Y2		0,784	1,000	0,784
Y3		0,853	1,000	0,853
Y4		0,730	1,000	0,730
Y5		0,671	1,000	0,671
Y6		0,709	1,000	0,709
Y7		0,701	1,000	0,701
Y8		1,000	1,000	1,000
Y9		0,834	1,000	0,834
Y10		0,917	1,000	0,917
Y11		1,000	1,000	1,000
Y12		1,000	1,000	1,000
Y13		1,000	1,000	1,000
Y14		1,000	1,000	1,000
Y15		1,000	1,000	1,000
Y16		0,645	1,000	0,645
Average		**0,865**	**1,000**	**0,865**

5.3.4.4 Scenario 4 – Number of Hospital Bed- Specialist and Dentist as Inputs Besides Stationery Expenses

In this scenario, the number of beds, number of specialists and dentists are included as inputs besides stationery costs. Therefore, different from the previous scenarios, this scenario includes two input variables in addition to stationery cost.

Table 5.16 Analysis of Scenario 4 Results-Input Oriented

Basic DEA (Technical Efficiency)-Input Oriented					
Digital Hospital (DMU)		**CCR**	**BCC**	**Scale Efficiency**	
X1	**HIMSS 7**	1,000	1,000	1,000	-
X2		0,890	0,923	0,965	irs
X3		1,000	1,000	1,000	-
X4		1,000	1,000	1,000	-
Average		**0,973**	**0,981**	**0,991**	
Y1	**HIMSS 6**	0,848	1,000	0,848	drs
Y2		0,891	1,000	0,891	drs
Y3		0,612	0,884	0,692	irs
Y4		0,963	1,000	0,963	irs
Y5		0,680	0,802	0,848	drs
Y6		0,833	0,842	0,989	drs
Y7		0,919	0,937	0,981	drs
Y8		1,000	1,000	1,000	-
Y9		0,921	1,000	0,921	irs
Y10		1,000	1,000	1,000	-
Y11		1,000	1,000	1,000	-
Y12		0,923	1,000	0,923	drs
Y13		0,672	1,000	0,672	drs
Y14		1,000	1,000	1,000	-
Y15		1,000	1,000	1,000	-
Y16		0,784	0,853	0,919	drs
Average		**0,878**	**0,957**	**0,915**	

Table 5.17 Analysis of Scenario 4 Results-Output Oriented

Basic DEA (Technical Efficiency)-Output Oriented					
Digital Hospital (DMU)		**CCR**	**BCC**	**Scale Efficiency**	
X1	**HIMSS 7**	1,000	1,000	1,000	-
X2		0,890	0,898	0,991	irs
X3		1,000	1,000	1,000	-
X4		1,000	1,000	1,000	-
Average		**0,973**	**0,975**	**0,998**	
Y1	**HIMSS 6**	0,848	1,000	0,848	drs
Y2		0,891	1,000	0,891	drs
Y3		0,612	0,753	0,813	irs
Y4		0,963	1,000	0,963	irs
Y5		0,680	0,849	0,801	drs
Y6		0,833	0,856	0,973	drs
Y7		0,919	0,944	0,974	drs
Y8		1,000	1,000	1,000	-
Y9		0,921	1,000	0,921	irs
Y10		1,000	1,000	1,000	-
Y11		1,000	1,000	1,000	-
Y12		0,923	1,000	0,923	drs
Y13		0,672	1,000	0,672	drs
Y14		1,000	1,000	1,000	-
Y15		1,000	1,000	1,000	-
Y16		0,784	0,868	0,904	drs
Average		**0,878**	**0,954**	**0,918**	

The outputs are the number of outpatients, the number of inpatients and the number of surgeries as in the previous scenarios. Therefore, there is no change in outputs. Considering these inputs and outputs, the technical efficiency scores of HIMSS 6 and HIMSS 7 stage hospitals were calculated. Unlike the previous scenarios, cost-efficiency analysis could not be calculated in this scenario since there are two other input variables in addition to stationery costs. This is because, in cost efficiency analysis, the number of input variables should be equal to the number of cost variables. However, the only variable that can be included in the analysis as a cost variable here is stationery expense. As a result, only "Basic DEA" was conducted under this scenario since cost efficiency analysis cannot be conducted with two inputs and one cost variable.

In the Basic DEA, as in the previous scenarios, both CCR and BCC models are taken into account in order to compare the results of constant returns to scale and variable returns to scale. Scale efficiency was also calculated by ratio CCR and BCC results. All results of the analysis are displayed in Table 5.16 and Table 5.17, with input and output-oriented results in separate tables.

5.3.4.5 Scenario 5 – Number of Hospital Bed- Specialist and Dentist- Nurse and Midwife as Inputs Besides Stationery Expenses

Scenario 5 was conducted by adding the number of nurses and midwives to the input variables in Scenario 4. In other words, in Scenario 5, the number of beds, the number of specialists and dentists, the number of nurses and midwives were taken into account as input variables besides stationery costs. Output variables are the same as the output variables in the previous scenarios. Accordingly, Scenario 5 was designed with 4 inputs and 3 outputs, including stationery costs. Since the number of input variables is higher than the number of cost variables in this scenario, cost efficiency analysis was not conducted. As in Scenario 4, the only variable that can be considered as a cost variable here is the stationery expenses. Therefore, considering these inputs and outputs, only Basic DEA was conducted under this scenario. As a result, the technical efficiency scores of HIMSS 6 and HIMSS 7 stage hospitals were calculated by including the inputs and outputs in the scenario.

In the Basic DEA, as in the previous scenarios, both CCR and BCC models are taken into account in order to compare the results of constant returns to scale and variable returns to scale. All results of the analysis are displayed in Table 5.18 and Table 5.19, with input and output-oriented results in separate tables.

Table 5.18 Analysis of Scenario 5 Results-Input Oriented

Basic DEA (Technical Efficiency)-Input Oriented					
Digital Hospital (DMU)		**CCR**	**BCC**	**Scale Efficiency**	
X1	**HIMSS 7**	1,000	1,000	1,000	-
X2		0,891	0,925	0,963	irs
X3		1,000	1,000	1,000	-
X4		1,000	1,000	1,000	-
Average		**0,973**	**0,981**	**0,991**	
Y1	**HIMSS 6**	0,848	1,000	0,848	drs
Y2		0,891	1,000	0,891	drs
Y3		0,625	0,896	0,697	irs
Y4		0,963	1,000	0,963	irs
Y5		0,693	0,802	0,864	drs
Y6		0,854	0,856	0,997	irs
Y7		0,919	0,937	0,981	drs
Y8		1,000	1,000	1,000	-
Y9		0,921	1,000	0,921	irs
Y10		1,000	1,000	1,000	-
Y11		1,000	1,000	1,000	-
Y12		1,000	1,000	1,000	-
Y13		0,702	1,000	0,702	drs
Y14		1,000	1,000	1,000	-
Y15		1,000	1,000	1,000	-
Y16		0,798	0,853	0,935	drs
Average		**0,888**	**0,959**	**0,925**	

Table 5.19 Analysis of Scenario 5 Results-Output Oriented

Basic DEA (Technical Efficiency)-Output Oriented					
Digital Hospital (DMU)		**CCR**	**BCC**	**Scale Efficiency**	
X1	**HIMSS 7**	1,000	1,000	1,000	-
X2		0,891	0,902	0,988	irs
X3		1,000	1,000	1,000	-
X4		1,000	1,000	1,000	-
Average		**0,973**	**0,976**	**0,997**	
Y1	**HIMSS 6**	0,848	1,000	0,848	drs
Y2		0,891	1,000	0,891	drs
Y3		0,625	0,761	0,822	irs
Y4		0,963	1,000	0,963	irs
Y5		0,693	0,849	0,817	drs
Y6		0,854	0,856	0,997	drs
Y7		0,919	0,944	0,974	drs
Y8		1,000	1,000	1,000	-
Y9		0,921	1,000	0,921	irs
Y10		1,000	1,000	1,000	-
Y11		1,000	1,000	1,000	-
Y12		1,000	1,000	1,000	-
Y13		0,702	1,000	0,702	drs
Y14		1,000	1,000	1,000	-
Y15		1,000	1,000	1,000	-
Y16		0,798	0,868	0,920	drs
Average		**0,888**	**0,955**	**0,928**	

5.4 Evaluation of DEA Results

In this section, the DEA results given in the previous section will be discussed. In the study, the DEA is constructed and detailed under two main analysis headings. These two main analyses are “Basic DEA” and “Cost Efficiency” analysis. The different efficiency scores calculated within the scope of these analyses are shown in detail in the tables in the previous section. In this section, these results will be compared and evaluated within the scope of HIMSS 7 and HIMSS 6 stage hospitals.

Under the Basic DEA title; technical efficiency and scale efficiency are calculated. However, scale efficiency is calculated by the ratio of CRS and VRS scores under technical efficiency. Therefore, in this section, only technical efficiency scores will be evaluated and discussed within the scope of Basic DEA. In other words, the efficiency scores of HIMSS 6 and HIMSS 7 stage hospitals will be compared and evaluated by considering the results of CRS and VRS models within the scope of technical efficiency analysis. On the other hand, both input and output-oriented results will also be evaluated.

Under the cost efficiency title; cost efficiency, technical efficiency and allocative efficiency scores are calculated. Here, the allocative efficiency score is calculated by the ratio of cost efficiency and technical efficiency scores. Therefore, only technical efficiency and cost efficiency scores will be evaluated in this section. In the comparison and evaluation of HIMSS 6 and HIMSS 7 stage hospitals within the scope of cost efficiency analysis; technical efficiency and cost efficiency scores calculated with CRS and VRS models will be taken into consideration. Since output orientation is not applicable in a cost efficiency DEA, the orientation has thus been set to "input". Therefore, the cost efficiency analysis was analyzed only as input oriented.

In the “Implementation of DEA” section, the efficiency results of HIMSS 6 and HIMSS 7 stage hospitals, which were selected as the sample, are presented separately on a hospital basis. These results indicate that HIMSS 6 and HIMSS 7 stage hospitals can have different efficiency scores on the basis of stationery expenses. The expectation is that, since "zero paper" is used in HIMSS 7 stage hospitals, the efficiency scores of HIMSS 7 stage hospitals (on the basis of stationery expenses) are higher than the efficiency scores of HIMSS 6 stage hospitals (on the basis of stationery expenses).

When the efficiency scores calculated under different assumptions for hospitals are observed, the results are remarkable. When the results are analyzed, it is seen that while the efficiency score of some HIMSS 7 stage hospitals is 1,000, some are below 1,000. When looking at HIMSS 6 stage hospitals, it is seen that the efficiency score of some hospitals is 1,000 while some are below 1,000. Therefore, the results may vary in line with the inputs and outputs as well as the assumptions taken into account. On the other hand, while the variable returns to scale in some hospitals are increasing, in others it is decreasing. These results are shown as IRS and DRS in the tables. ***However, when the efficiency scores are analyzed in general terms, it is seen that the efficiency scores of HIMSS 7 stage hospitals are higher on average and proportionally compared to HIMSS 6 stage hospitals, in spite of exceptional cases.***

Accordingly, in this study, while evaluating the efficiency scores calculated by DEA method, the average efficiency score of HIMSS 7 stage hospitals will be considered and the average efficiency score of HIMSS 6 stage hospitals will be considered. In other words, the efficiency scores of HIMSS 6 and HIMSS 7 stage hospitals will be evaluated on an average basis. The conclusion and discussion part of the study will be based on the average efficiency scores of HIMSS 6 and HIMSS 7 stage hospitals.

Table 5.20 and Table 5.21 demonstrate the results of the average efficiency scores of HIMSS 6 and HIMSS 7 stage hospitals under different assumptions. The evaluation of this section will be based on these tables.

5.4.1 Evaluation of Basic DEA Results

Table 5.20 summarizes the results of input and output oriented Basic DEA for CCR and BCC models in the scope of HIMSS 6 and HIMSS 7.

Under the assumption of constant returns to scale (CCR), the rate of increase in inputs and outputs is equal. If input is increased by one unit, output also increases by one unit. Under the assumption of variable returns to scale (BCC), the rate of increase in inputs and outputs is different. If the rate of increase in output is higher when input is increased by a certain amount, we have increasing returns to scale; if the rate of increase in output is lower, we have decreasing returns to scale.

When looking at input and output-oriented analyses; the input-oriented model aims to minimize inputs to meet the minimum output level. In the output-oriented model, it is aimed to maximize the output value without the need for more input values. The quantity of inputs is changed in the input-oriented model, while the quantity of outputs is changed in the output-oriented model.

Table 5.20 Average of HIMSS 6 and HIMSS 7 Efficiency Scores on Basic DEA

Basic DEA (Technical Efficiency) Analysis					
Scenario	**HIMSS Stage**	**CCR Input**	**BCC Input**	**CCR Output**	**BCC Output**
Scenario 1.1	HIMSS 7	0,902	0,981	0,902	0,966
	HIMSS 6	0,770	0,902	0,770	0,898
Scenario 1.2	Cost Efficiency Analysis				
Scenario 2.1	HIMSS 7	0,935	0,947	0,935	0,955
	HIMSS 6	0,759	0,850	0,759	0,880
Scenario 2.2	Cost Efficiency Analysis				
Scenario 3.1	HIMSS 7	0,935	0,973	0,935	0,957
	HIMSS 6	0,796	0,887	0,796	0,880
Scenario 3.2	Cost Efficiency Analysis				
Scenario 4	HIMSS 7	0,973	0,981	0,973	0,975
	HIMSS 6	0,878	0,957	0,878	0,954
Scenario 5	HIMSS 7	0,973	0,981	0,973	0,976
	HIMSS 6	0,888	0,959	0,888	0,955

Considering the results in Table 5.20, the average efficiency score of HIMSS 7 stage hospitals is higher than the average efficiency score of HIMSS 6 stage hospitals in both input and output oriented CCR and BCC models. Therefore, it is possible to say that the use of zero paper in HIMSS 7 stage hospitals has a positive impact on the efficiency analysis results on the basis of stationery expenses.

Under the assumption of constant returns to scale, the efficiency scores of both input and output oriented analyses are equal to each other. Therefore, under the assumption of constant returns to scale, the efficiency score is calculated the same whether an analysis is input oriented or output oriented.

Under the assumption of variable returns to scale, the results vary according to input and output orientation. In addition, when the tables with hospital based efficiency scores in the previous section are observed, while a hospital is inefficient under the CCR assumption, it can be efficient under the BCC assumption. It was stated in the previous chapter of the study that efficiency score calculated under the assumption of variable returns to scale is higher than efficiency score calculated under the assumption of constant returns to scale. Accordingly, when the hospital based tables given in the previous section are analyzed, it is seen that BCC scores are higher than CCR scores.

However, looking at the input oriented and output oriented scores under the BCC assumption, the input oriented model is more efficient in some scenarios, while the output oriented model is more efficient in others. In all scenarios, the same output variables were used and input variables were varied. Therefore, the difference in the efficiency scores of the input and output oriented models is due to the different input variables used in the scenarios. For instance, Scenario 1.1 and Scenario 3.1, where the number of hospital beds and the number of nurse-midwives were used as input variables, produced higher efficiency scores in input oriented model, whereas Scenario 2.1, where the number of specialist was used as an input variable, produced higher efficiency scores in output oriented model. These results can be interpreted as that changing the number of beds and the number of nurse-midwives as input variables produces more efficient results than changing the number of specialist.

When the efficiency scores of all scenarios are reviewed in Table 5.20, it is seen that the highest score belongs to the BCC-Input assumption of HIMSS 7 stage Scenario 1.1, Scenario 4 and Scenario 5 with 0.981. The lowest efficiency score belongs to the CCR-Input and CCR-Output assumption of HIMSS 6 stage Scenario 2.1 with 0.759. As can be understood from these results, the average efficiency scores of hospitals at HIMSS 7 stage are higher than HIMSS 6. In addition, the average efficiency score of hospitals with HIMSS 7 is above 0,900 for all scenarios. Even if this score is not 1,000, it is a very successful score. From these results, it is clearly seen that the use of zero paper in HIMSS 7 stage hospitals has a positive impact on the efficiency score of hospitals on the basis of stationery expenses.

On the other hand from the results, it can be said that the efficiency scores are relatively low compared to the other scenarios when the number of specialist and then the number of nurse-midwives are included as input variables besides stationery costs. It is also understood that in inefficient hospitals, more output can be produced without an increase in inputs (stationery expenses, number of physicians and number of nurse-midwives) or the same outputs can be produced by reducing the existing inputs in order to be an efficient hospital. For example, reducing stationery cost or increasing number of impatient further in an inefficient hospital will be able to increase the efficiency score of the hospital.

5.4.2 Evaluation of Cost Efficiency Analysis Results

Table 5.21 summarizes the results of input oriented Cost Efficiency analysis for CCR and BCC models in the scope of HIMSS 6 and HIMSS 7. In this analysis, stationery expense is assumed as the cost variable and accordingly, technical efficiency and cost efficiency results are evaluated using different input combinations.

Table 5.21 Average of HIMSS 6 and HIMSS 7 Efficiency Scores on Cost Efficiency

Cost Efficiency Analysis					
Scenario	**HIMSS Stage**	**Technical Efficiency CCR**	**Cost Efficiency CCR**	**Technical Efficiency BCC**	**Cost Efficiency BCC**
Scenario 1.1	Basic DEA				
Scenario 1.2	HIMSS 7	0,829	0,829	0,914	0,914
	HIMSS 6	0,756	0,756	0,895	0,895
Scenario 2.1	Basic DEA				
Scenario 2.2	HIMSS 7	0,904	0,904	0,918	0,918
	HIMSS 6	0,718	0,718	0,824	0,824
Scenario 3.1	Basic DEA				
Scenario 3.2	HIMSS 7	0,876	0,876	0,916	0,916
	HIMSS 6	0,757	0,757	0,865	0,865
Scenario 4	Basic DEA				
Scenario 5	Basic DEA				

The results in Table 5.21 show that when the stationery expense variable is assumed as a cost variable, the technical efficiency score is equal to the cost efficiency score. Similar to the previous Basic DEA, the BCC results are naturally higher than the CCR results.

In overall terms, when Table 5.21 is observed, it is seen that the average efficiency score of HIMSS 7 stage hospitals is higher than HIMSS 6 in all scenarios similar to the previous Basic DEA. In other words, in the cost efficiency analysis, *use of zero paper* in HIMSS 7 stage hospitals affects the efficiency scores positively. The average efficiency score of HIMSS 7 stage hospitals is equal to or above 0,829 in all scenarios. Even if this number is not 1,000; a 0,829 score is also a successful score in terms of efficiency.

Considering the scenarios, Scenario 2.2 of HIMSS 7, where the number of specialist is assumed as the input variable, has the highest score with 0,918. In the Basic DEA, Scenario 2.1, where the number of specialist was assumed as the input variable, was lower than in the other scenarios. In other words, if the stationery cost is considered as a cost variable, the efficiency score is higher in the scenario where the number of specialist is assumed as the input variable. This means that since the outputs in all scenarios are the same, the most efficient results on an input basis are achieved with the number of specialist when stationery costs are assumed as the cost variable. In other words, compared to other inputs such as the number of beds and the number of nurse-midwives, the efficiency score is higher in scenarios where the number of specialist is assumed as input.

However, it is seen that the lowest score is again Scenario 2.2, but this time it belongs to HIMSS 6 with 0,718. Interestingly, while the efficiency score is higher in the analysis where the number of specialist in HIMSS 7 stage hospitals is accepted as an input, the scenario where the number of specialist in HIMSS 6 stage hospitals is accepted as an input is lower compared to other scenarios. In other words, taking the number of specialist as an input variable in HIMSS 7 and HIMSS 6 stage hospitals does not give the same response as a result of the analysis.

When average Basic DEA and Cost efficiency results are compared, it is seen in Table 5.20 and Table 5.21, that both technical efficiency and cost efficiency scores are lower in Scenario 1.2, Scenario 2.2, and Scenario 3.2 compared to the technical efficiency scores in Basic DEA. Therefore, it is observed that average efficiency is lower in the cost efficiency analysis where stationery expense is considered as a cost variable compared to the Basic DEA where stationery expense is considered as an input.

As a result, the average efficiency score of HIMSS 7 stage hospitals was calculated higher in DEA under different scenarios, both in "Basic DEA" and "Cost Efficiency" analysis. In other words, the average efficiency score of HIMSS 7 stage hospitals was higher than HIMSS 6 stage hospitals in the analyses where stationery costs and outputs were kept constant. Therefore, it is seen that "zero paper use",

which is the criterion of HIMSS stage 7 hospitals, has a positive impact on the stationery expenses of HIMSS stage 7 hospitals. This situation is clearly understood from the average efficiency scores of HIMSS 7 stage hospitals.

5.5 Statistical Evaluation of the DEA Results

In the previous section, the efficiency scores calculated by DEA technique were evaluated and it was seen that the efficiency average of HIMSS 7 stage hospitals was higher than HIMSS 6. In this section, whether there is a statistically significant difference in the efficiency scores calculated on hospital basis is examined by the IBM SPSS Statistics 22 program. The scores evaluated in DEA technique will be examined in terms of statistical significance. Statistical analysis will be applied to CCR and BCC scores in "Basic DEA" and technical efficiency and cost efficiency scores in "Cost Efficiency" analysis.

The study is based on three separate hypotheses and the statistical significance of the scenarios in the previous section is analyzed through these hypotheses. The hypotheses in the study are as follows:

Hypothesis 1: The efficiency of hospitals differs significantly according to HIMSS 7 and HIMSS 6 stages.
Hypothesis 2: The efficiency of hospitals differs significantly in terms of hospital role (Hospital roles are A1, A2, and B).
Hypothesis 3: The efficiency of hospitals differs significantly in terms of the average number of beds (Under 500 beds and above).

The significance analysis of the hypotheses was measured by Independent T-Test or ANOVA according to the number of variables in the hypothesis. Since the Independent T-Test and ANOVA test can be applied to normally distributed data, it was tested whether the data were normally distributed before these tests. Table 5.22 and Table 5.23 shows the normality test results for all scenarios.

Table 5.22 Normality Test Results of Basic DEA

	CCR/Input		BCC/Input		CCR/Output		BCC/Output	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Scenario 1.1	-0,279	-1,300	-1,485	0,959	-0,279	-1,300	-1,451	-0,656
Scenario 2.1	-0,435	-1,039	-1,198	0,083	-0,435	-1,039	-1,200	0,356
Scenario 3.1	0,082	-1,622	-0,859	-0,999	0,082	-1,622	-0,729	-1,254
Scenario 4	-1,162	0,343	-1,471	0,802	-1,162	0,343	-1,663	1,981
Scenario 5	-1,180	0,400	-1,524	1,113	-1,180	0,400	-1,624	1,746

Table 5.23 Normality Test Results of Cost Efficiency Analysis

	Technical Efficiency CCR		Cost Efficiency CCR		Technical Efficiency BCC		Cost Efficiency BCC	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Scenario 1.2	0,069	-1,380	0,069	-1,380	-1,106	-0,081	-1,106	-0,081
Scenario 2.2	-0,291	-0,816	-0,291	-0,816	-1,130	0,249	-1,130	0,249
Scenario 3.2	0,469	-1,050	0,469	-1,050	-0,452	-1,457	-0,452	-1,457

In order for a distribution to be considered normal, according to Tabachnick and Fidell [81], Skewness and Kurtosis values should be in the range of “-1.5 +1.5”. On the other hand, according to George and Mallery [82], Skewness and Kurtosis values in the range of “-2.0 +2.0” indicate that the distribution is also a normal distribution. Therefore, it is seen that almost all of the values in Table 5.22 and all of the values in Table 5.23 are in the range of “-1.5 +1.5”. It is also seen that the values in Table 5.22, which are not in the “-1,5 +1,5” value range, are in the “-2,0 +2,0” value range. In this way, it is possible to say that the distribution of the data has a normal distribution due to the sources cited in the above.

Since the data were normally distributed, Independent T-Test or ANOVA test was applied to the hypotheses. If the number of variables belonging to the group in the hypothesis is two, "Independent T-Test" was used; if more than two, ANOVA test was used. Analyses of all scenarios on the basis of hypothesis are given below under subheadings.

5.5.1 Hypothesis 1

Hypothesis 1: The efficiency of hospitals differs significantly according to HIMSS 7 and HIMSS 6 stages.

In the previous section, the average efficiency scores of HIMSS 7 and HIMSS 6 stage hospitals on the basis of stationery expenses were analyzed and compared. As a result of the DEA, it was observed that the average efficiency of HIMSS 7 stage hospitals was higher than HIMSS 6 stage hospitals. In this section, it is analyzed whether the hospital efficiencies of HIMSS 7 and HIMSS 6 stage hospitals differ statistically on the basis of stationery expenses. Since there are two groups as HIMSS 7 and HIMSS 6, Independent T-Test was used in this analysis. In order to understand whether there is a statistical difference in the efficiency of HIMSS 7 and HIMSS 6 stage hospitals, the "Sig. (2-tailed)" value in the Independent T-Test output was considered. Since the analysis was conducted over a 95% confidence interval, the "Sig. (2-tailed)" value of 0.05 was taken as a reference. If the Sig. (2-tailed) value is less than 0.05, it is concluded that there is a significant difference between the groups, and if it is greater than 0.05, it is concluded that there is no significant difference between the groups. Table 5.24 and Table 5.25 below demonstrate the "Sig. (2-tailed)" values calculated on the basis of scenarios and models for “Basic DEA” and “Cost Efficiency” analyses, respectively. When the calculated Sig. (2-tailed) values are observed, it is seen that all values belonging to all scenarios and models are greater than 0.05. Therefore, it is concluded that the efficiencies of HIMSS 7 and HIMSS 6 stage hospitals do not differ statistically.

However, when values above 0.05 but close to 0.05 are considered, the BCC/Input value for Scenario 3.1 in Table 5.24 is calculated as 0.072, and the CCR values for Scenario 2.2 in Table 5.25 are calculated as 0.070. In accordance with these results, it can be said that in the Basic DEA analysis; when the number of nurses and midwives is included in the analysis as an input (Scenario 3.1), although there is no significant difference between HIMSS 6 and HIMSS 7 stage hospitals, under the assumption of variable returns to scale and input oriented, the result is slightly more significant compared to other values. In this case, when the number of nurse-midwives is taken into consideration as an input, HIMSS 7 stage hospitals may differ slightly from HIMSS 6 stage hospitals.

In the Cost Efficiency analysis, it can be said that although there is no significant difference between HIMSS 6 and HIMSS 7 stage hospitals, under the assumption of constant returns to scale in Scenario 2.2, where the number of specialist/dentist is included in the analysis as an input, the result is slightly more significant compared to other values. In this case, when the number of specialist/dentist is considered as an input, HIMSS 7 stage hospitals may differ slightly from HIMSS 6 stage hospitals.

Table 5.24 Independent T-Test Results of Basic DEA

	CCR/Input		**BCC/Input**		**CCR/Output**		**BCC/Output**	
	Sig. (2-tailed)	**Significant Difference or Not**	**Sig. (2-tailed)**	**Significant Difference or Not**	**Sig. (2-tailed)**	**Significant Difference or Not**	**Sig. (2-tailed)**	**Significant Difference or Not**
Scenario 1.1	,159	No Significant Difference	,068	No Significant Difference	,159	No Significant Difference	,412	No Significant Difference
Scenario 2.1	,097	No Significant Difference	,359	No Significant Difference	,097	No Significant Difference	,371	No Significant Difference
Scenario 3.1	,094	No Significant Difference	,072	No Significant Difference	,094	No Significant Difference	,217	No Significant Difference
Scenario 4	,177	No Significant Difference	,535	No Significant Difference	,177	No Significant Difference	,634	No Significant Difference
Scenario 5	,212	No Significant Difference	,542	No Significant Difference	,212	No Significant Difference	,619	No Significant Difference

Table 5.25 Independent T-Test Results of Cost Efficiency Analysis

	Technical Efficiency CCR		**Cost Efficiency CCR**		**Technical Efficiency BCC**		**Cost Efficiency BCC**	
	Sig. (2-tailed)	**Significant Difference or Not**	**Sig. (2-tailed)**	**Significant Difference or Not**	**Sig. (2-tailed)**	**Significant Difference or Not**	**Sig. (2-tailed)**	**Significant Difference or Not**
Scenario 1.2	,430	No Significant Difference	,430	No Significant Difference	,805	No Significant Difference	,805	No Significant Difference
Scenario 2.2	,070	No Significant Difference	,070	No Significant Difference	,384	No Significant Difference	,384	No Significant Difference
Scenario 3.2	,150	No Significant Difference	,150	No Significant Difference	,508	No Significant Difference	,508	No Significant Difference

It should be emphasized that when the average the efficiency scores of HIMSS 7 and HIMSS 6 stage hospitals are calculated, the average efficiency score of HIMSS 7 stage hospitals is higher than HIMSS 6. In other words, the mean of HIMSS 7

efficiency score is higher than mean of HIMSS 6 efficiency score.* However, while there is a difference in the mean value of the groups, there is no statistical difference due to the fact that some HIMSS 6 stage hospitals have high efficiency scores, 1,000 or close to 1,000. *Therefore, it was concluded that there was no statistically significant difference between the groups but it is clearly seen that the mean of HIMSS 7 efficiency scores on the basis of stationery expenses is higher than the mean of HIMSS 6 efficiency score.

5.5.2 Hypothesis 2

Hypothesis 2: The efficiency of hospitals differs significantly in terms of hospital role (Hospital roles are A1, A2, and B).

In this hypothesis, it was tested whether the calculated efficiency scores differ significantly in terms of the A1, A2, and B roles in which hospitals are grouped by the Ministry of Health. Training and research hospitals are defined as role A1; hospitals that are not training and research hospitals but relatively large hospitals are defined as role A2; and smaller hospitals compared to A2 role hospitals are defined as role B.

Table 5.26 ANOVA Test Results of Basic DEA

	CCR/Input		**BCC/Input**		**CCR/Output**		**BCC/Output**	
	Sig.	**Significant difference or not**	**Sig**	**Significant difference or not**	**Sig.**	**Significant difference or not**	**Sig.**	**Significant difference or not**
Scenario 1.1	,513	No Significant Difference	,360	No Significant Difference	,513	No Significant Difference	,196	No Significant Difference
Scenario 2.1	,079	No Significant Difference	,542	No Significant Difference	,079	No Significant Difference	,671	No Significant Difference
Scenario 3.1	,577	No Significant Difference	,908	No Significant Difference	,577	No Significant Difference	,672	No Significant Difference
Scenario 4	,868	No Significant Difference	,574	No Significant Difference	,868	No Significant Difference	,393	No Significant Difference
Scenario 5	,869	No Significant Difference	,604	No Significant Difference	,869	No Significant Difference	,402	No Significant Difference

Since there are three groups under this hypothesis, ANOVA test was used in the statistical analysis. ANOVA test results of the efficiency scores calculated on the basis of "Basic DEA" and "Cost Efficiency" analysis are presented in Table 5.26 and Table 5.27.

Table 5.27 ANOVA Test Results of Cost Efficiency Analysis

	Technical Efficiency CCR		Cost Efficiency CCR		Technical Efficiency BCC		Cost Efficiency BCC	
	Sig.	**Significant Difference or Not**	**Sig.**	**Significant Difference or Not**	**Sig.**	**Significant Difference or Not**	**Sig.**	**Significant Difference or Not**
Scenario 1.2	,478	No Significant Difference	,478	No Significant Difference	,095	No Significant Difference	,095	No Significant Difference
Scenario 2.2	,081	No Significant Difference	,081	No Significant Difference	,581	No Significant Difference	,581	No Significant Difference
Scenario 3.2	,622	No Significant Difference	,622	No Significant Difference	,419	No Significant Difference	,419	No Significant Difference

Since the analysis was conducted over a 95% confidence interval, the "Sig." value of 0.05 was taken as a reference. If the Sig. (2-tailed) value is less than 0.05, it is concluded that there is a significant difference between the groups, and if it is greater than 0.05, it is concluded that there is no significant difference between the groups. ***When the ANOVA test results in Table 5.26 and Table 5.27 are observed, it is seen that all Sig. values are greater than 0.05. Accordingly, it is concluded that the efficiency scores of the hospitals do not differ in terms of the hospital roles A1, A2 and B.***

5.5.3 Hypothesis 3

Hypothesis 3: The efficiency of hospitals differs significantly in terms of the average number of beds (Under 500 beds and above).

Hypothesis 3 is designed to measure whether efficiency scores differ significantly based on the number of hospital beds or not. The number of hospital bed selected as the sample vary between 205 beds and 1620 beds. Accordingly, in terms of hospital size, "500 hospital beds" was accepted as the reference number in terms of the number of beds. Hospitals with more than 500 beds and hospitals with less than 500 beds are grouped and it is tested whether there is a significant difference between these two groups on the basis of efficiency. Since there are two groups in the hypothesis, "Independent T-Test" was carried out on the efficiency scores. Independent T-Test results of the efficiency scores calculated on the basis of "Basic DEA" and "Cost Efficiency" analysis are presented in Table 5.28 and Table 5.29.

Table 5.28 Independent T-Test Results of Basic DEA

	CCR/Input		BCC/Input		CCR/Output		BCC/Output	
	Sig. (2-tailed)	**Significant Difference or Not**	**Sig. (2-tailed)**	**Significant Difference or Not**	**Sig. (2-tailed)**	**Significant Difference or Not**	**Sig. (2-tailed)**	**Significant Difference or Not**
Scenario 1.1	,173	No Significant Difference	,188	No Significant Difference	,173	No Significant Difference	,499	No Significant Difference
Scenario 2.1	,154	No Significant Difference	,947	No Significant Difference	,154	No Significant Difference	,653	No Significant Difference
Scenario 3.1	,373	No Significant Difference	,375	No Significant Difference	,373	No Significant Difference	,756	No Significant Difference
Scenario 4	,111	No Significant Difference	,315	No Significant Difference	,111	No Significant Difference	,755	No Significant Difference
Scenario 5	,177	No Significant Difference	,305	No Significant Difference	,177	No Significant Difference	,726	No Significant Difference

Table 5.29 Independent T-Test Results of Cost Efficiency Analysis

	Technical Efficiency CCR		Cost Efficiency CCR		Technical Efficiency BCC		Cost Efficiency BCC	
	Sig. (2-tailed)	**Significant Difference or Not**	**Sig. (2-tailed)**	**Significant Difference or Not**	**Sig. (2-tailed)**	**Significant Difference or Not**	**Sig. (2-tailed)**	**Significant Difference or Not**
Scenario 1.2	,280	No Significant Difference	,280	No Significant Difference	,410	No Significant Difference	,410	No Significant Difference
Scenario 2.2	,228	No Significant Difference	,228	No Significant Difference	,689	No Significant Difference	,689	No Significant Difference
Scenario 3.2	,803	No Significant Difference	,803	No Significant Difference	,827	No Significant Difference	,827	No Significant Difference

Since the analysis was conducted over a 95% confidence interval, the "Sig. (2-tailed)" value of 0.05 was taken as a reference. If the Sig. (2-tailed) value is less than 0.05, it is concluded that there is a significant difference between the groups, and if it is greater than 0.05, it is concluded that there is no significant difference between the groups. ***When the test results in Table 5.28 and Table 5.29 are observed, it is seen that all Sig. (2-tailed) values are greater than 0.05. Accordingly, it is concluded that the***

efficiency scores of the hospitals do not differ in terms of the number of hospital beds.

5.6 Results and Discussion

In this study, the efficiency scores of HIMMS 7 and HIMSS 6 stage digital hospitals were calculated and analyzed on the basis of stationery expenses. HIMSS 7 and HIMSS 6 certificated hospitals are both recognized as digital hospitals both nationally and internationally. HIMSS 7 stage hospitals are more advanced than HIMSS 6 stage hospitals and HIMSS 7 stage hospitals have zero paper use criteria. Therefore, this study aims to compare the efficiency of HIMSS 7 and HIMSS 6 stage hospitals on the basis of stationery expenses.

In the first section of the analysis, 4 HIMSS 7 and 16 HIMSS 6 stage digital hospitals were selected as a sample, considering certain criteria. In the efficiency calculation, 2021 data of the selected samples were used. The data were obtained from the General Directorate of Public Hospitals of the MoH. These data are stationery expenses, number of hospital beds, number of specialist/dentist, number of nurse/midwife, number of inpatient, number of outpatient, and number of surgery. All of these data were analyzed by the DEAP 2.1 DEA program. In the DEA technique, stationery expenses, number of hospital beds, number of specialist/dentist, and number of nurse/midwife were included as inputs; number of inpatient, number of outpatient and number of surgery were included as outputs.

In total, the analysis was carried out over eight different scenarios, including sub-scenarios. Since the main objective of the study is to calculate efficiency in digital hospitals on the basis of stationery costs, stationery costs are considered either as an input variable or as a cost variable in all scenarios. Other input variables were analyzed with different combinations on a scenario basis. All three output variables are included in all scenarios. In this way, eight scenarios were constructed with different combinations.

In five of the eight scenarios, input and output oriented CCR and BCC modeled technical efficiencies were calculated within the scope of “Basic DEA”; in three scenarios, input oriented CCR and BCC modeled technical efficiencies and cost efficiencies were calculated within the scope of “Cost Efficiency” analysis.

The efficiency scores of all hospitals separately on the basis of the scenarios and the models are demonstrated in the tables in the previous section. Then, the average efficiency scores of hospitals at HIMSS 6 and HIMSS 7 stages were evaluated and shown in tables.

As a result of DEA, it was observed that the average efficiency of HIMSS 7 stage hospitals was higher than HIMSS 6 stage hospitals for all models used in scenarios. In other words, on the basis of stationery expenses, the average efficiency of HIMSS 7 stage hospitals was higher than the average efficiency of HIMSS 6 stage hospitals. In addition, the average efficiency score of hospitals with HIMSS 7 is above 0,829 for all scenarios. In fact, this value is above 0,829 in "Cost Efficiency" analysis while it is above 0,900 in "Basic DEA". Even if this score is not 1,000, it is a very successful score. Therefore, efficiency scores calculated by DEA were positively affected by zero paper use in HIMSS 7 stage hospitals. However, as a result of the findings, although HIMSS 7 was higher on average, it was also observed that some HIMSS 6 stage hospitals had high efficiency scores such as 1,000 or close to 1,000. This shows that a HIMSS 6 stage hospital with these scores can also be efficient or fully efficient on the basis of stationery expenses. Yet as stated, when the average is calculated, it is seen that HIMSS 7 is higher than HIMSS 6. The zero paper use criterion in HIMSS 7 stage hospitals positively affects the digital hospital's efficiency on the basis of stationery expenses.

Analyzing the average efficiency scores on a model basis, the following results are obtained.

According to "Basic DEA" results, the highest score belongs to the BCC-Input assumption of HIMSS 7 stage Scenario 1.1, Scenario 4 and Scenario 5 with 0.981. The lowest efficiency score belongs to the CCR-Input and CCR-Output assumption of HIMSS 6 stage Scenario 2.1 with 0.759. It means that the efficiency scores are relatively low compared to the other scenarios when the number of specialist and then the number of nurse-midwives are included as input variables besides stationery costs. According to "Cost Efficiency" analysis, the highest score belongs to the technical and cost efficiency results of BCC in Scenario 2.2 of HIMSS 7, where the number of specialist is assumed as the input variable, 0,918. The lowest score belongs to again Scenario 2.2, but BCC technical and BCC cost efficiency results of HIMSS 6 with

0,718. This means that taking the number of specialist as an input variable in HIMSS 7 and HIMSS 6 stage hospitals does not give the same response as a result of the "Cost Efficiency" analysis.

When average Basic DEA and Cost Efficiency results are compared, it is seen that both technical efficiency and cost efficiency scores are lower in Scenario 1.2, Scenario 2.2, and Scenario 3.2 compared to the technical efficiency scores in Basic DEA. Therefore, it is observed that efficiency is lower in the cost efficiency analysis where the stationery expense is considered as a cost variable compared to the Basic DEA where stationery expense is considered as an input.

After the evaluation of DEA results, these efficiency scores were analyzed statistically and the IBM SPSS Statistics 22" program was used to test whether there is a significant difference in these scores. The data calculated on a scenario basis were analyzed under three different hypotheses. These hypotheses are given below.

Hypothesis 1: The efficiency of hospitals differs significantly according to HIMSS 7 and HIMSS 6 stages.
Hypothesis 2: The efficiency of hospitals differs significantly in terms of hospital role (Hospital roles are A1, A2, and B).
Hypothesis 3: The efficiency of hospitals differs significantly in terms of the average number of beds (Under 500 beds and above).

First of all, the normality test was used to analyze whether the data were normally distributed or not. Then, Independent T-test or ANOVA test was carried out on the data found to be normally distributed. Independent T-test was applied to Hypothesis 1 and Hypothesis 3 since there were two variable groups, and ANOVA test was applied to Hypothesis 2 since there were three variable groups. As a result of the tests applied to the hypotheses, it was seen that there was no significant difference between the groups in all three hypotheses.

As a result of Hypothesis 1, the mean value of HIMSS 7 stage hospitals was higher than HIMSS 6. However, there was no significant difference between the two groups in terms of the efficiency scores of HIMSS 6 and HIMSS 7 stage hospitals. Likewise, as a result of DEA, it was observed that the average efficiency score of HIMSS 7 stage hospitals was higher than HIMSS 6. On the other hand, as stated before, the efficiency score of some HIMSS 6 stage hospitals was high. In this case, no statistically significant difference was found between the groups due to the high efficiency score of some HIMSS 6 stage hospitals, although HIMSS 7 was leading in terms of average value.

When the results of Hypothesis 2 and Hypothesis 3 are observed, no significant difference was found between the groups. However, unlike Hypothesis 1, there was also no difference in the mean values of the groups in Hypothesis 2 and Hypothesis 3. Therefore, it is revealed from the results of Hypothesis 2 and Hypothesis 3 that digital hospital efficiencies do not significantly differ in terms of number of hospital beds and hospital role.

Consequently, the efficiency scores calculated on the basis of stationery expenses are, on average, higher in HIMSS 7 stage hospitals compared to HIMSS 6 stage hospitals. However, it was observed that there was no statistically significant difference in the efficiency scores of the hospitals between the groups identified as HIMSS stage, hospital role and number of beds. ***Finally, in order to increase the efficiency of digital hospitals, either more outputs should be produced with existing inputs or existing outputs should be produced with fewer inputs. Pursuing this way in hospitals that have low efficiency will make the hospital more efficient.***

CHAPTER 6

CONCLUSION

This section includes a summary of the study, the main findings of the study, and recommendations for future studies.

The main purpose of the study is to increase the awareness of the digital hospital, which pioneers the development of the health sector, and to increase the number of quantitative studies on digital hospitals.

Today, one of the biggest benefits of technology in our lives is digitalization. Digitalization is reflected in every part of our lives and affects many sectors day by day. One of the sectors affected and benefited by technology is the health sector. Quality and accessible healthcare services are important for healthy individuals and a healthy society. Today, with digital health applications and digitalization of hospitals, more effective and accessible health services are provided.

Digital hospitals are internationally graded by HIMSS according to EMRAM criteria. Hospitals that comply with these criteria are given HIMSS certification. HIMSS 6 stage and HIMSS 7 stage hospitals are accepted as digital hospitals. Gazi Mustafa Kemal Hospital was the first hospital in Türkiye to receive HIMSS 6 stage digital hospital certificate in 2013. Afterward, the number of digital hospitals has increased gradually with the importance given by Türkiye to digitalization in the health sector. As of September, 2023, Türkiye have 57 HIMSS 6 stage hospitals and 7 HIMSS 7 stage hospitals by HIMSS EMRAM criteria. On the other hand, there are 18 HIMSS 6 stage and 3 HIMSS 7 stage health centers by HIMSS O-EMRAM criteria [1].

Currently, with these data, Türkiye is in a good position globally in terms of the number of digital hospitals. Although Türkiye is in a good position on a global scale in terms of the number of digital hospitals, awareness of the concept of digital hospitals is not at the desired level. It is seen that quantitative studies on digital hospitals on a national and international scale are quite limited. When the studies in the literature are examined, it is seen that there are more qualitative studies or studies conducted with observational data on hospital basis. Despite the fact that there are many efficiency analysis studies conducted in hospitals in the health sector, it is seen that efficiency analysis techniques have not been adapted to digital hospitals. In particular, there are many studies in the literature on data envelopment analysis, which is frequently used in efficiency analysis, but none of these studies has been conducted for digital hospitals. For this reason, based on the efficiency in the literature, a study on "Efficiency Analysis in Digital Hospitals" is carried out in order to increase the number of scientific studies on digital hospitals and to analyze the efficiency of digital hospitals with DEA technique.

As a result of the research on digital hospitals, it is realized that there are differences in practice between HIMSS 6 and HIMSS 7 stages, which are accepted as digital hospitals. While there is a "zero paper" usage criterion in HIMSS 7 stage hospitals, this criterion is not included in HIMSS 6. Therefore, it is thought that the stationery expenses of HIMSS 6 stage hospitals should be higher compared to HIMSS 7 stage hospitals. Based on this, it is expected that the efficiency of HIMSS 7 stage hospitals will be higher than HIMSS 6 stage hospitals on the basis of stationery expenses. Therefore, the study aims to analyze the efficiency of HIMSS 6 and HIMSS 7 stage hospitals on the basis of stationery expenses using DEA technique.

For this aim, 4 HIMSS 7 and 16 HIMSS 6 stage digital hospitals are selected as a sample by considering certain criteria. The inputs and outputs used in the DEA technique applied to traditional hospitals have been examined in the literature. In this direction, the data for 2021 for a total of 20 digital hospitals selected as the sample is obtained from the MoH General Directorate of Public Hospitals. Stationery cost, number of hospital beds, number of specialists/dentists, and number of nurses/midwives, were identified as inputs and number of impatiens, number of outpatients, number of surgeries are identified as outputs.

Using these data in various combinations, a total of eight scenarios, three of which are sub-scenarios, are constructed. Since the aim of the study is to measure the efficiency of digital hospitals on the basis of stationery expenses, "stationery expenses" are included as an input in all scenarios. In all eight scenarios, all outputs are included in the analysis, but inputs are included in different combinations, thus eight different scenarios are generated.

In the scenarios, the efficiency of the sample hospitals is measured using "Basic DEA" and "Cost Efficiency" analyses. BCC and CCR models are used in all scenarios and the results are compared. While "Basic DEA" is analyzed as input and output oriented, "Cost Efficiency" analysis is designed as input oriented since it can only be analyzed as input oriented. Technical efficiency score and scale efficiency score are calculated under "Basic DEA"; technical efficiency score, cost efficiency score and allocation efficiency score are calculated under "Cost Efficiency" analysis. In "Basic DEA", variables are included in the analysis as inputs or outputs. In the "Cost Efficiency" analysis, stationery expense is included as a cost variable and other variables are included in the analysis as input or output variables.

When the DEA results are evaluated;

- As the main and most important finding of this study, when the efficiency scores calculated on the basis of stationery expenses in all scenarios are analyzed, it is seen that the average efficiency score of HIMSS 7 stage hospitals is higher than HIMSS 6 stage hospitals. Therefore, it is revealed that the "zero paper" criterion has a positive impact on the efficiency scores on the basis of stationery expenses in HIMSS 7 stage hospitals.
- Although there is no zero paper criterion in HIMSS 6 stage hospitals, it has been observed that some HIMSS 6 stage hospitals have an efficiency score of 1,000 or close to 1,000. Therefore, the study reveals that some HIMSS 6 stage hospitals are also operated fully efficiently or close to fully efficiently.
- It is observed that the efficiency scores of hospitals vary for each scenario and the models used in each scenario. For example, a hospital may be more efficient in Scenario 1 and less efficient in Scenario 2. Therefore, hospital efficiencies may vary according to the inputs used in the scenarios. However,

since this variability is different on the basis of each hospital, it is not possible to relate it to a standardized result.

- Looking at the average efficiency values on the basis of HIMSS 6 and HIMSS 7; it is seen that the efficiency scores are lower in the scenario where the number of specialist is used as the input in the "Basic DEA" compared to the other scenarios. This is the same for both HIMSS 7 and HIMSS 6 stage hospitals. However, when the average values of the "Cost Efficiency" analysis are observed, the efficiency score is the lowest in the scenario where the number of beds is used as an input in HIMSS 7 while the efficiency score is the lowest in the scenario where the number of specialist is used as an input in HIMSS 6.
- The efficiency scores calculated under the assumption of variable returns to scale (BCC) are higher than the efficiency scores calculated under the assumption of constant returns to scale (CCR). As a matter of fact, in the chapter on DEA, it is stated that the analyses under the BCC assumption are higher than under the CCR assumption.
- In "Basic DEA", it is observed that the efficiency scores calculated under the assumption of constant returns to scale are equal for input-oriented and output-oriented efficiency scores. Therefore, under the assumption of constant returns to scale, conducting the analysis either input-oriented or output-oriented doesn’t cause any change in the results. However, under the assumption of variable returns to scale, in some scenarios the input-oriented efficiency score is higher, while in others the output-oriented efficiency score is higher.
- In the "Cost Efficiency" analysis, stationery expense is accepted as a cost variable, and both technical efficiency score and cost efficiency score are calculated under this analysis. When the results are observed, it is seen that under the "Cost Efficiency" analysis, the technical efficiency and cost-efficiency scores are equal when the stationery expense is accepted as the cost variable. Therefore, the allocative efficiency score is calculated as 1,000 in all scenarios.
- When the average efficiency results of "Basic DEA" and "Cost Efficiency" analyses are compared, it is seen that “Basic DEA” results are higher. In the Cost Efficiency analysis, the stationery expense was included in the analysis

as a cost variable, whereas in the Basic DEA analysis, the stationery expense is included in the analysis as an input variable. Therefore, including stationery expense as a cost variable in the analysis has reduced the efficiency scores.

After implementation of DEA, the efficiency scores are analyzed statistically to test whether there is a significant difference or not. The data calculated on a scenario basis are analyzed under three different hypotheses. The efficiency scores of all scenarios are tested under these three hypotheses.

In these hypotheses, it is tested whether there is a significant difference in the efficiency scores of the digital hospitals selected as a sample, calculated on the basis of stationery cost; in terms of HIMSS 7 and HIMSS 6 stages; in terms of hospital roles (A1, A2, and B); and in terms of number of hospital beds (under 500 beds and over 500 beds).

Since there are two variable groups in Hypothesis 1 and Hypothesis 3, the Independent T-test is used in Hypothesis 1 and Hypothesis 3; since there are three variable groups in Hypothesis 2, the ANOVA test is used in Hypothesis 2.

As a result of the tests,

- In the Hypothesis 1, the mean value of HIMSS 7 stage hospitals for all scenarios is higher than the mean value of HIMSS 6 stage hospitals. However, there is no significant difference between HIMSS 6 and HIMSS 7 stages according to the significant test. This is because some HIMSS 6 stage hospitals also have high efficiency scores. Due to the success of some HIMSS 6 stage hospitals in terms of stationery expenses, no significant difference is observed between HIMSS 6 and HIMSS 7 stages.
- No significant difference is observed in Hypothesis 2 and Hypothesis 3. Contrary to Hypothesis 1, no significant difference is observed in terms of the mean value. Therefore, it is concluded that hospital roles and number of beds don’t cause a significant difference in the efficiency of digital hospitals in terms of stationery costs.

The overall findings and conclusions that emerged as a result of the efficiency analysis with DEA and hypothesis tests conducted in the study are listed below.

- In the study, unlike HIMSS 6 stage hospitals, HIMSS 7 stage hospitals have a zero paper use criteria and therefore, it is measured whether there is a difference in efficiency on the basis of stationery expenses for HIMSS 6 and HIMSS 7 stage hospitals in this study. As a result of the DEA technique and hypothesis tests, it is concluded that the average efficiency of HIMSS 7 stage hospitals is higher compared to HIMSS 6. Therefore, the “zero paper” criteria provide an efficiency increase to HIMSS 7 stage hospitals on the basis of stationery expenses. However, it is observed that some HIMSS 6 stage hospitals also has high efficiency scores in terms of stationery costs. Due to the success of some HIMSS 6 stage hospitals in terms of stationery expenses, no significant difference is observed between HIMSS 6 and HIMSS 7 stages. In conclusion, the fact that the average efficiency score of HIMSS 7 stage hospitals is higher than HIMSS 6 reveals that the "zero paper" criteria applied in HIMSS 7 stage hospitals reduces stationery costs.
- When the efficiency scores are evaluated, it is observed that except for some hospitals, HIMSS 6 and HIMSS 7 stage hospitals generally have high efficiency scores. Yet, hospitals with low efficiency scores are also observed. For hospitals with low efficiency scores to achieve high efficiency, they need to either produce higher outputs with the existing inputs or achieve the same outputs by reducing the existing inputs. Which option should be chosen varies for each hospital and scenario.
- Hospitals that want to increase their efficiency can set some targets by taking into account the results of the efficiency analysis conducted with existing inputs and outputs. Targeting higher outputs with existing inputs rather than reducing existing inputs will increase the efficiency of hospitals. Because none of the hospitals want to reduce their inputs. For example, none of the hospitals will prefer to reduce the number of health personnel or bed capacity.

Considering the limitations of the study, suggestions for future studies are presented below.

- Because of the beginning date of the study, 2021 year data is used in the study. Therefore, since the digital hospitals in 2021 are included in the study, the number of HIMSS 7 stage digital hospitals selected as a sample is unfortunately limited. However, as of 2023, the number of HIMSS 7 stage digital hospitals has reached to 7 in Türkiye. Therefore, for future studies, it is recommended to include more HIMSS 7 stage hospitals as a sample and make observations.

- As another suggestion for further studies, it is thought that it would be useful to compare the efficiencies calculated on the basis of different years. However, for year-based efficiency comparison, having at least a three-year HIMSS history of the sample hospitals will contribute to the feasibility and reliability of the study.
- The study is carried out on the cost axis by considering the stationery expense data. However, the inclusion of different cost variables such as medication, consumables, etc. other than stationery expenses as a cost element, or the inclusion of data that can measure the duration of health service delivery as input and output to reveal the optimization provided by digital hospitals on time basis will contribute to the literature in terms of the width of the study.
- The study is conducted using the DEAP 2.0 program with the DEA technique, but expanding the study with different data analysis methods other than DEA will contribute to the diversity and reliability of the study.
- Conducting the study at a higher level with various heuristic algorithms widely used in the field of Industrial Engineering will play an important role in the diversity of the literature.

Finally, when digital hospital practices are examined, it is obvious that digital hospitals bring great innovations and benefits to the health sector. When the digital hospital studies in the literature are reviewed, it is seen that digital hospitals provide benefits in terms of cost and time saving and reduce mistakes and gaps in treatments. Therefore, it is thought that the number of qualitative and quantitative studies on digital hospitals should be increased. As a conclusion, it is one of the requirements of the digital age that more digital hospital studies using various techniques and various data should be included in the literature.

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