Applying Data Envelopment Analysis to Improve Performance of Emergency Departments in Iranian Hospital: A Case Study

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ABSTRACT

One of the most important parts of the health system in each society is hospitals. It should not be forgotten that the emergency room of a hospital is the first point of entry for patients and their companions with the medical system, and one of the problems that often affect the performance of the emergency department is the length of time patients wait in the emergency room. This dissertation has been conducted with the aim of reducing the average waiting time of patients in the emergency department, improving the efficiency of nurses, and increasing the performance of the emergency department. The case study was “Razi Hospital” located in Ahwaz, Iran. It is a general hospital wich at present, with an area of 7,971 square meters, medical services including general surgery, orthopedics 1 and 2, internal medicine, infectious diseases, obstetrics, neonatology, CCU, ICU, emergency department, operating room, physiotherapy, radiology, laboratory, dialysis, echocardiography and specialized clinics visit patients.

The data were prepared from the emergency department of the hospital for 12 months in 2018, 2019, and 2020. Data analysis obtained in this study is performed using PIM-DEA software based on the CCR model as a method that is one of the techniques of data envelopment analysis. According to the results, the most important priority is the number of patients with CPR procedures. With this in mind, we can focus on accepting patients with CPR in order to increase the level of emergency function. The next most important factor is the average time the patient leaves the hospital. According to the hospital experts, the time of the patient's discharge from the hospital is a very important indicator, because according to the capacity of the hospital and the number of staff, the lower the average time of the patient's discharge from the emergency room, the better

the emergency performance.

Keywords: Cardiopulmonary Resuscitation as CPR, CCR Model, Data Envelopment Analysis as DEA, Emergency Department

ÖZ

Her toplumda sağlık sisteminin en önemli parçalarından biri hastanelerdir. Unutulmamalıdır ki, bir hastanenin acil odası, hastalar ve refakatçileri için tıbbi sisteme ilk giriş noktasıdır ve acil servisin performansını sıklıkla etkileyen sorunlardan biri de hastaların bekleme sürelerinin uzunluğudur. acil servis. Bu tez, acil serviste hastaların ortalama bekleme sürelerinin kısaltılması, hemşirelerin verimliliğinin artırılması ve acil servisin performansının artırılması amacıyla yapılmıştır. Örnek olay İran'ın Ahvaz kentinde bulunan "Razi Hastanesi" idi. Şu anda 7,971 metrekare alana sahip, genel cerrahi, ortopedi 1 ve 2 dahil tıbbi hizmetler, dahiliye, enfeksiyon hastalıkları, obstetrik, neonatoloji, CCU, YBÜ, acil servis, ameliyathane, fizyoterapi, radyoloji, laboratuvar, diyaliz, ekokardiyografi ve özel klinikler hastaları ziyaret eder.

Veriler 2018, 2019 ve 2020 yıllarında hastanenin acil servisinden 12 ay süreyle hazırlanmıştır. Bu çalışmada elde edilen veri analizi, aşağıdaki tekniklerden biri olan CCR modeline dayalı olarak PIM-DEA yazılımı kullanılarak yapılmıştır. veri zarflama analizi. Sonuçlara göre en önemli öncelik CPR işlemi uygulanan hasta sayısıdır. Bunu akılda tutarak, acil durum işlevinin seviyesini artırmak için CPR'li hastaları kabul etmeye odaklanabiliriz. Bir sonraki en önemli faktör, hastanın hastaneden ortalama ayrılma süresidir. Hastane uzmanlarına göre hastanın hastaneden taburcu süresi çok önemli bir göstergedir çünkü hastanenin kapasitesi ve personel sayısına göre hastanın acil servisten ortalama taburcu olma süresi ne kadar düşükse acil durum performansını iyileştirir.

Anahtar Kelimeler: CPR Olarak Kardiyopulmoner Resüsitasyon, CCR Modeli, DEA olarak Veri Zarflama Analizi, Acil Servis

DEDICATION

I dedicate my dissertation work to my family and encouraging friends. A special gratitude to my loving parents, whose encouragement and support lead to my promotion in personal educational journey.

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Chapter 1

INTRODUCTION

In this section, we will discuss the research issue and give a brief description of the problems in the emergency department of the hospital, and then we will provide an explanation for controlling these problems, introduce the research method, and finally discuss the structure of the dissertation.

1.1 Problem Description

Therapeutic care is a complex configuration that includes primary, secondary, and post-operative care (Al-Refai & et al, 2014), and the hospital is one of the most important organizations in this field, the most crowded of which is the emergency department. It is considered as the most vital element in the treatment system (Amral and Costa 2014; Kholghabad & et al, 2019).

The emergency department is a unit of the hospital that works 24 hours a day, 365 days a year to quickly treat all emergency, semi-emergency, and non-emergency patients (Gull and Guttierez, 2015). The hospital emergency department only treats It does not provide emergency care. This department receives up to 30 million critically ill outpatients in the country on a 24-hour basis each year and provides immediate medical care for them (Baratloo & et al, 2015).

Overcrowding in hospital emergencies is a global issue that has become a major concern due to the increasing number of patients, dealing with overly complex cases and the limited resources available to hospitals, and can provide emergency services to patients. Delay (Koo & et al, 2018). Besides, due to the overcrowding of patients, the emergency department is far more tolerant than other components of the healthcare system and this pressure limits the medical staff's communication with the patient (Bartlow). Et al., 2015) and increase the probability of error by system components. It has also challenged issues such as increasing patient waiting time, excessive patient inflows, budget constraints, and increasing demand for high-quality services for the flow of work and the flow of patients in the emergency department of hospitals (Elalouf & Wachtel, 2015).

Prolongation is one of the major problems of all institutions in the treatment system. Optimizing patient flow and eliminating bottlenecks in the emergency room can be a solution to reduce treatment costs and increase treatment quality (Al-Rafiei et al., 2014).

Given the above, the focus of this study is on reducing patients 'waiting times and identifying sources that affect patients' waiting times. For this purpose, data envelopment analysis has been used to evaluate resources affecting patients' waiting time.

The aims of this study are as follows:

1. Evaluating the performance of the hospital emergency department;
2. Determining the best performance period as a benchmark;
3. Defining the suitable input and output for the current situation of the hospital emergency department;
4. Identifying more significant input and output;

5. Suggesting input and output for preserving efficiency performance.

1.2 Control Description

The approach of optimal allocation of available resources is an issue that has always been considered. This discussion is quite noticeable in all areas of production and services because human beings have no choice but to make the best use of available facilities to achieve greater production and higher quality to create better living conditions. In this regard, all organizations need an evaluation system to measure the performance of their sub-groups to measure the efficiency of controlled units, because measuring performance in today's competitive world as a strategy-based philosophy and perspective. Improving the first letter is also one of the most important ways to identify the strengths and weaknesses of the units in question, which ultimately allows the managers of the units to take steps to improve the strengths and weaknesses.

Recently, researchers in the field of treatment are evaluating their scientific research using data envelopment analysis. By focusing on bottlenecks and resource change, the research seeks to improve the quality of treatment and patient flow in the emergency room. Influence employees to analyze "what if", to determine the desired system settings and to examine the relationships between variables, resources, and operational changes (Zheng, Mae Ho, Lee, & Bryant, 2012).

1.3 Methodology Description

In this study, the DEA method has been used to evaluate the performance of the hospital emergency department. DEA is an efficient optimization method that has been proposed with several responses to improve process product performance. DEA is a linear planning method for measuring the efficiency of several decision-making units process (Al-Rafei et al., 2014; Yazdi et al., 2018).

Chartres, Cooper, and Rhodes (1978) introduced the definition of performance ratio by defining the CCR ratio, which can define the classical scientific-engineering ratio of single output to a single input to multiple inputs and outputs without the need for pre-allocated weights. Generalized (Butker, Charles, and Cooper, 1984). Data envelopment analysis evaluates the relative efficiency of decision-making units.

1.4 Structure of the Thesis

In the second chapter, we present the national indicators of the Iranian emergency department that were examined in this study, as well as the study of past studies on patients' waiting times in emergencies and minimizing this waiting time for patients and the method of data envelopment analysis in the second chapter. Placed. In the third chapter, we examine the research method. This chapter examines the input-axis and output-axis views in solving CCR models, which is one of the techniques in data envelopment analysis and has been solved using PIM-DEA software. We pay. Chapter 4 includes research findings. The results obtained using PIM-DEA software are presented in this chapter. In Chapter Five, we will analyze the results obtained in Chapter 4, which is the analysis of research data and discuss the meaning of the findings of Chapter 4. Finally, in the sixth chapter, we present the results of this research, and also in the most important part of this chapter, we provide practical suggestions for hospitals as well as research suggestions for future studies. After the sixth chapter, the references used in this research are stated and in the end, the contents of the appendices, which include the raw tables of software data, are presented. Figure 1.1 summarizes the general structure of the dissertation below:

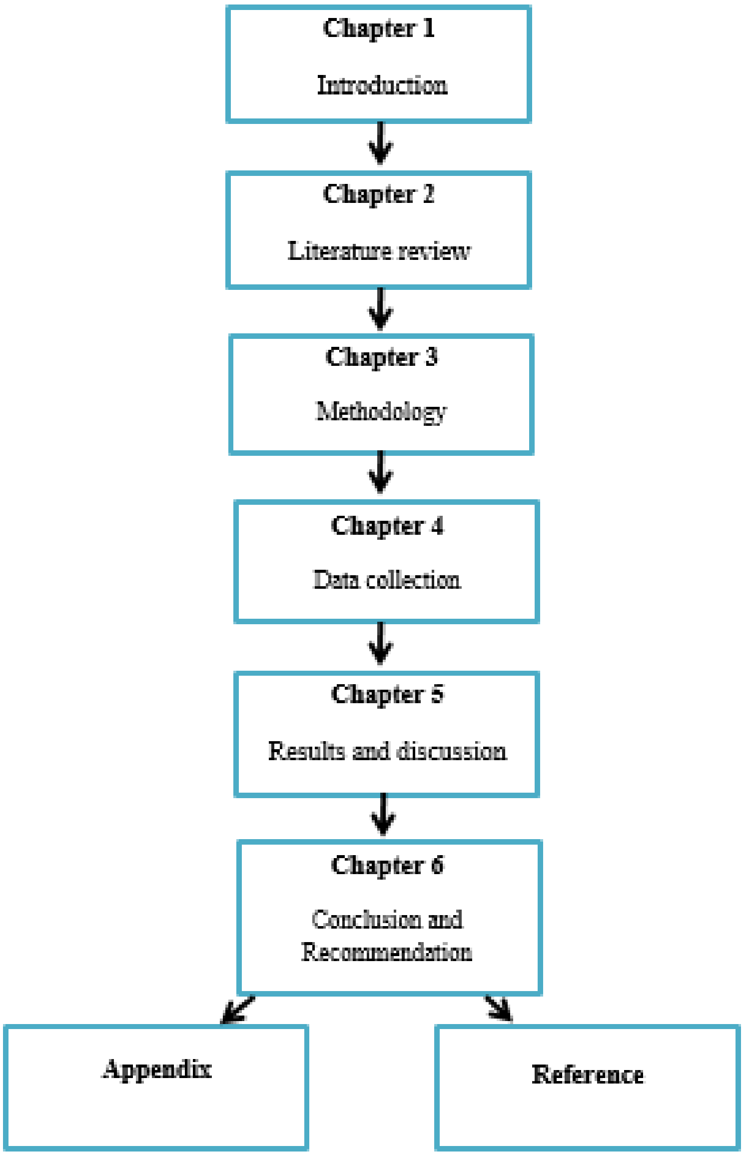

Figure 1: Structure of the Thesis

Chapter 2

LITERATURE REVIEW

The hospital is the most important provider of health care services, providing prevention services, early detection, timely treatment, and rehabilitation of clients. Proper performance of the hospital plays an important role in improving and returning patients to the community, as the slightest mistake in managing it will lead to severe consequences and problems. As the entrance to the hospital, the emergency department receives about 30 million patients each year. This section has been introduced as the heart of the health care system and improving the situation and organizing it has become the most important priority of the Ministry of Health.

2.1 National Hospital Emergency Department Indicators

Indicators are defined in the definition of the chart, source, and base, and are a valuable tool, a desired fixed quantity that describes a statistical community or is fixed in a set of certain conditions and changed in other conditions. Indicators determine the direction of organizations to achieve their goals (Soraia Oueida et al, 2020).

To measure the performance of the hospital, including the emergency department, it is necessary to adjust the performance indicators after reviewing the mission, macro goals, and strategy of the hospital emergency unit. Hospital indicators are the most important functional indicators of the hospital in various fields. Therefore, comprehensive attention to these indicators is necessary because by looking at the status of hospital indicators, the performance of the hospital is clarified and with more reflection on these indicators, its strengths and weaknesses are revealed, as well as indicators related to the emergency department. It also shows the performance of this section in various fields (Soraia Oueida et al, 2020).

The number of health indicators is very high, but a small number of them are measured correctly. Therefore, it is necessary to first identify and measure the priority indicators, which we will examine below.

2.1.1 Definitions and Concepts

Time Period: The time period used in the definition of indicators is a shift, a day and night (24 hours), a month, three months, etc., and is different for different indicators (Vahidi et al, 2013).

Time Measurement Basis: The start and end time measurements are different in different time periods. So that for a period of one shift, the hours are the beginning and the end of the shift, and for the period of the day and night, the time is zero in the morning until midnight on the same day (Vahidi et al, 2013).

Indicator Collector: refers to the person who collects the data related to the indicators from the mentioned sources and calculates the indicators for different time periods. This person is one of the employees of the emergency department at the discretion of the head of the emergency department and it is necessary to be trained in checking the registration and correct collection of data (Jan Babaei et al, 2008).

Education Officer: The person in charge of educating the people who collect the data in the emergency department and calculate the index is the expert in charge of the hospital emergency department at the university along with an expert in the medical statistics department of the hospital (Jan Babaei et al, 2008).

Index Collection Alternation: Collective periodicity is the time when the necessary data are collected to calculate the index. This frequency depends on several factors, including the type of indicator. These are the turns:

1- In shifts

2- Daily and 24 hours

3- On a monthly basis

4- months (seasonal).

CPR Successful Adults: The patient should have a blood circulation within 20 minutes after resuscitation. Lung cardiopulmonary resuscitation for a patient in short and frequent periods of time is ultimately one case, but if the time interval is more than eight hours, it will be considered in the calculation of the index of two cases (Dixon A, Ham C., 2012).

Trauma: Trauma is any type of trauma, injury, shock, injury, or accident that occurs on the human body, provided that it enters the body from the outside and the internal factor or disease in the body is not the cause of the injury (Dixon A, Ham C., 2012).

Defining Patients Without Vital Symptoms Before Hospitalization: Patients who are brought to the hospital emergency room by personal or non-emergency care system and do not have vital signs such as heart rate and respiration when entering the hospital.

2.1.2 The Percentage of Patients Assigned to the Task within 6 Hours

This index is the ratio of patients admitted to the emergency department and assigned within 6 hours to the total number of patients admitted to the emergency department in a given period.

A hospitalized patient is a patient who, after triage or initial visit by a physician, forms an emergency hospitalization file and needs to stay in the emergency room for diagnostic and therapeutic procedures. In other words, all patients are hospitalized except for those who are discharged immediately or without a prescription immediately after the initial visit (Guidotti TL, 2012).

The purpose of determining the patient's assignment is to determine the patient's condition by the emergency physician as follows:

- Order for discharge from the emergency department after the necessary diagnostic and therapeutic action by the emergency physician;
- The order of definitive transfer of the patient to a specific medical service for hospitalization by the emergency physician - The order to be sent to other hospitals by the emergency physician;
- Death.

The basis of the time at the beginning of the index (assignment) is the time of the first doctor's order, which is the issuance of the hospital order. This order is entered by the doctor in the form of triage or patient booklet and must be extracted from the patient's file. Recorded, which can be extracted from the patient's file (Jan Babaei et al, 2008).

Patients who have been admitted to the emergency department and are assigned within 6 hours are the number of patients who have referred to the emergency department over a period of time and have been diagnosed with a type of referral. 6 hours with less in the emergency department (Guidotti TL, 2012).

The total number of patients admitted to the emergency department in a given period is the total number of patients who have referred to the hospital emergency department during a period of time and have filed an emergency hospital admission file. These patients include levels 1, 2, 3 triage, and atherosclerotic levels that require an invasive procedure. Obviously, outpatients and people with personal responsibility are not included in this statistic (face and denominator of the index formula) (Guidotti TL, 2012).

Since that when calculating the assignment index below 6 hours, it is necessary to write down the time of hospitalization and discharge order to differentiate the number of patients who are assigned under 6 hours and over 6 hours, so with The use of recorded time data needs to be calculated and reported from now on the meantime and meantime of patient assignment (Jan Babaei et al, 2008).

To calculate the average time of assignment of patients, it is necessary to determine the time of assignment (order to be discharged from the emergency department, the order of definitive transfer of the patient to a specific medical service, order to be sent to other hospitals and death). It is deducted and finally, with the calculated times of other patients, it is collected in a certain period of time and divided by the total number of emergency hospitalized patients in the same specified period of time to obtain the average time of determining the total task of hospitalized patients. The midpoint is the point where half of the distribution of homework assignment times for all inpatients is within a certain time frame and the other half is at the bottom. First, we sort the computed time assignments for patients from small to large, if the number If the numbers are individual, the mean is a number that is in the middle, and if the calculated times are the assignment of the couple's patients, the mean is the average of the two numbers that are in the middle (Jan Babaei et al, 2008).

2.1.3 The Percentage of Hospitalized Patients Discharged from the Emergency Room within 12 Hours

Definition of the index refers to the ratio of hospitalization to an emergency, which within 12 hours from the time of the first doctor's order (order) in addition to determining the task by the emergency physician, have been physically removed from the emergency department to all patients referred to an emergency hospital in a certain period of time (Heydaranlou E. et al, 2018).

The purpose of leaving patients is to physically leave the emergency department for any reason other than personal consent and to leave without notice. These patients include people who are:

1- In the group of patients, emergency clients are diagnosed as outpatients and hospitalized;

2- Within less than 12 hours, the necessary medical procedures have been performed for them;

3- The emergency physician has determined the task and the order for discharge from the emergency department has been recorded in his file;

4- They have left the emergency room physician, that is, they have gone home or have been transferred to one of the wards of the same hospital or have been sent to another hospital.

Obviously, in order not to distort the information, cases of personal satisfaction and leaving without information should be removed from this statistic. The number of hospitalized patients assigned out of the emergency department under 12 hours in a period of time is, in fact, the number of patients who referred to the emergency department during a period of time and in terms of the type of referral, the hospital was diagnosed and within 12 hours or less. Out of the emergency department, multiplied by 100 according to the definition of emergency patients) (Heydaranlou E. et al, 2018).

The total number of patients admitted to the emergency room during the same period of time means the total number of hospitalized patients who have referred to the hospital emergency department over a period of time. Important Note: The difference between this index and the previous index is that the first indicator is related to determining the patient's assignment and the patient's discharge order from the ward by the emergency physician, and the second indicator is related to the patient's physical exit from the emergency department. Leaving with personal responsibility is not included in these statistics (face and denominator of the index formula) (Jan Babaei et al, 2008).

Since that when calculating the index of hospitalized patients discharged from the emergency room within 12 hours, it is necessary to write down the times of the first doctor's order and the patient's physical exit from the emergency department.

Separated from the emergency, so using the recorded time data, it is necessary to calculate and report the average time and timeout of patients discharged from the emergency room (Jan Babaei et al, 2008).

To calculate the average time of discharge of patients hospitalized from the emergency room, it is necessary to deduct the time of physical withdrawal of the patient from the emergency department for each patient hospitalized by the doctor from the time of the first doctor's order and finally with the calculated times of other patients in a certain period The sum of the total number of hospitalized patients is divided in the same specific time period to obtain the average time of withdrawal of hospitalized patients from the emergency room to the total number of hospitalized patients (Jan Babaei et al, 2008).

The midpoint is the point at which half of the distribution time of the emergency exit of all patients admitted to the emergency room is at the top and the other half is at the bottom. First, the calculated time of the emergency evacuation of patients from small to large We arrange that if the number of numbers is one, the average is normal, which is in the middle, and if the calculated time is the exit of patients admitted from the couple's emergency, the average is two times when it is in the middle (Jan Babaei et al, 2008).

2.1.4 Successful CPR Percentage Index

The definition of an index indicates the ratio of successful CPR in an emergency to total CPR performed over a period of time. Successful CPR Definition Successful CPR refers to CPRs after which the patient has spontaneous blood circulation and does not need to be resuscitated for at least 20 minutes. Found spontaneously and did not require CPR, is a successful CPR (American Heart Association Guidelines, 2006).

The number of successful CPR cases in the emergency room over a period of time is the number of cardiopulmonary resuscitation (CPR) cases that have finally been successful (ie, the blood circulation has been spontaneous for 20 minutes after resuscitation). The total number of CPR cases in the emergency room at the same time means the total number of CPR pulmonary resuscitation cases over a given period (American Heart Association Guidelines, 2006).

Important Note: In emergencies where an emergency medicine specialist works, the resuscitation team is responsible for the resuscitation team, and the resuscitation team is led by the emergency medicine specialist. In other emergencies, the coding system is the same as before, and the anesthesiologist is in charge of the resuscitation team. The source of data collection is the CPR offices and forms communicated by the Ministry of Health and Medical Education is This indicator should be calculated 24 hours a day (according to the start and end hours of the day, zero in the morning until 24 hours) and its report should be checked daily by the head nurse and emergency physician. Either it is calculated monthly (according to the beginning and end of the month, zero bandwidth on the first day of the month until 24:00 on the last day of the month) and its report is reviewed every month by the head of the hospital and the university. (According to the beginning and end of the season, zero in the morning on the first day of the season until 24:00 on the last day of the season) should be calculated and its report should be reviewed at the end of each season by the hospital emergency department of the Ministry of Health (Goroll AH, Mulley AG, 2012).

2.1.5 Index of Patients Leaving the Emergency Room with Personal Responsibility

The ratio of the number of hospitalized patients who have left the emergency department with personal responsibility and despite the doctor's advice refers to the total number of hospitalized patients Nordstrom, Zun, Wilson, Stiebel, Ng, Bregman, & Anderson, 2012).

A Turkish person with personal liability is a patient who refuses to continue treatment by a medical team despite a doctor's recommendation and signs a personal liability leave form (former personal consent form) to be removed from the emergency room. The number of cases left with personal responsibility from the emergency department in a period of time is the number of patients who have referred to the emergency department during a period of time and has been diagnosed in terms of hospital referral and need to file an emergency hospital file. The medical staff refused to continue the treatment and for various reasons demanded to leave the emergency room and signed a personal liability leave a form to remove the responsibility from the hospital (Nordstrom K. et al, 2012).

Obviously, outpatients whose only document is a triage sheet are not included in this statistic (should be analyzed focally in the emergency department) and patients who refuse treatment but do not leave the hospital are not included in this statistic (Jan Babaei et al, 2008).

Important Note: It is important to avoid writing the word "sick" when leaving with personal responsibility in the patient's file. He fills in the blanks with personal responsibility and is therefore not discharged by the doctor (Jan Babaei et al, 2008).

The total number of patients admitted to the emergency room means the total number of hospitalized patients who have referred to the hospital emergency department during a given period. The source of data collection is the patient's file, and if there is an office in the emergency room where the cases of leaving are recorded with personal responsibility, the secretary can write down these cases, but of course, all cases must be registered in this office. So that the statistics are reliable and comparable. Of course, to understand the importance of the subject of statistics, it is necessary to provide emergency training and explain the importance of the subject (Jan Babaei et al, 2008).

This index should :

- Calculate in shifts (according to the hours of the beginning and end of the shift) and its report should be checked daily by the emergency supervisor;
- It should be calculated 24 hours a day (according to the beginning and end hours of the day, zero in the morning until 24 hours) and its report should be reviewed daily by the head nurse and emergency physician;
- It should be calculated monthly (according to the beginning and end of the month of zero in the morning of the first day of the month until 24:00 on the last day of the month) and its report should be reviewed every month by the head of the hospital and university;
- To be calculated quarterly (according to the beginning and end of the season, zero in the morning on the first day of the season until 24:00 on the last day of the season) and its report should be reviewed by the Ministry of Health at the end of each season.

Among the things that should be considered in the analysis and interpretation of data are:

- Cases that have not been hospitalized and for which no cases have been filed yet and leave the emergency room are not included in this index. It is necessary to collect, analyze, and analyze emergency processes separately in each hospital;
- The items that sign the Turkish liability form when going to the subspecialty centre are calculated in this index;
- Classification is not a reason to leave with personal responsibility in the index;
- The difference between different hospitals in terms of educational and non-educational, umbrella and specialization, and referral is very important in data analysis.

The results of the indicators in hospitals with the admission of patients with a particular field orientation will be different from those in general: for example, in centres where most clients are trauma patients with heart disease, it is different (Jan Babaei et al, 2008).

2.1.6 Index of the Average Waiting Time for Patients for the First Visit to the Doctor at Each Level of Triage

Definition of the mean of patient waiting time between primary nursing triage and initial physician visit by triage level based on patient triage level by ESI triage method. These levels will vary depending on the five-level ESI triage method used in each hospital. It is important to note that in an emergency department, there must be an ESI triage system and scientific method of triage. Since that the Ministry of Health and Medical Education has taught ESI triage methods in TOT workshops to all universities in the country, it is necessary to have all the emergency departments that do not use other scientific methods to triage patients. Calculate based on ESI triage levels and send the sections that are used by the specialists at the discretion of the patients for triage, along with the relevant scientific documentation (Casalino, Choquet, Bernard, Debit, Doumenc, Berthoumieu, & Wargon, 2013)

The total waiting time for patients for the first doctor's visit is one ESI triage level. The total waiting time for the first visit of the patient's physician is one ESI triage level (meaning the nurse's triage time until the doctor's first visit and contact with the patient). The total number of patients with the same ESL triage level refers to the total number of patients referring to the same level over a period of time (Casalino E. et al, 2013).

The source of data collection is the patient's file and the triage sheet, and the nurse's training time is determined by the time the nurse fills in the triage sheet and signs it, and the doctor's visit time is determined by the time of the first medical visit in the file. The patient is calculated. The triage sheet must be attached to the file of all patients (Casalino E. et al, 2013).

This index should:

- Calculate in shifts (according to the hours of the beginning and end of the shift) and its report should be checked daily by the emergency supervisor;
- It should be calculated 24 hours a day (according to the beginning and end hours of the day, zero in the morning until 24 hours) and its report should be reviewed daily by the head nurse and emergency physician;
- To be calculated monthly (according to the beginning and end of the month of Safar in the morning of the first day of the month until 24:00 on the last day of

the month) and its report should be reviewed every month by the head of the hospital and university;

- Seasonally (according to the beginning and end of the season, zero or the first day of the season until the last 24 hours of the season) should be calculated and its report should be reviewed by the Ministry of Health at the end of each season (Jan Babaei et al, 2008).

2.2 Data Covering Analysis

DEA is an efficient optimization method that has been proposed with several responses to improve process product performance. DEA is a linear planning method for measuring the efficiency of several decision-making units (DMUs) that provides the process of structural production from multiple inputs and outputs (Al-Rafi'i et al., 2014; Yazdi et al., 2018).

Charens, Cooper, and Rhodes (1978) introduced the definition of performance ratio or CCR ratio definition, which can define the classical scientific-engineering ratio of single output to a single input to multiple inputs and outputs without the need for pre-allocated weights. Generalized (Banker, Charles, and Cooper, 1984). Data envelopment analysis evaluates the relative efficiency of decision-making units but does not allow the ranking of efficient units (Andersen and Petersen, 1993). For this purpose, efficient cloud methods that are specific to ranking should be used.

2.3 Background Research

To measure the productivity and efficiency of economic enterprises, various methods have been presented, which is a general division can be divided into two categories: parametric (SFA border analysis) and non-parametric data envelopment analysis (DEA). The parametric method based on Econometric models and microeconomic theories is based on this method. In this method, using combined data (Panel Data, first the production function (cost) is estimated according to the intended assumptions and considering the mentioned function, the efficiency of the units It is measured, but the data envelopment analysis method is based on a series of optimizations using linear programming. In this method, an efficient boundary curve is created from a series of points determined by linear planning. The advantage of this method is that there is no need to explain the type of production function. Also, production factors and products can have different units of measurement. In the above method, a reference set and index can be specified for each inefficient observation. Inclusive data analysis can examine models with several factors of production and product (Liu, Rexachs, Apple and Luke, 2017).

Recently, researchers in the field of treatment are conducting their scientific research using computer simulation and using simulation as an efficient tool in modelling and improving processes. This focus of research focuses on bottlenecks and changes in resources, seeking to improve the quality of treatment and the flow of patients in the emergency room. Simulation models have been widely used to address the problem of system management efficiency, which is becoming increasingly complex, due to the fact that simulation is safer, cheaper, and faster to run and test. In recent years, the use of computer simulations to help efficient decision-making in health care to improve operations has been on the rise. A simulation model can represent the patient's flow and treatment processes, demonstrate its processes and dynamics under specific random distributions, and provide predictions for measuring performance. It is also a tool that can help manage treatment in evaluating the effectiveness of current practices, analyze "what if" to predict employee impact, perform optimal system settings, and examine the relationships between variables, resources, and operational changes (Zeng, Ma, hu, Lee, and Bryant. 2012).

Deciding on emergency resources is a worrying activity and has a significant impact on the emergency department. Any wrong decision can have serious consequences for the quality of services (Zeinali, Mahutchi, and Sepehri, 2015). Therefore, the decision-maker must properly analyze the system in order to make the best decision for Maine. In order to ensure the availability of quality resources and services, the Ministry of Health in Iran has provided an incentive plan for government emergencies, according to which emergencies are required to provide timely services to patients. Provide that each patient should receive the necessary services and leave the outpatient ward in less than 6 hours (Zeinali et al., 2015). Since more than 10% of emergency department admissions are hospitalized, the quality of service delivery in this department is a symbol of the general condition of hospital services (Bratlow et al., 2015).

Cochran and Rock (2009) presented a paradigm that reduces the urgency of emergency medical care and increases access to emergency care through operational research so that each hospital can use specific elements of hospital data. Zeng and et al. (2012) used computer simulation in the emergency department of a local hospital in Lexington, Kentucky, to improve the quality of health care, which is able to improve the quality of health care in terms of length of stay (LOS), waiting time and missing. Evaluate patients. Also, by analyzing the sensitivity of the workforce and diagnostic equipment, they showed that these cases affect the quality performance of the emergency department. Konrad, R. et al. (2013) improved patient waiting time by using discrete simulation-based on support for process progress in hospital emergencies and using process flow segmentation; Experimental data from a hospital in the United States were then used to validate the model. Based on the results of this sample study, it was found that the waiting time in 70 defined scenarios has significantly improved. Mielczarek (2014) examined the impact of projected demand on the workload of the emergency unit next year and provided a method for estimating the expected volume of hospital emergency services. It also developed a discrete simulation model to improve reliable predictions of performance components, based on elements identified by the Polish National Health Fund (NFZ) for emergencies.

Amaral and Costa (2014) used a multi-criteria decision-making technique (MCDA) called Promethee I to support decision making and emergency management. They also used experimental data from a Brazilian public hospital to validate it. The results showed that six months after the implementation of the best-case scenario implemented by the Promethee II method, the waiting time was reduced by about 70%. Al-Refaie et al(2014) used simulation in the hospital emergency room to reduce the average waiting time for patients, improve the use of nurses, and increase the number of patients served. Benefited. They also offered a cellular service system for nurses. Gul, M., and Guneri, A (2015) reviewed articles presented in recent years in the field of hospital emergency simulation in both normal and catastrophic situations, and at the end suggested these topics for further research: a) new context and current trend Simulation for system analysis through multiple modelling and ORMS 'methods; B) Pay attention to the cost approach in the emergency room; B) Use innovative methods in data collection to ensure the reliability of the study; D) Focus more on acute and catastrophic situations and early preparation of physical and human resources during the occurrence of Aloof and Watchel (2015).

In order to assess the optimal timing for patients awaiting treatment in the emergency department, they provided an algorithm to empower emergency department decision-makers. This algorithm is an extension of the Karp sequence model used in the simulation model. They first estimated the time of stay in the emergency department with the scenario that the triage decision-maker knows all the patient's information; Considering the real and uncertain situation, they examined the next scenario in which the person in charge of triage based on the patient's characteristics can decide at any time to continue examining the patient or sending it to other parts. Zeinali et al. (2015) decided that it could be used to improve patient flow and reduce congestion by changing the number of resources, as well as to decide on operational, tactical, and strategic levels. In this study, budget constraints and capacity constraints were considered and evaluated and validated. It used data from one of Iran's hospitals, which resulted in a 48% reduction in patients' waiting time. In addition, to measure the efficiency of the selected cloud model, the results were checked in terms of accuracy and expected time with OptQuest software output. In fact, these two researchers have compared the scope of application of Air models to similar ones They broke up the hospital emergency room.

Al-Refaie, (2014) used Applying simulation and DEA to improve performance of the emergency department in a Jordanian hospital. Simulation Modelling Practice and Theory, 41, 59-72.

Oh et al (2016) used discrete simulation simulations to target that 80% of patients had to leave the hospital emergency room in less than 3 hours while allocating resources optimally. According to the simulation results, 81% of patients left the emergency room in less than 3 hours. Azadeh et al(2016) optimized the emergency department of one of Iran's public hospitals by modelling human errors (a combination of mistakes made by nurses and technicians). They then used a randomized data analysis (SDEA) to evaluate the scenarios set for the simulation model. In Iran, they used integrated simulation, first using Process Analyzer software to define 54 scenario simulation models, then considering these scenarios as the decision-making unit, control variables as inputs and variables. Response as an output used the Super-SBM method to determine the best-case scenario. Liu et al. (2017) used simulation-based optimization to develop a systematic method for automatically calibrating a public emergency model with incomplete data. They also used a sample survey to validate the model. The validation results showed the accuracy of the simulation model with incomplete data. Kuo et al. (2018) used simulation to model patients' operations and flow in the hospital emergency room. Using a fast-tracking system on performance Damat examined the presentation. The results showed that although the system is beneficial for some groups of patients and leads to a high level of responsiveness, it may increase the waiting time for some groups. They used simulation to assess the possible difference in waiting time for different types of patients in the rapid prevention system. The results showed that this system could be useful for all patients in terms of waiting time.

Chapter 3

METHODOLOGY

In this study, we use data envelopment analysis to evaluate the performance of the hospital emergency department. Data envelopment analysis shows the concept of calculating performance levels within a group of organizations that calculates the performance of each unit compared to the number of units that have the most performance. This technique is based on the linear programming approach, the main purpose of which is to compare and measure the efficiency of many similar decision-making units that have different numbers of inputs and outputs. These units can be branches of a bank, schools, hospitals, refineries, power plants, offices covered by a ministry, or similar factories. Comparison and performance measurement also means how well a decision-making unit has used its resources to produce compared to other decision-making units.

The applied parameters in the formulas are as follows:

r_k= Efficiency

m = Number of inputs used in each decision-making units (DMUs)

s = Number of Outputs produced in each Decision making units(DMUs)

u_r = Output weight ($r = 1, 2, 3 \ldots s$)

v_i = Input weight (i = 1, 2, 3….m)

y_{rk} = Amount of output r produced the observed DMU_o

x_{ik} = Amount of input i used by the observed DMU_o

y_{rj} =Amount of output i produced by DMU_j

x_{ij} = Amount of input i used DMU_j

n = Number of decision making units (DMUs)

3.1 Introduction to Data Envelopment Analysis (DEA)

In the field of microeconomics and manufacturing, a company's input and output combinations can be considered as a function. Such a function is sometimes called a "Production Function." To get the most output, you can consider different combinations of input values and variables. In this way, we can achieve technology that can optimize the company or factory.

In 1957, Farrel came up with the original idea for data envelopment analysis (DEA), and later with Abraham Charnes, William Cooper, and Edward. Rhodes (theory) and its calculations were used, and it was possible to use several variables as inputs and outputs in data envelopment analysis (DEA). Due to the simplicity and effectiveness of the analytical method in DEA, this technique is often used to evaluate the performance of production or service units.

As you can see in the image below, the input and output values are measured between several different units, and their ratios of productivity ratios are calculated. In this way, productivity is calculated based on the deficit, the form of which is the output (output) and the denominator is the input (data). Therefore, efficiency or productivity can be considered as the ratio of output to data. Since the amount of data always exceeds the output, efficiency, or productivity will be slightly less than 1. This value is sometimes expressed as a percentage.

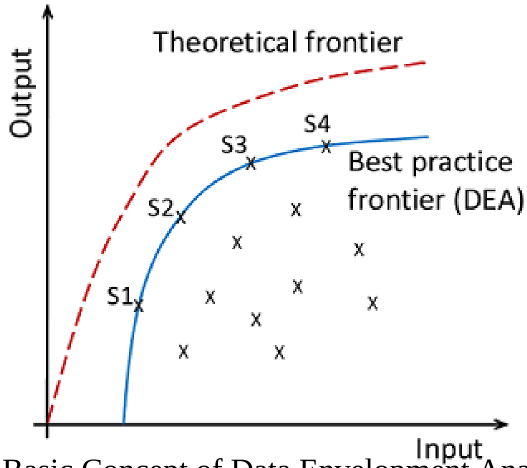

Figure 2: Basic Concept of Data Envelopment Analysis DEA

The DEA is based on linear programming, and its goal is to maximize performance. Therefore, it can be considered in the group of multi-objective (multi-output) linear optimization methods. For example, DEA can be used to compare the performance of Decision Making Units or DMUs in a company. DEA can also be used to measure relative performance between different industries or companies to compare them.

Data envelopment analysis has different types; The most important of these is known as the CCR method, which is derived from the names Charns, Cooper, and Rhodes. The basis of the formation of this model is the definition of efficiency as the ratio of an output to an input. In other words, in the CCR model, to calculate the technical efficiency, instead of using the ratio of one output to one input, the ratio of the total coordinated output (virtual output) to the total harmonized input (virtual input) is used.

To begin this research, we select each of the decision-making units, or DMU, where the months of each year are considered DMU. First, the input and output indicators that express the consumed and output resources are identified and calculated.

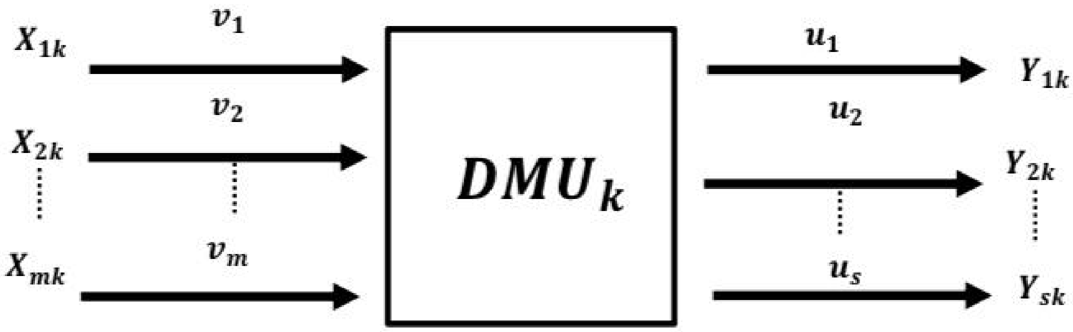

Figure 3: Structure of Decision Making Units

In order to maximize productivity, we must maximize u_i weights and v_j weights as much as possible according to the following formula, but the following conditions must be observed : in formula 3.3 mentioned in appendix.

Based on what has been said and using the raw data collected from the hospital emergency room, we calculate the inputs and outputs, the table of these inputs and outputs for each DMU is shown in the next chapter. The model we use for data envelopment analysis is the CCR model, which we will describe below.

3.2 CCR Model

The CCR model is the first data envelopment analysis model to consist of the initials of its creators (Charnes, Cooper, Rhodes). In this model, in order to determine the highest efficiency ratio and to intervene in the number of inputs and outputs of other decision-making units in determining the optimal weights for the unit under review, the following basic model was proposed in formulas 3.5, 3.6 & 3.7 which are mentioned in appendix.

The above deductible programming model is known as the CCR deductible model, in which: u_r, the weight of the headquarters r; v_i Weighted i; And o, the index of the decision-making unit is under consideration. y_{rj} and x_{ij} are also, respectively, the values of the r-head and the i-institution for the unit under review (unit o). Also, y_{rj} and x_{ij} are, respectively, the values of the r headquarters and the value of the input i for unit j. S, number of headquarters; m, number of inputs; And n also indicates the number of units. Note that the definition of efficiency in the CCR deficit model is "the result of dividing the weighted composition of the headquarters by the weighted composition of the inputs."

Input-axis and output-axis perspectives in solving CCR models. In DEA models, the way to improve inefficient units is to achieve efficiency. The efficiency limit consists of 1 unit of efficiency size 1. In general, there are two ways to improve inefficient units and bring them to efficiency:

A. Reduction of inputs without reduction of headquarters until the arrival of a unit on border work (this attitude is called the nature of performance improvement institutions or performance measurement with input-axis nature).

B. Increasing the number of headquarters until the unit reaches the efficiency limit without attracting more inputs (this attitude is called the nature of performance improvement headquarters or performance measurement with output-axis nature).

These two patterns of performance improvement are shown in Figure 3. As shown in the figure, unit A is inefficient. The improved A1 with input-axis nature (inputs) and A2, the improved version with output-axis (headquarters) nature.

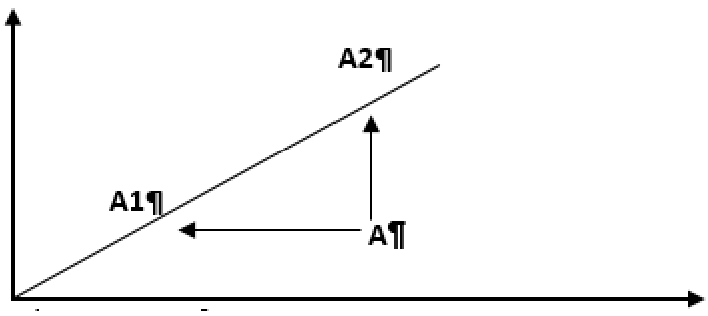

Figure 4: Performance Improvement Pattern

Output-axis view, we are looking for a ratio that the outputs should increase so that the unit reaches the efficiency limit without changing the number of inputs. At the suggestion of Charns and Cooper, by applying $\sum_{i=1}^{m} V_i x_{i\circ} = 1$ constraints to the CCR fractional programming model, this model became the following linear programming model basedon the formula 3.8 which is shown in appendix.

The above performance determination model is known as the Input-Axis CCR Multiple Model (CCR.I). But there is another way to convert a CCR deficit model to a linear programming model. In this method, by applying the constraint $\sum_{r=1}^{s} u_r y_{ro} = 1$, the CCR fractional programming model is converted to the following linear programming model, which indicates the output-axis (CCR.O) multiple CCR model which is based on the 3.11, 3.12 & 3.13 formulas that are shown in appendix.

3.2.1 Ranking Efficient Units

The basic data analytics models do not make it possible to compare efficient units with each other due to the lack of complete ranking between efficient units. In other words, these models divide the units under study into two groups: "efficient units" and "inefficient units." Inefficient units can be ranked by achieving efficiency scores, but efficient units cannot be ranked because they have equal efficiency scores (unit efficiency). Therefore, some researchers have proposed methods for ranking these efficient units, the most famous of which are the AP model and the mutual efficiency method. In the Anderson-Peterson model (AP model), the corresponding limitation with the unit under study is removed from the evaluation. This limitation causes the maximum value of the objective function to be one. By removing this limitation, the efficiency of the unit under review can be more than 1. But sometimes the AP model has a major problem. In other words, by deleting some units, the optimal value of the objective function becomes very large, so that it cannot be scientifically applied in the ranking. Such units have small input or output values, the removal of which leads to model instability.

Another method used to fully rank decision-making units is called mutual efficiency. In data envelopment analysis, the optimal coefficients for outputs and inputs vary from unit to unit, because each time the model is solved for one of the units and allowed to that unit, the best set of optimal weights is considered, given the limitations of the performance of other units. To choose for themselves, so that the ratio of the weight of the outputs to the weight of the inputs is greater. This process is repeated n times and each time for one of the units. Therefore, the weights obtained cannot be compared. It was here that the researchers decided to provide a unique set of weights for all the units being evaluated so that they could rank all the units from the most efficient to the most inefficient. In 1986, Sexton et al. First introduced the reciprocal assessment matrix, which was used in the interaction method.

3.2.2 CCR Provides A Model With an Input and Output Approach

In this section, the goal is to provide a model that, in order to improve the performance of inefficient units, has both the input and output nature of the axis. In other words, the goal is to provide a model that simultaneously suggests reducing inputs and increasing outputs as a way to improve the efficiency of inefficient units. The two conventional approaches of the input-axis and output-axis in the CCR model are derived from the definition of efficiency in the CCR deficit model as "the ratio of the weighted composition of the outputs to the weighted composition of the inputs". However, in the input-output approach in the CCR model, a comparison of the efficiency of the decision-making units from the volume of conversion of multiple inputs to multiple outputs (the difference in weight composition of the inputs of each unit from the weighted combination of the outputs of that unit) is compared. The input-output CCR model of the axis is defined in 3.14and 3.15 formulas that are mentioned in appendix:

In this model, the unit of performance of the unit under study is obtained from the relation $\frac{\sum_{r=1}^{s} u_r y_{ro} - \sum_{i=1}^{m} v_i x_{io}}{m}$, in which: o, the index of the unit of decision under study and the variable m also indicate the maximum value obtained by the difference in weight composition of the outputs minus the weight of the input steps between n units. In other words, it can be stated that the efficiency of the unit under study is equal to formula 3.16 which is mentioned in appendix.

Since the model presented above is nonlinear, arrangements must be made to convert it to a linear programming model. For this purpose, we divide the constraints of this model on the positive variable m on both sides so that the model changes based on 3.17 and 3.18 formulas mentioned in appendix. Now in this new model, we apply two variables, $u'_r = \frac{u_r}{m}$ and $v'_i = \frac{v_i}{m}$.

In this case, the nonlinear CCR.IO programming model will be converted to the CCR.IO linear programming model according to the 3.18 and 3.19 formulas that are shown in the appendix.

Note: According to the two linear and nonlinear CCR.IO programming models, it can be seen that by placing the number 1 instead of the variable m in the CCR.IO nonlinear programming model, the CCR.IO linear programming model can be achieved. In other words, in the CCR.IO nonlinear programming model, it is sufficient to assume that the maximum value of the difference in the weighted composition of the inputs from the weighted combination of the outputs that the decision-making units can take is equal to one. In this case, the value of the objective function also indicates the efficiency of the CCR.IO model. In order to clarify this model, a numerical example has been used in which the efficiency of several decision-making units using the CCR model and according to the three approaches mentioned in this article have been calculated and then compared with each other.

In conventional DEA models, the input-output level of the unit's performance is generally not monitored by the input-output levels of the reference units, while regression analysis (RA) estimates the intermediate level of the dependent variables relative to the independent variables. Some researchers have used DEA and RA in combination as a comparative performance appraisal method, which can be referred for further study. We can also mention the DEARA model, which considers the CCR model and the RA method as two special cases in ideal programming as shown in formulas 3.19, 3.20 and 3.21 that mentioned in appendix.

ρ_j and η_j, respectively, indicate the positive and negative differences between the weighted output of the j unit and the weight input of the j unit. Also, a_j and b_j are weight coefficients. The linear programming model presented in this section, which is a combination of DEA and RA, is called DEARA. In this model, the working size of the unit under study is calculated according to the formula 3.22 and 3.23 mentioned in the appendix.

Conventional data envelopment analysis models use two separate approaches to measure and evaluate the efficiency of the unit under study: reducing the size of the inputs without changing the size of the outputs (input-axis approach) and increasing the output without changing the inputs (input). In this study, a new approach to data envelopment analysis was proposed to evaluate the efficiency of the unit under study, which aims to reduce the size of inputs and at the same time increase the size of outputs (input-output approach).

In this approach, a comparison of the efficiency of the decision-making units from the volume of conversion of multiple inputs to multiple outputs (the difference in the weighted composition of the inputs of each unit from the weighted combination of the outputs of that unit) is made. This approach, in particular, makes more sense for comparing the performance of decision-making units that have inputs and outputs with the same measurement unit.

Chapter 4

DATA COLLECTION

In this chapter, we examine research data, that is, input and output variables. In fact, our study includes three inputs and four outputs. Inputs include: the total number of CPR patients, total number of nurses and doctors, number of triage-level patients 1 to 5, and outputs include: number of successful CPRs, average patient determined situation time, average patient discharge time, waiting time patients at the level of 1 to 5 triage.

4.1 Raw Data Collection

We first went to the hospital to collect raw data for two different years. The hospital provided us with the data related to 1397 and 1398 on a monthly basis, and we collected the initial data as follows. The first case was the total number of patients admitted to the hospital temporarily. In the following, one of the most important issues in the hospital emergency department is determining the patients' homework in 6 hours, and the next case is the number of patients who are assigned in 6 hours. Subsequent data is the total time of assignment of emergency patients in the emergency room. The next important case in the emergency room of the hospital is the withdrawal of patients from the emergency room within 12 hours. The data obtained include the total number of patients admitted to the emergency room and the number of patients discharged from the emergency room within 12 hours. Other data in this section are the total length of hospital stay of patients in the emergency room and the total number of patients admitted to the hospital emergency room. Also the total number of CPR cases in the emergency room, the number of successful CPR cases in the emergency room, the number of CPR cases in a period, the number of CPR cases of trauma patients, the number of successful CPR cases of patients without vital signs before entering the hospital, and the number of internal CPR cases and the number of successful CPR cases. Patients without vital signs were also collected upon arrival at the hospital. In another case, the total number of patients at different levels of 1 to 5 triage and also the waiting time of patients for the first visit to the doctor at different levels of 1 to 5 triage was collected. Finally, data on the number of patients discharged with personal consent were collected.

4.1.1 Data Aggregation

We used high bending data to obtain the indicators and data required for use in this study. In order to obtain the percentage of patients assigned in 6 hours per month in different years, we obtained the ratio of the number of patients assigned in an emergency under 6 hours per month to the total number of patients admitted to the emergency room during the same period. To calculate the time average of assigning patients, we calculate the ratio of the total time of assigning patients admitted to the emergency room to the total number of patients admitted to the emergency room in a period of time. The percentage of hospitalized patients discharged from the emergency room within 12 hours is the ratio of the number of emergency patients to the total number of hospitalized patients in an emergency over a period of 12 hours. The average length of hospital stay in the emergency room is the ratio of the total length of hospital stay in the emergency room to the total number of hospitalized patients in the emergency room. The percentage of successful CPR is the ratio of the number of successful CPR cases in the emergency to the total number of CPR cases in the emergency room. In fact, this formula is divided into several formulas based on the type and causes of CPR.

Includes CPR for trauma patients, CPR for patients without vital signs, and CPR for internal patients. The average waiting time for patients for the first visit to the doctor at each level of triage The ratio of patient waiting time for the first visit to the doctor at different levels of 1 to 5 triage to the total number of patients is the same level of triage. The percentage of patients leaving the emergency room with personal responsibility is the ratio of the number of patients discharged with personal satisfaction to the total number of patients admitted to the emergency room. By collecting this data, we extract the required inputs and outputs from this data.

4.2 Inputs and Outputs Data Selection

4.2.1 Inputs

In this section, we examine the input variables of the research. Input variables include the total number of patients and nurses and physicians. The patients studied in our study are patients who need CPR. In fact, the input variables include the number of CPR patients and doctors and nurses in this department, and of course the number of patients based on the triage classification system (ESI). The number of nurses and physicians is known from hospital statistics, but below we will talk briefly about CPR patients and the triage classification system.

4.2.1.1 Inputs 1

Pulmonary cardiopulmonary resuscitation (CPR) involves measures to restore vital functions of two important organs of the heart and brain in a person who has lost consciousness, and efforts are made to circulate blood and respiration until the flow returns The normal blood is established. Input 1 includes the total number of CPR patients who referred to Razi Hospital during April 2018 to November 2019, as well as the number of patients of December 2019 to March 2020 obtained by data simulation.

4.2.1.2 Inputs 2

Input 2 includes the total number of nurses and physicians in the CPR department of the hospital who worked in different shifts during the months of April 2018 to November 2019, such as input 1 we use data simulation for the months of December 2019 to March 2020.

4.2.1.3 Inputs 3

A triage system is a 5-level system in which patients are graded based on two main factors:

1. The severity of the disease and the severity of the patient's clinical condition.
2. The number of facilities required by the patient in the emergency room.

Very ill patients, dying patients, cardiac arrest, suffocation and shock or internal bleeding are patients who are treated in the first minutes and are placed in level-1 triage, and if necessary,be cardiopulmonary resuscitation (CPR) .

level-2 patients include chest pain (with the possibility of a heart attack), multiple strokes, and multiple (accidental) fractures, and stroke patients. Level-2 patients are usually high-risk individuals and are treated immediately after Level-1 patients.

Level-3 are patients who need to be seen immediately after Level-1 and level-2 patients with mental and psychiatric symptoms, weakness, and lethargy. Low-risk fractures and trauma, kidney stones, and broken limbs that are not life-threatening are among the patients of level 3.

level-4 are patients who do not have acute problems and pain and, for example, need a serum, painkillers, sutures, catheters, etc., and these patients are treated after levels 1, 2 and 3.

Level-5 patients who only need a visit or consultation or a prescription, and is outpatient. These patients are not admitted to the emergency room and do not receive a red card and are referred to as general, specialized, and subspecialty clinics for outpatient treatment.

The Triage (ESI) does not specify a specific time to treat patients, for example, Level 1 patient must be treated first, and immediately after Level 1, Level 2 patient must be treated, but if don't have Level 1 and 2 patients, the level 3 patient should be treated immediately, but if the patient was level 1 and 2, priority is given to level 1, then level 2, and then level 3.

Input 3 includes the total number of patients at levels 1 to 5 triage in the period of April 2018 to March 2020, with data from December 2019 to March 2020 obtained by simulation.

4.2.2 Outputs

In this section, the output variables are examined. Outputs include the number of successful CPRs, average time of determining the situation of patients, the average time of discharge of patients admitted from the emergency room, the average waiting time for patients for the first visit to the doctor at the level of triage, which in below we review and how to collect output data.

4.2.2.1 Output 1

Successful CPRs refers CPRs which after that the patient has spontaneous blood circulation and does not need to be resuscitated for at least 20 minutes. In other words, if the patient recovers within 20 minutes of the resuscitation operation and does not need CPR, it is considered a successful CPR.

CPR for a patient in short and frequent time intervals is ultimately one case, but if the time interval is more than eight hours, it will be considered in the calculation of the index of two cases:

- The ratio of successful CPR cases in the emergency room to the total CPR performed in a single time period. the formulation is:

$$\frac{100 \times The\ number\ of\ successful\ CPR\ cases\ in\ the\ emergency\ room\ over\ a\ period\ of\ time}{The\ total\ number\ of\ CPR\ cases\ in\ the\ emergency\ room\ at\ the\ same\ time} \tag{4.1}$$

- The ratio of successful CPR cases of trauma patients in the emergency room to the total CPR performed at the same time. the formulation is:

$$\frac{100 \times The\ number\ of\ successful\ CPR\ cases\ of\ trauma\ patients\ at\ emergency\ room\ over\ a\ period\ of\ time}{The\ total\ number\ of\ CPR\ cases\ in\ the\ emergency\ room\ at\ the\ same\ time} \tag{4.2}$$

- The ratio of successful CPRs cases of internal patients in the emergency room to the total CPRs performed over a period of time. the formulation is:

$$\frac{100 \times The\ number\ of\ successful\ CPRs\ cases\ of\ internal\ patients\ in\ the\ emergency\ room\ a\ period\ of\ time}{The\ total\ number\ of\ CPR\ cases\ in\ the\ emergency\ room\ at\ the\ same\ time} \tag{4.3}$$

- The proportion of successful CPR cases of patients without vital signs before hospitalization in the emergency room compared to the total CPR performed at the same time. the formulation is:

$$\frac{100 \times \begin{array}{c} The\ number\ of\ successful\ CPR\ cases\ of\ patients \\ without\ vital\ signs\ before \\ hospitalization\ in\ the\ emergency\ room\ over\ a\ period\ of\ time \end{array}}{\begin{array}{c} The\ total\ number\ of\ CPR\ cases\ in\ the \\ emergency\ room\ at\ the\ same\ time \end{array}} \tag{4.4}$$

4.2.2.2 Output 2

- An inpatient is a patient who, after triage or initial visit by a physician, forms an emergency hospitalization file and needs to stay in the emergency room for diagnostic and therapeutic procedures. In other words, all patients are immediately hospitalized, with or without a doctor's prescription, after the initial visit.
- These patients include levels of 1,2,3 triage and level4 triage that require an invasive procedure.

The purpose of determining the patient's status is to determine the patient's condition by the emergency physician as follows:

- Order for discharge from the emergency department after the necessary diagnostic and therapeutic action by the emergency physician;
- The order of definitive transfer of the patient to a specific medical service for hospitalization by the emergency physician;
- Order to be sent to other hospitals by the emergency physician
- Death.

The percentage of patients assigned within 6 hours is The proportion of patients admitted to the emergency department and assigned within 6 hours, to all patients admitted to the emergency department at the same time. the formulation is:

$$\frac{100 \times \begin{array}{c} The\ number\ of\ patients\ admitted \\ to\ the\ emergency \\ department\ and\ assigned\ within\ 6\ hours \end{array}}{\begin{array}{c} The\ total\ number\ of\ patients\ admitted\ to\ the \\ emergency\ department\ at\ the\ same\ time \end{array}} \tag{4.5}$$

- Obviously, outpatients and patients leave with personal responsibility are not included in this statistic (face and denominator of the index formula).
- Cases of death, which are undesirable results and are calculated in the numerator of the index, increase the rate of this index, which is one of the challenges of this index due to the low number of hospitalizations and death counts in unsuccessful CPRs, there are ignored.
- Due to the fact that all efforts are made to assign all hospitalized patients in less than 6 hours, the normal index is 100%.

Average time to determine patients status is the total time of determining patients status to the total number of hospitalized patients in the emergency department. the formulation is

$$\frac{The\ total\ time\ of\ determine\ patients\ status\ in\ a\ period\ of\ time}{\begin{array}{c} the\ total\ number\ of\ hospitalized\ patients \\ in\ the\ emergency\ department\ at\ the\ same\ time \end{array}} \tag{4.6}$$

4.2.2.3 Output 3

patient's exit is meant to be physically discharged from the emergency department for any reason other than personal consent and uninformed withdrawal.

- physically discharged means that they have either gone home or been transferred to one of the wards of the same hospital or have been sent to another hospital.
- Due to the fact that all efforts are made to remove all hospitalized patients from the emergency department in less than 12 hours (physical exit), so the normal index is 100%.

Patients who have referred to the emergency department over a period of time and have been diagnosed with the type of hospital referral need to file an emergency referral, but after visiting the doctor and during treatment, they refuse to continue treatment and for various reasons want to leave the emergency room. And in order to remove the responsibility from the hospital, they sign the form of leaving with personal responsibility:

- Outpatients whose only document is a triage sheet are not included in this statistic (should be analyzed focally in the emergency department).
- Patients who refuse treatment but do not leave the hospital are not included in this statistic.
- Cases that have not been hospitalized and have not yet been filed and are leaving the emergency room are not included in this index, which needs to be collected, analyzed and evaluated separately in each hospital and in quality improvement sessions of emergency procedures.
- The items that sign the hospital leave form with personal responsibility when going to the subspecialty center are calculated in this index.
- The presence of dissatisfaction in the service delivery system is predictable and it should be noted that it is reasonable to have 4% of the acceptable dissatisfaction

and review to reduce it, but all efforts will be made to ensure that the loss is not significant and not be key and vital.

- It is worth mentioning that in studies conducted in scientific texts, the normal level of this index in the world is 2%, but according to the conditions and facilities available in the Iranian system, this index is designed at about 4% and it is hoped that with The efforts of colleagues and experienced health care personnel of the country's hospitals to reduce this index to the normal amount intended.

Percentage of leaving with personal responsibility is the proportion of patients who have left the emergency room under personal responsibility and despite a physician's recommendation (AMA) is proportional to the total number of emergency hospitalized patients. the formulation is:

$$\frac{\begin{array}{c}100 \times The\ number\ of Number\ of\ emergency\\ leave\ cases\ with\ personal\ responsibility\\ over\ a\ period\ of\ time\end{array}}{\begin{array}{c}The\ total\ number\ of\ patients\ admitted\\ to\ the\ emergency\ room\ during\ the\ same\ period\end{array}} \quad (4.7)$$

Percentage of patients discharged from the emergency room within 12 hours is the proportion of hospitalized patients in the emergency department who, within 12 hours of arrival, have been determined to be out of the emergency department to all patients referred to the emergency hospital. the formulation is:

$$\frac{\begin{array}{c}100 \times The\ number\ of\ hospitalized\ patients\ that\ discharged\ from\\ the\ emergency\ room\ within\ 12\ hours\ over\ a\ period\ of\ time\end{array}}{\begin{array}{c}The\ total\ number\ of\ patients\ admitted\\ to\ the\ emergency\ room\ during\ the\ same\ period\end{array}} \quad (4.8)$$

The average time for patients to leave the emergency room is the ratio of the total time of patients staying in the emergency room to the total number of patients admitted to the emergency department. the formulation is:

$$\frac{\begin{array}{c}100 \times time\ of\ patients\ staying\ in\ the\ emergency\ room\\ over\ a\ period\ of\ time\end{array}}{\begin{array}{c}The\ total\ number\ of\ patients\ admitted\\ to\ the\ emergency\ room\ during\ the\ same\ period\end{array}}$$

(4.9)

For Intermediate leave time patients admitted from theemergency room:

- Adjust the time values of hospitalized patients who leave the emergency room at the same time from small to large;
- Select the number in the middle of the set (middle);
- If the number of data is even, the mean is equal to the average of the two middle numbers.

For the average waiting time for patients for the first visit to the doctor at the level-1 triage:

- The average waiting time for patients between the initial nursing triage and the initial visit of the physician to the total number of patients in a patient triage level-1.

For levels 2 to 5, it is also calculated as level 1.

The data obtained from the hospital for the purposes of this study are given in table 4-1. As mentioned, input 1 includes the total number of cprs, input 2 the number of nurses and doctors working in this department, and input 3 includes the total number of patients in the five levels of triage. Outputs include output 1, the number of successful CPRs, output 2 include average times of patient assignment, output 3 include the average time of patients leave the emergency room, and output 4, the waiting time for patients for the first visit to the doctor. In this study, DMUs show the time periods that each DMUs is one of the months between 2018 and 2020.

Table 4.1: Input and Output Data

			input 1	input 2	input 3	output 1	output 2	Output 3	output 4
2018	April	DMU01	22	212	15459	1	0.5	0.4081	0.000015
	May	DMU02	6	197	15252	1	0.3333	0.2481	0.000013
	June	DMU03	6	200	14755	0	0.25	0.1526	0.000012
	July	DMU04	3	212	14722	0	0.5	0.2932	0.00002
	August	DMU05	23	212	14133	3	0.25	0.2463	0.000045
	September	DMU06	36	212	12097	1	0.5	0.3891	0.000009
	October	DMU07	9	187	11393	0	0.5	0.1342	0.000008
	November	DMU08	12	202	13579	0	0.3333	0.1342	0.000013
	December	DMU09	31	183	14034	2	0.5	0.2923	0.000017
2019	January	DMU10	18	187	18291	0	1	1.1764	0.000009
	February	DMU11	14	174	17888	1	0.3333	0.3921	0.000013
	March	DMU12	23	214	10093	2	0.3333	0.3802	0.000018
	April	DMU13	14	216	19770	3	0.25	0.2551	0.000006
	May	DMU14	18	181	19518	1	0.3333	0.2816	0.000006
	June	DMU15	21	186	17778	4	0.25	0.2717	0.000007
	July	DMU16	15	206	4780	1	0.3333	0.268	0.000052

	August	DMU17	26	216	9031	4	0.3333	0.3058	0.000018
	September	DMU18	12	224	10197	0	0.3333	0.3333	0.000012
	October	DMU19	17	194	11024	2	1	0.3125	0.000015
	November	DMU20	12	181	12809	1	0.5	0.3164	0.000012
	December	DMU21	22	186	7842	2	0.25	0.3378	0.000027
2020	January	DMU22	9	199	8749	0	0.3333	0.3144	0.000017
	February	DMU23	17	189	10583	4	0.3333	0.3076	0.000016
	March	DMU24	18	214	10116	1	1	0.3215	0.000014

Also below are the comparison charts and data tables to calculate the indicators.

Table 4.2: The Number of Patients Determined Situation in 6 Hours

		Total number of patients admitted temporarily	The number of patients determined situation in 6 hours
2018	April	2114	1926
	May	1851	1731
	June	1564	1487
	July	1580	1444
	August	1809	1767
	September	1613	1375
	October	1429	1326
	November	1528	1429
	December	1546	1414
2019	January	1999	1838
	February	2055	1889
	March	3558	3224

	April	1872	1662
	May	1909	1711
	June	1641	1461
	July	1594	1424
	August	1656	1455
	September	1600	1387
	October	1775	1577
	November	1916	1627

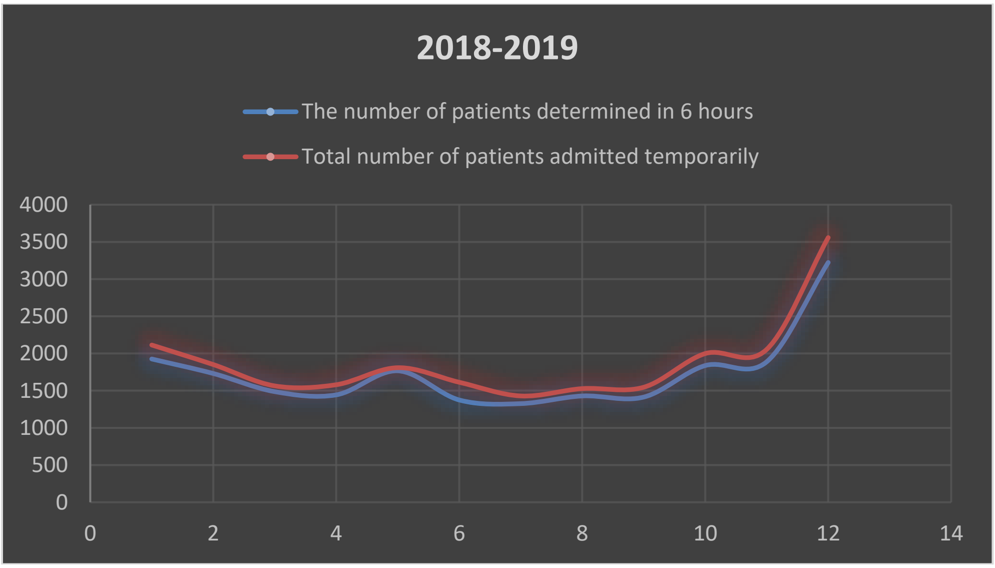

Figure 5: The Number of Patients Determined Situation in 6 Hours(2018-2019)

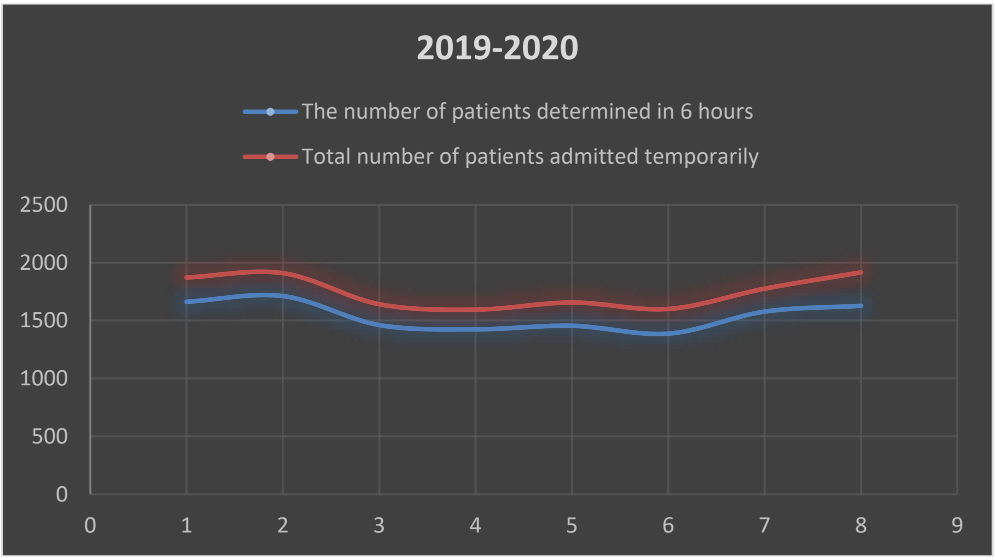

Figure 6: The Number of Patients Determined Situation in 6 Hours(2019-2020)

Table 4.3: Average Time to Determine Situation of Patient

		The total number of patients admitted to the emergency	total time to determined situation of the hospitalized patients
2018	April	7568	2114
	May	9625	1851
	June	11261	1564
	July	14252	1580
	August	18144	1809
	September	13750	1613
	October	10617	1429
	November	16503	1528
	December	6803	1546
2019	January	5690	1999
	February	1124	2055
	March	34513	3558
	April	7684.6	1872
	May	8363.3	1909
	June	6112.7	1641
	July	6578.4	1594
	August	5514.4	1656
	September	5843.2	1600
	October	6299.5	1775
	November	8321.2	1916

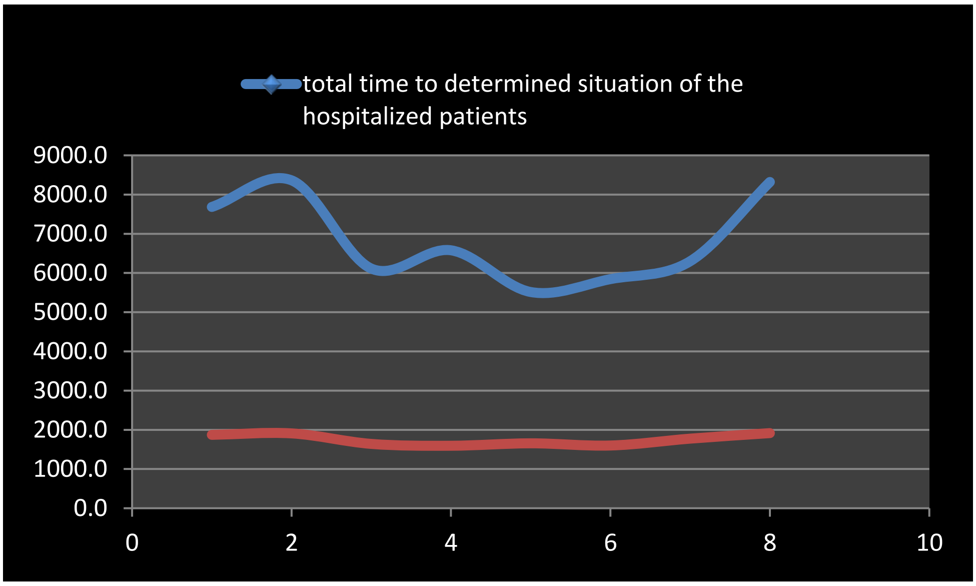

Figure 7: Average Time to Determine Situation of Patients (2018-2019)

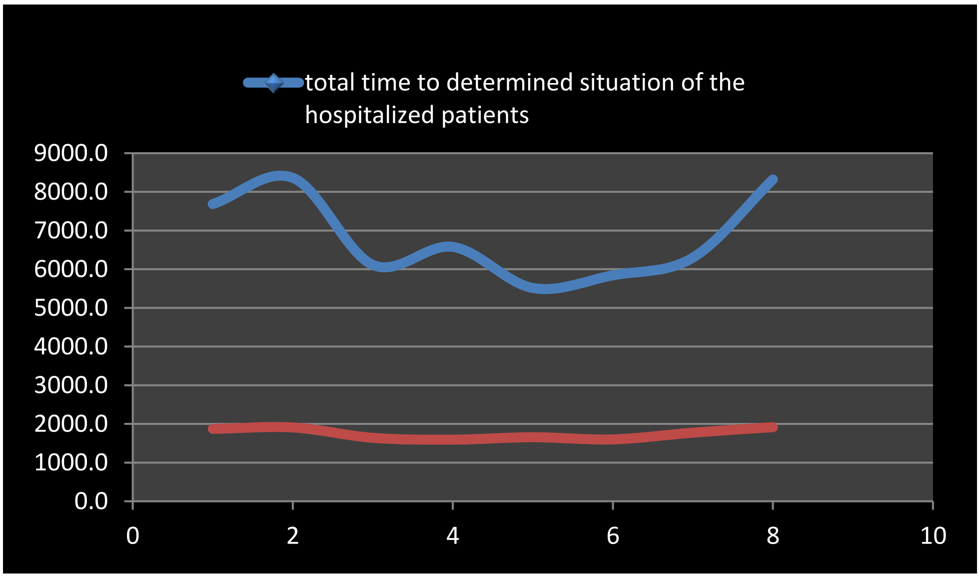

Figure 8: Average Time to Determine Situation of Patients (2019-2020)

Table 4.4: Percentage of Patients Discharged from the Emergency Room within 12 Hours

		total number of Interim hospitalized patients	number of patients discharged from the emergency within 12 hours
2018	April	7568	2114
	May	9625	1851
	June	11261	1564
	July	14252	1580
	August	18144	1809
	September	13750	1613
	October	10617	1429
	November	16503	1528
	December	6803	1546
2019	January	5690	1999
	February	1124	2055
	March	34513	3558
	April	7684.6	1872
	May	8363.3	1909
	June	6112.7	1641
	July	6578.4	1594
	August	5514.4	1656
	September	5843.2	1600
	October	6299.5	1775
	November	8321.2	1916

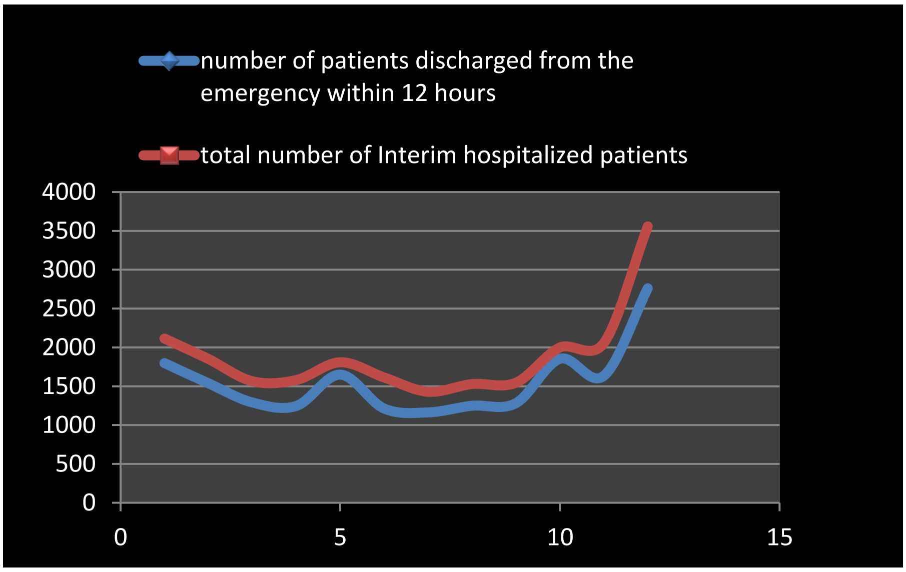

Figure 9: Percentage of Patients Discharged from the Emergency Room within 12 Hours (2018-2019)

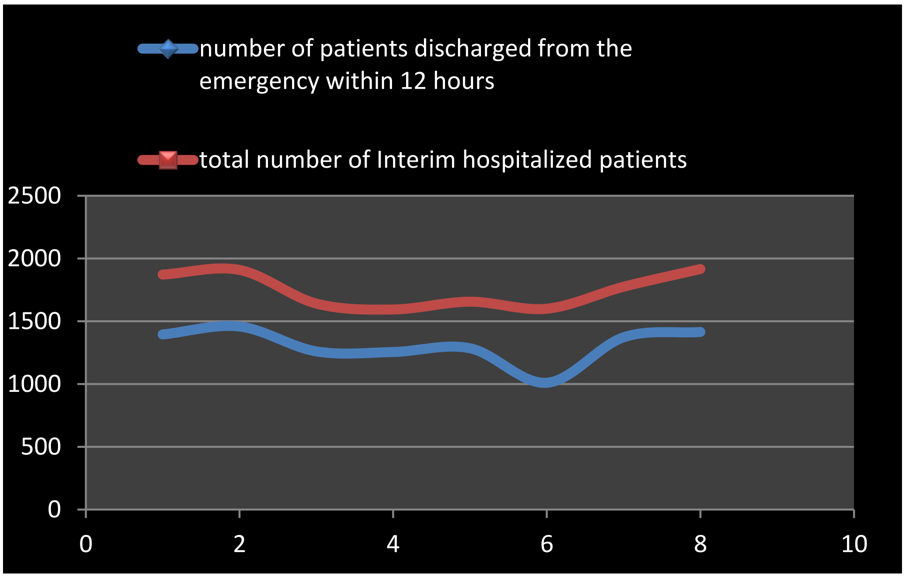

Figure 10: Percentage of Patients Discharged from the Emergency Room within 12 Hours (2019-2020)

Table 4.5: Average Time for Exiting Admitted Patients in Emergency

		total number of admitted patients in emergency room	The total Durability time of hospitalized patients on the emergency room
2018	April	2114	17630
	May	1851	17307
	June	1564	13373
	July	1580	15992
	August	1809	15105
	September	1613	11888
	October	1429	8931
	November	1528	16808
	December	1546	9370
2019	January	1999	1251
	February	2055	26715
	March	3558	57284
	April	1872	24891
	May	1909	24349
	June	1641	20824
	July	1594	16503
	August	1656	17173
	September	1600	23821
	October	1775	19250
	November	1916	20082

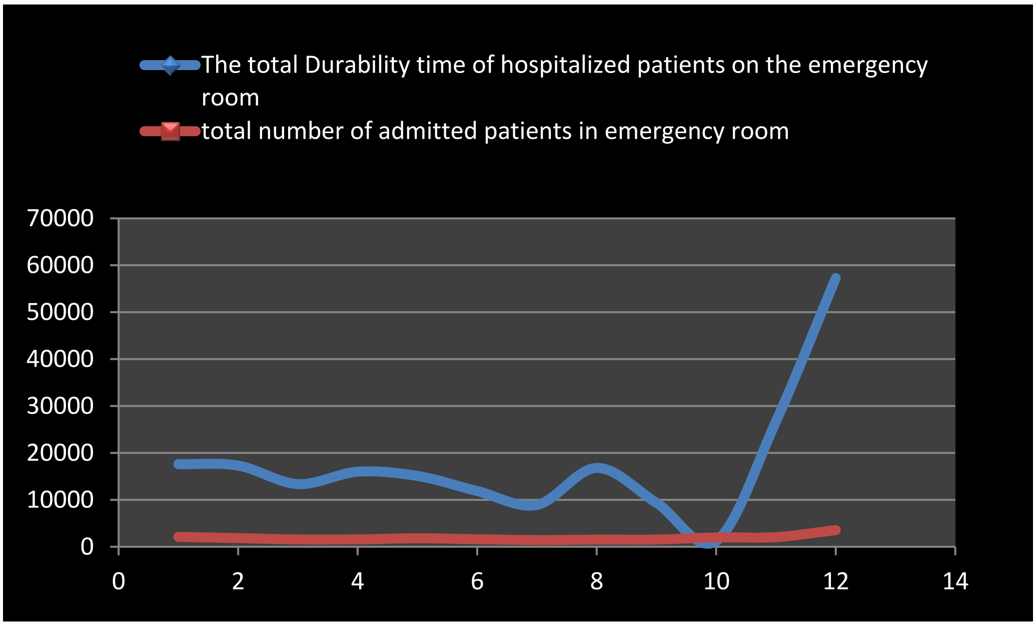

Figure 11: Average Time for Exiting Admitted Patients in Emergency Room Hours (2018-2019)

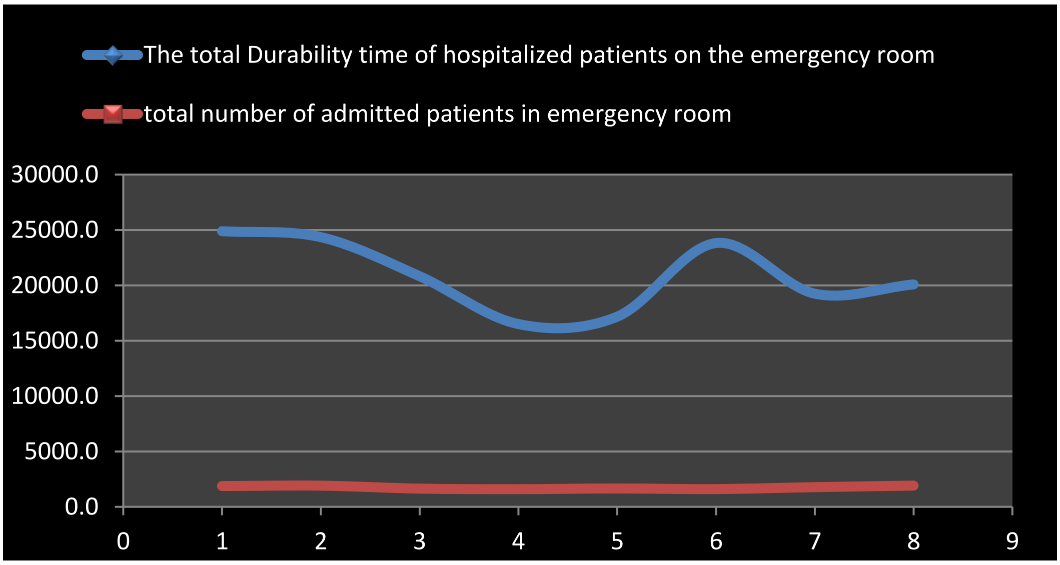

Figure 12: Average Time for Exiting Admitted Patients in Emergency Room Hours (2019-2020)

Table 4.6: Average Time Exit Admitted Patients in Emergency Room

		Total number of CPR cases in the emergency room	The number of successful CPR cases in the emergency room
2018	April	6	1
	May	2	1
	June	2	0
	July	1	0
	August	7	3
	September	12	1
	October	3	0
	November	4	0
	December	9	2
2019	January	6	0
	February	4	1
	March	7	2
	April	4	3
	May	6	1
	June	5	4
	July	5	1
	August	8	4
	September	4	0
	October	5	2
	November	4	1

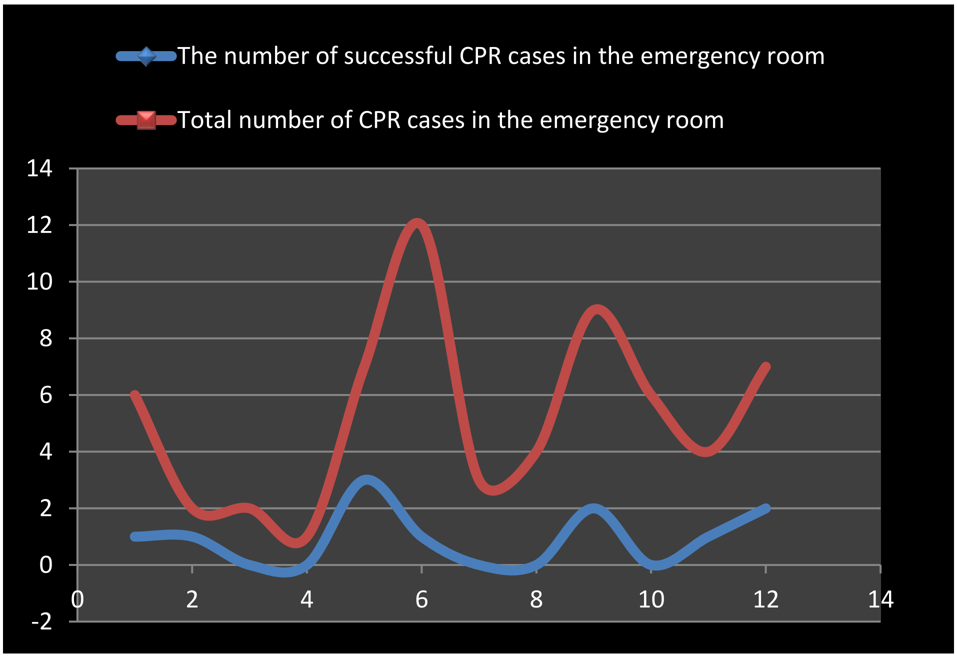

Figure 13: Average Time Exit Admitted Patients in Emergency Room (2018-2019)

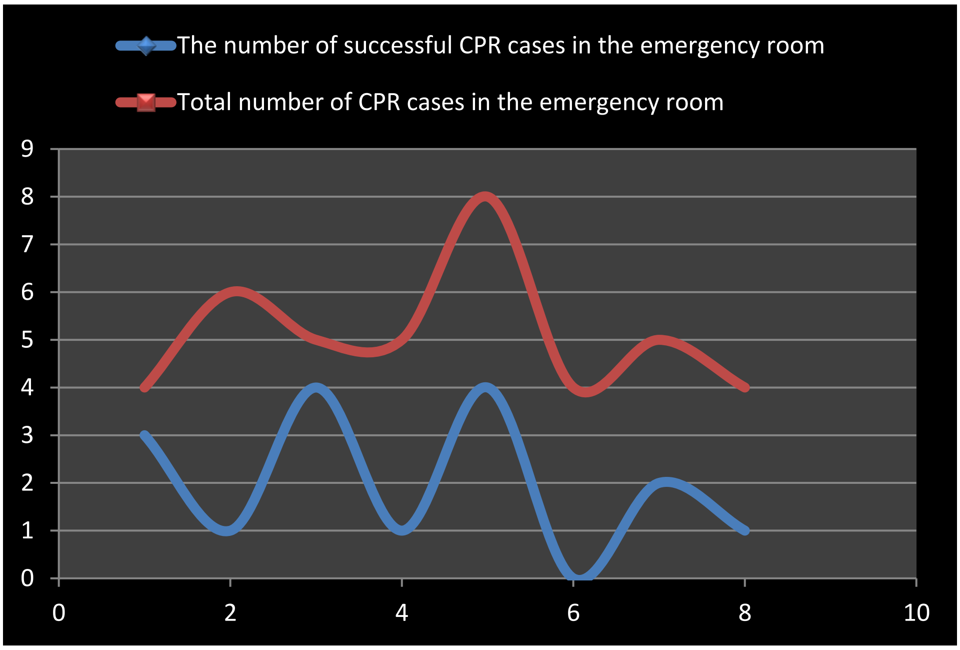

Figure 14: Average Time Exit Admitted Patients in Emergency Room (2019-2020)

Table 4.7: Percentage of Leaving with Personal Responsibility

		Total number of patients admitted temporarily	Number of patients leaving with personal consent
2018	April	182	2114
	May	177	1851
	June	125	1564
	July	155	1580
	August	110	1809
	September	117	1613
	October	113	1429
	November	115	1528
	December	161	1546
2019	January	136	1999
	February	113	2055
	March	117	3558
	April	158	1872
	May	119	1909
	June	129	1641
	July	113	1594
	August	401	1656

	September	327	1600
	October	365	1775
	November	474	1916

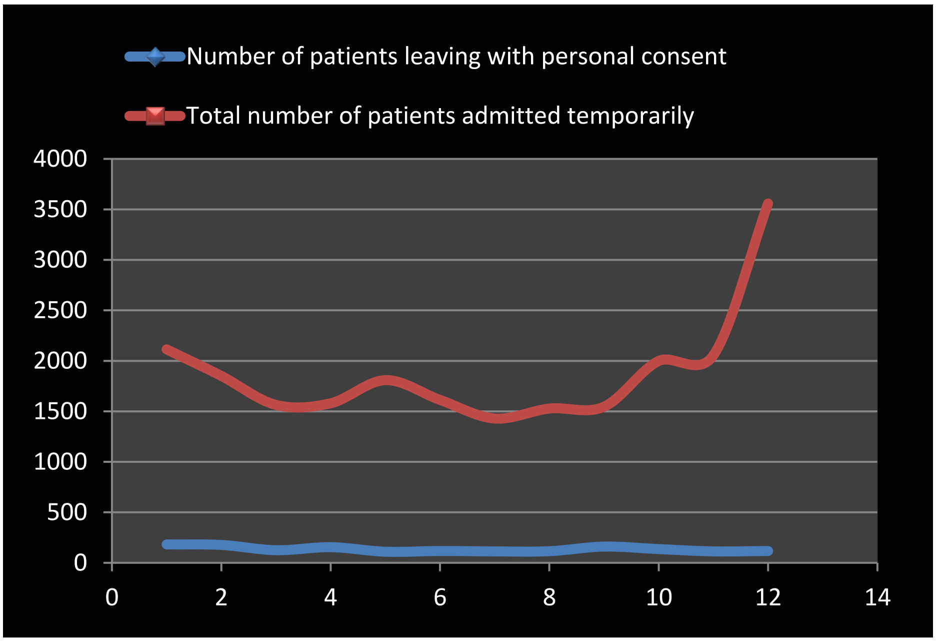

Figure 15: Percentage of Leaving with Personal Responsibility (2018-2019)

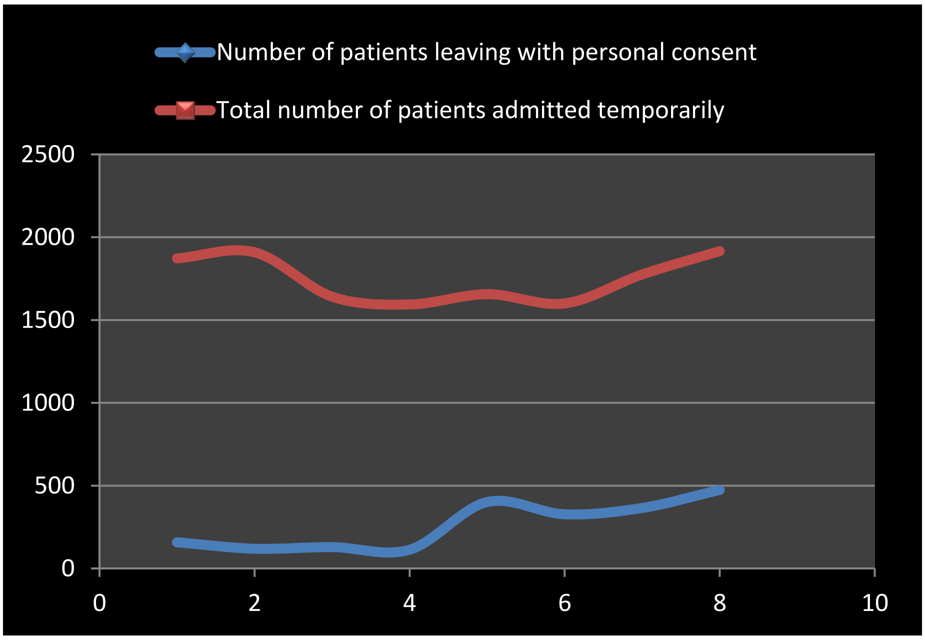

Figure 16: Percentage of Leaving with Personal Responsibility (2019-2020)

Table 4.8: The Average Duration of Triage at the Level One Triage

		Total number of patients of level one triage	Time of wait patients for the first visit to the doctor at the level one triage
2018	April	36	21
	May	61	26
	June	68	25
	July	9	7
	August	29	10
	September	31	15
	October	12	8
	November	15	9
	December	20	14
2019	January	37	8
	February	22	7
	March	24	9
	April	14	7
	May	63	31
	June	15	9
	July	13	8
	August	31	13
	September	11	6
	October	12	6
	November	9	5

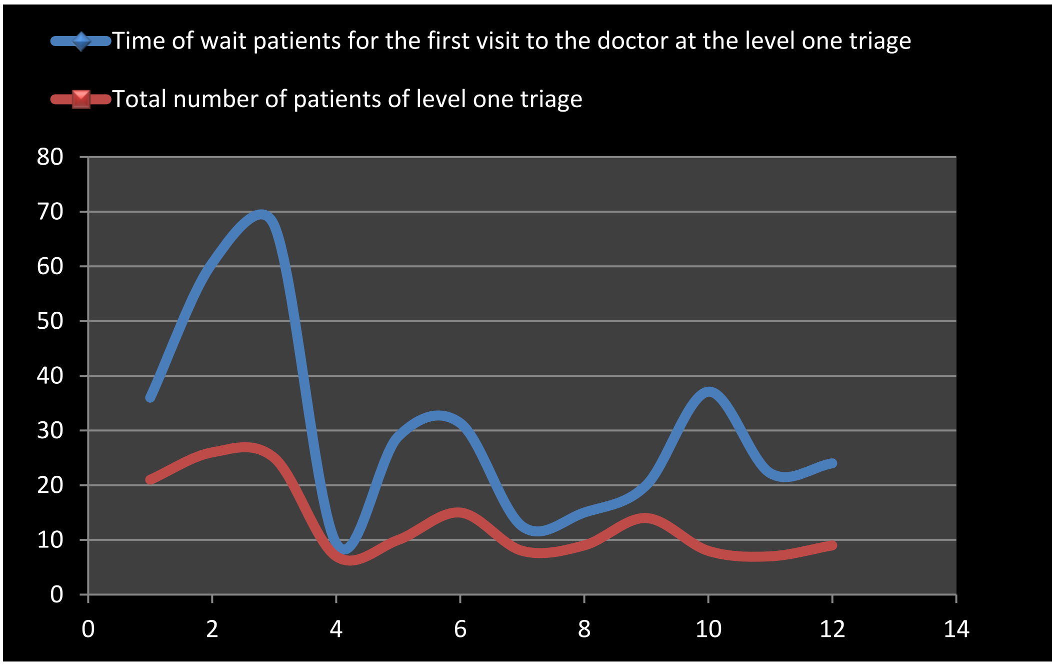

Figure 17: The Average Duration of Triage at the Level One Ttriage (2018-2019)

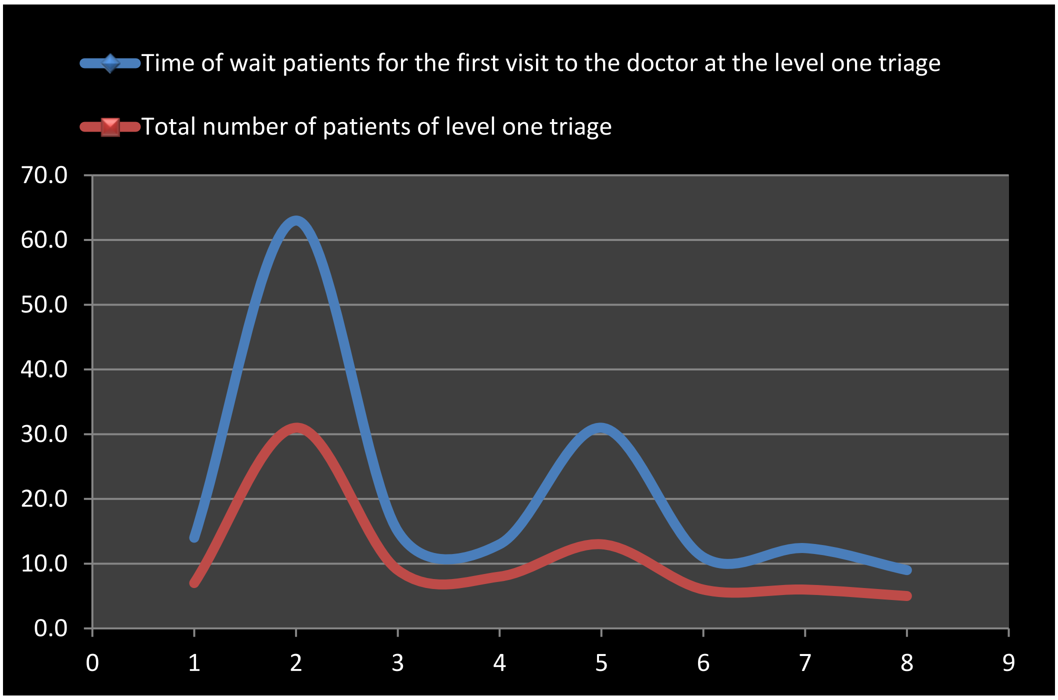

Figure 18: The Average Duration of Triage at the Level One Triage (2019-2020)

Table 4.9: The Average Duration of Triage at the Level Two Triage

		Total number of patients of level two triage	Time of wait patients for the first visit to the doctor at the level two triage
2018	April	9300	1069
	May	9746	1072
	June	11759	1056
	July	8120	1160
	August	7147	979
	September	6453	884
	October	5972	818
	November	9851	1263
	December	4999	1089
2019	January	4969	1022
	February	3424	815
	March	1927	795
	April	9746	886
	May	8335	958
	June	10702	1039
	July	5253	520
	August	9881	1025
	September	14607	873
	October	13397	876
	November	10530	958

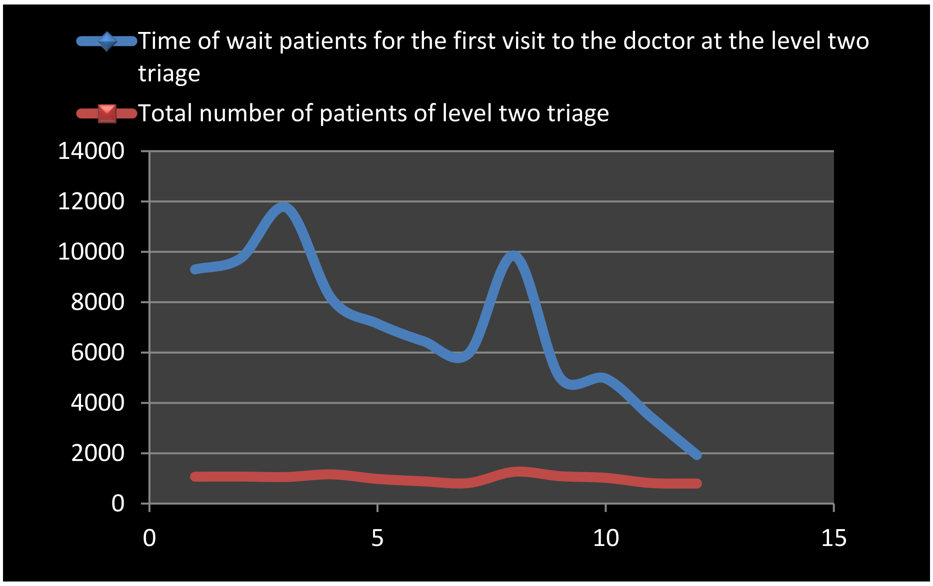

Figure 19: The Average Duration of Triage at the Level Two Triage (2018-2019)

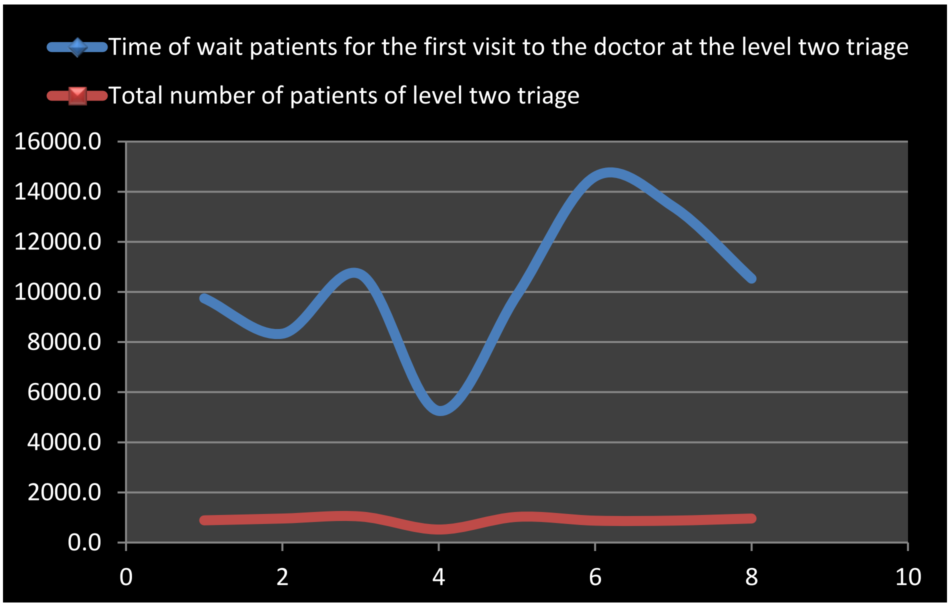

Figure 20: The Average Duration of Triage at the Level Two Triage (2019-2020)

Table 4.10: The Average Duration of Triage at the Level Three Triage

		Total number of patients of level three triage	Time of wait patients for the first visit to the doctor at the level three triage
2018	April	28378	2355
	May	26671	2416
	June	20127	2033
	July	11778	2265
	August	8956	2357

	September	10785	1586
	October	5433	603
	November	5499	1349
	December	11424	1625
2019	January	45476	3512
	February	47158	3633
	March	33749	1466
	April	20176	1552
	May	16986	894
	June	6523	593
	July	7224	602
	August	7554	618
	September	24533	1277
	October	23634	1313
	November	30031	1435

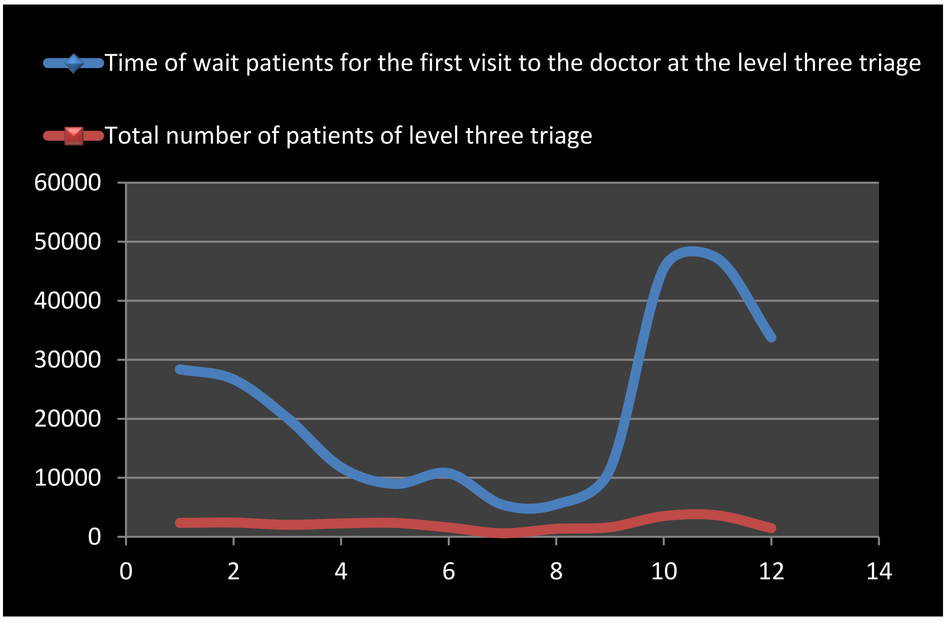

Figure 21: The Average Duration of Triage at the Level Three Triage (2018-2019)

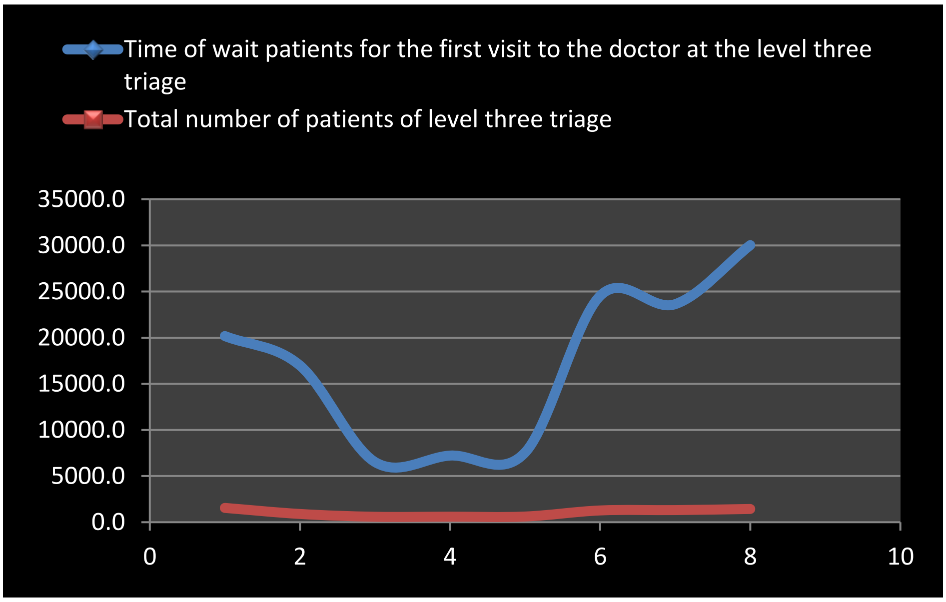

Figure 22: The aAverage Duration of Triage at the Level Three Triage (2019-2020)

Table 4.11: The Average Duration of Triage at the Level Four Triage

		Total number of patients of level four triage	Time of wait patients for the first visit to the doctor at the level four triage
2018	April	27184	1928
	May	35028	1668
	June	47070	2092
	July	26151	1429
	August	4830	1380
	September	68496	1427
	October	104347	2956
	November	58050	2150
	December	33525	2235
2019	January	45476	1731
	February	25543	1806
	March	17358	1182
	April	119448	5688
	May	98957	5821
	June	94465	5162
	July	5851	390
	August	35552	1408

	September	38311	1337
	October	27155	1659
	November	37469	2140

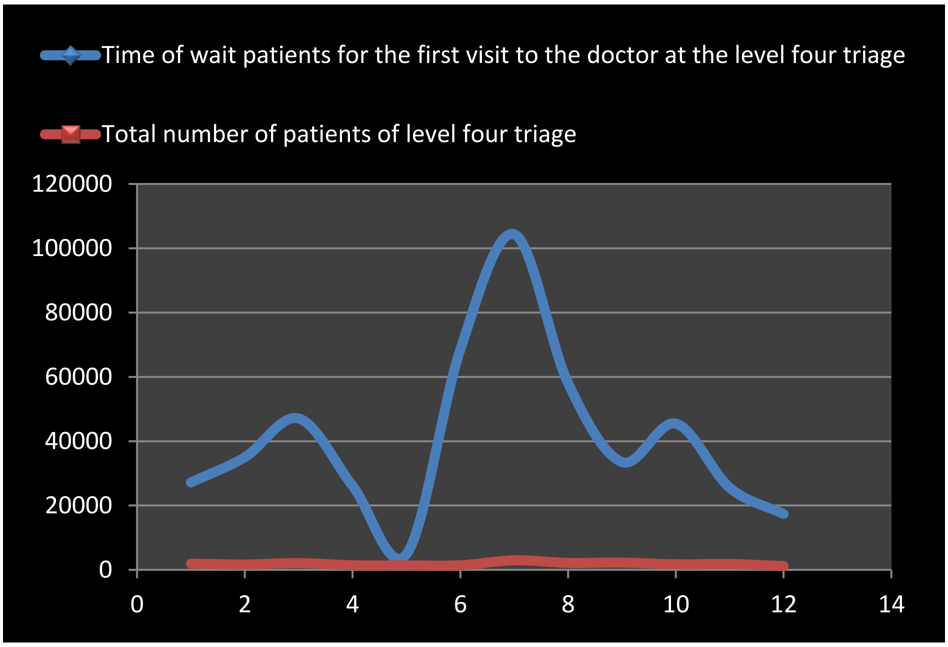

Figure 23: The Average Duration of Triage at the Level Four Triage (2018-2019)

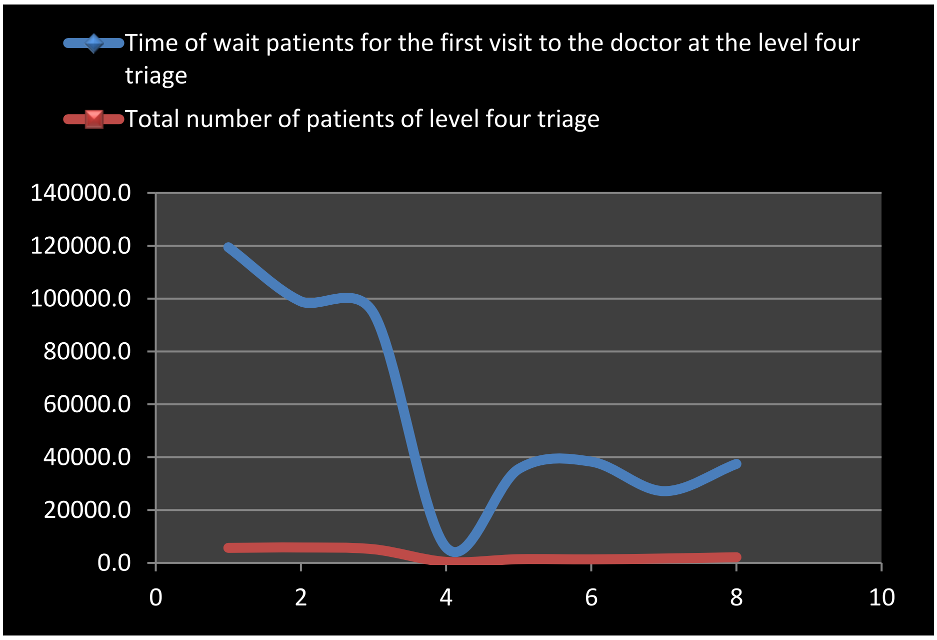

Figure 24: The Average Duration of Triage at the Level Four Triage (2019-2020)

Table 4.12: The Average Duration of Triage at the Level Five Triage

			Total number of patients of level five triage	Time of wait patients for the first visit to the doctor at the level five triage
2018	April		1351	157
	May		1575	250
	June		628	123
	July		3191	394
	August		1042	336
	September		20102	874
	October		7560	360
	November		1013	135
	December		6049	263
2019	January		6263	165
	February		551	82
	March		1762	106
	April		1004	159
	May		24140	1207
	June		17688	1474
	July		581	74
	August		1737	196
	September		1313	170
	October		1573	233
	November		1010	167

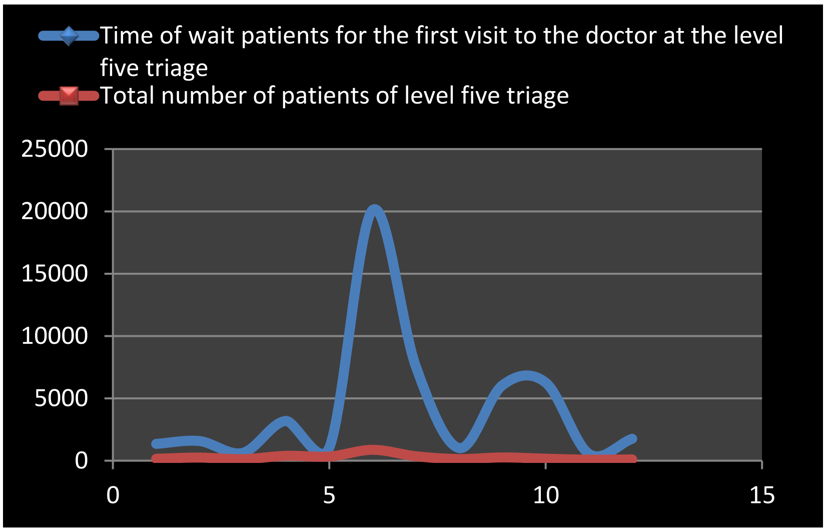

Figure 25: The Average Duration of Triage at the Level Fve Triage (2018-2019)

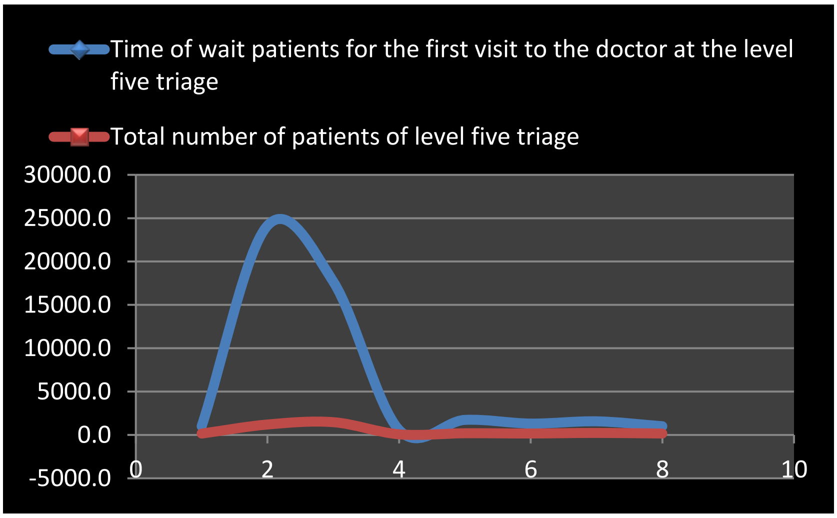

Figure 26: The Average Duration of Triage at the Level Five Triage (2019-2020)

Chapter 5

RESULTS AND DISCUSSION

In this chapter, we describe the results of analyzing the input and output data (DMU) of Table 5.1 data obtained using PIM-DEA software. These results include CCR efficiency result, benchmark (Lamdas) of CCR result, Weight of CCR result, the result for the input target of CCR and the result for the output target of CCR.

Table 5-1 shows the normalized data. To normalize the data in each of the variables, we first find the maximum amount of DMU in that variable and then divide each DMU by it. For example, in input 1, the maximum value belongs to DMU6, ie 36, so in input 1, we divide each of the DMUs by 36. See the results in the table below.

Table 5.1: Normalized Input and Output Data

DMU	input 1	input 2	input 3	output 1	output 2	output3	output 4
DMU 01	0.611111	0.946429	0.781942	0.25	0.5	0.346906	0.288462
DMU 02	0.166667	0.879464	0.771472	0.25	0.3333	0.210898	0.25
DMU 03	0.166667	0.892857	0.746333	0	0.25	0.129718	0.230769
DMU 04	0.083333	0.946429	0.744664	0	0.5	0.249235	0.384615
DMU 05	0.638889	0.946429	0.714871	0.75	0.25	0.209368	0.865385
DMU 06	1	0.946429	0.611887	0.25	0.5	0.330755	0.173077

DMU07	0.25	0.834821	0.576277	0	0.5	0.114077	0.153846
DMU08	0.333333	0.901786	0.686849	0	0.3333	0.114077	0.25
DMU09	0.861111	0.816964	0.709863	0.5	0.5	0.24847	0.326923
DMU10	0.5	0.834821	0.92519	0	1	1	0.173077
DMU11	0.388889	0.776786	0.904805	0.25	0.3333	0.333305	0.25
DMU12	0.638889	0.955357	0.510521	0.5	0.3333	0.323189	0.346154
DMU13	0.388889	0.964286	1	0.75	0.25	0.216848	0.115385
DMU14	0.5	0.808036	0.987253	0.25	0.3333	0.239374	0.115385
DMU15	0.583333	0.830357	0.899241	1	0.25	0.230959	0.134615
DMU16	0.416667	0.919643	0.24178	0.25	0.3333	0.227814	1
DMU17	0.722222	0.964286	0.456803	1	0.3333	0.259946	0.346154
DMU18	0.333333	1	0.515781	0	0.3333	0.283322	0.230769
DMU19	0.472222	0.866071	0.557613	0.5	1	0.265641	0.288462
DMU20	0.333333	0.808036	0.647901	0.25	0.5	0.268956	0.230769
DMU21	0.611111	0.830357	0.396662	0.5	0.25	0.287147	0.519231
DMU22	0.25	0.888393	0.442539	0	0.3333	0.267256	0.326923

DMU 23	0.472222	0.84375	0.535306	1	0.3333	0.261476	0.307692
DMU 24	0.5	0.955357	0.511684	0.25	1	0.273291	0.269231

5.1 CCR Efficiency

According to the calculations performed with the software and using the input-axis CCR model, as can be seen in Table 5-1, the efficiency of each decision unit has been shown. Each decision unit has its return using normalized inputs and outputs that were calculated in Table 4-2.

Table 5.2: CCR Efficiency Result

DMUs	Efficiency	DMUs	Efficiency
DMU01	61.47	**DMU13**	92.85
DMU02	100	**DMU14**	48.55
DMU03	50.68	**DMU15**	100
DMU04	100	**DMU16**	100
DMU05	100	**DMU17**	100
DMU06	64.64	**DMU18**	59.07
DMU07	74.61	**DMU19**	100
DMU08	49.97	**DMU20**	76.86
DMU09	83.25	**DMU21**	95.4
DMU10	100	**DMU22**	78.21
DMU11	70.68	**DMU23**	100
DMU12	78.84	**DMU24**	100

As you can see, the table above shows the efficiency score for each DMU. The highest efficiency DMUs are marked with different colors in the table. According to the inputs and outputs of this study, the highest returns for DMU 2 (May 2018), DMU 4 (July 2018), DMU 5 (August 2018), DMU 10 (January 2019), D MU15 (June 2019), DMU 16 (July 2019), DMU 17 (August 2019), DMU 19 (October 2019), DMU 23 (February 2020), DMU 24 (March 2020) Was obtained. In fact, these DMUs have the highest performance and efficiency among others. It can now be said that the above DMUs have the highest number of successful CPRs, the best time to assign patients, the best time for patients to leave the emergency room, and the shortest waiting time for a doctor's visit at the triage level.

We now know what DMUs we need to focus on to improve the overall situation. Given that it is easier to deliver the ideal efficiency of DMUs closer to 100, we first consider DMUs with an efficiency above 70%. , Such DMUs are close to optimal performance. Therefore, in order to increase the number of successful CPRs and reduce the median time for assigning patients and the median time for patients to leave the emergency room and the waiting time for a doctor's visit at the triage level, less effort is required than for DMUs below 70%, Which leads to higher efficiency and improved performance of the emergency department. DMUs with an efficiency between 70% and 100% are DMU13, DMU12, DMU11, DMU9, DMU7 and DMU20, and DMU22, DMU21.

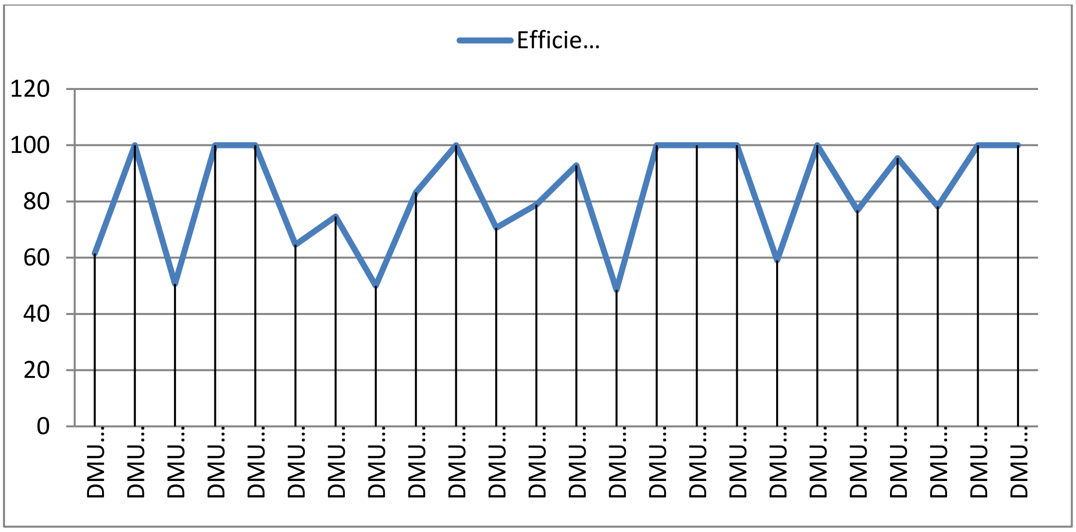

Figure 27: Performance Diagrams of DMUs

5.2 Lamdas of CCR

Using the software, the benchmark results were obtained, which can be seen in table 2.5. This is a benchmark for comparison in the performance of inefficient DMUs.

Table 5.3: Benchmark Result

	DMU02	DMU04	DMU05	DMU10	DMU15	DMU16	DMU17	DMU19	DMU23	DMU24
DMU1	0	0	0.18	0.25	0	0.03	0	0.19	0.01	0
DMU2	1	0	0	0	0	0	0	0	0	0
DMU3	0	0.36	0	0.01	0	0.08	0	0.03	0	0
DMU4	0	1	0	0	0	0	0	0	0	0
DMU5	0	0	1	0	0	0	0	0	0	0
DMU6	0	0	0	0.21	0	0.18	0.11	0.19	0	0
DMU7	0	0.32	0	0	0	0	0	0.34	0	0
DMU8	0	0.16	0	0	0	0.13	0	0.21	0	0
DMU9	0	0	0.19	0.07	0	0	0	0.31	0.2	0
DMU10	0	0	0	1	0	0	0	0	0	0

DMU11	0	0.06	0	0.23	0	0.12	0	0	0.22	0
DMU12	0	0	0	0.16	0	0.2	0.45	0	0	0
DMU13	0.14	0	0	0	0	0	0	0	0.71	0
DMU14	0	0	0	0.16	0	0	0	0.11	0.2	0
DMU15	0	0	0	0	1	0	0	0	0	0
DMU16	0	0	0	0	0	1	0	0	0	0
DMU17	0	0	0	0	0	0	1	0	0	0
DMU18	0	0.06	0	0.23	0	0.16	0	0.02	0	0
DMU19	0	0	0	0	0	0	0	1	0	0
DMU20	0	0.2	0	0.12	0	0.03	0	0.23	0.13	0
DMU21	0	0	0	0.1	0	0.37	0.24	0	0.17	0
DMU22	0	0.18	0	0.17	0	0.23	0	0	0	0
DMU23	0	0	0	0	0	0	0	0	1	0
DMU24	0	0	0	0	0	0	0	0	0	1

As the results in Table 5.2 show, DMU02, DMU04, DMU05, DMU10, DMU15, DMU16, DMU17, DMU19, DMU23, DMU24 have the highest returns. Therefore, these DMUs are used as an efficient criterion for comparison with all DMUs. Table 5.3 shows that DMU1 can be compared to DMU10, DMU15, DMU16, DMU17, DMU19, DMU23, DMU24, but its best can be compared to DMU10. This means that the DMU10 is the best decision unit among the optimal DMUs that can be compared to the DMU1. In fact, by changing the outputs, you can achieve the optimal DMU1 compared to the DMU10. Overall, inefficient DMUs can be compared to the positive values of lambda (benchmark) of optimal DMUs, and the maximum lambda value is the best criterion. Comparing the rest of the DMUs is best described in Table 5.4 below. This is the best measure of any DMU. Table 5.4 can also help find the number of times to use each of the optimal DMUs as a criterion for inefficient DMUs. According to the chart, DMU10 and DMU19 can be used as criteria for improving the efficiency of 5 decision units, DMU16 and DMU23 for 3 decision units, DMU4 and DMU17 for 2 decision units and DMU2, DMU5, DMU15 and DMU24 for 1 decision unit to be used. Therefore, DMU10 and DMU19 are the best criteria, followed by DMU16, DMU23, DMU4, DMU17, and finally DMU2, DMU5, DMU15, and DMU24.

Table 5.4: Best Benchmark per DMU

DMUs	Best Benchmark	DMUs	Best Benchmark
DMU1	DMU 10	DMU13	DMU 23
DMU2	DMU 2	DMU14	DMU 23
DMU3	DMU 4	DMU15	DMU 15
DMU4	DMU 4	DMU16	DMU 16
DMU5	DMU 5	DMU17	DMU 17
DMU6	DMU 10	DMU18	DMU 10

DMU7	DMU 19	DMU19	DMU 19
DMU8	DMU 19	DMU20	DMU 19
DMU9	DMU 19	DMU21	DMU 16
DMU10	DMU 10	DMU25	DMU 16
DMU11	DMU 10	DMU23	DMU 23
DMU12	DMU 17	DMU24	DMU 24

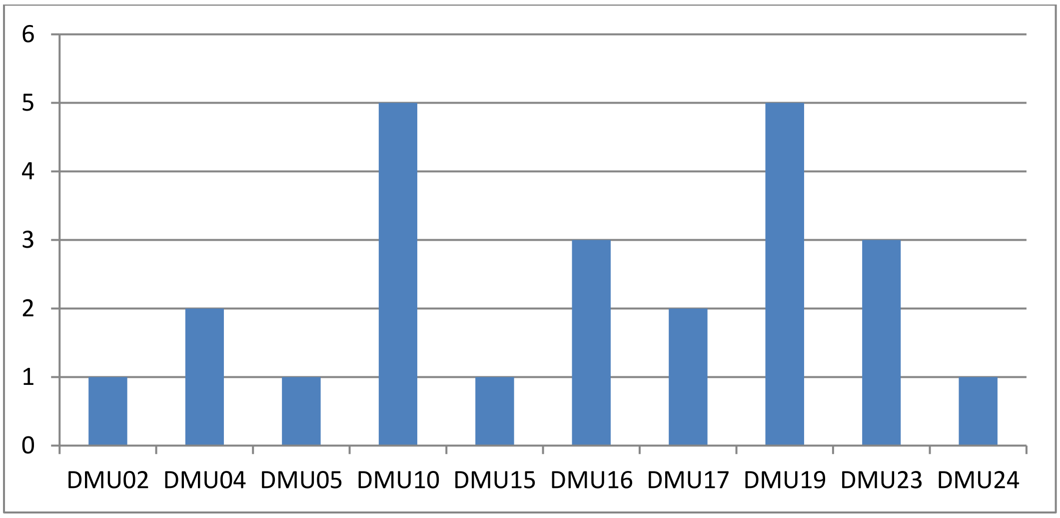

Figure 28: Number of DMUs that Were Referenced for Each of the Best Benchmark

5.3 Weights of CCR

One of the results of the software is the share and importance of each of the inputs and outputs used in evaluating the efficiency of DMUs. These results are shown in Table 5.5 below. In fact, any variable with zero weight in the decision-making unit indicates that is not helping to evaluate the performance of DMU.

Table 5.5: Weights of CCR Result

	Input1	Input2	Input3	Output1	Ouputt2	Output3	Output4
DMU01	0	0.9	0.19	0.45	0.39	0.45	0.53
DMU02	5.99	0	0	2.3	0	2.01	0
DMU03	1.31	0.88	0	0	1.06	0.16	0.96
DMU04	2.7	0.82	0	0	1.97	0.07	0
DMU05	0	0.86	0.26	0.47	0	0.87	0.54
DMU06	0	0.14	1.42	0.38	0.47	0.96	0
DMU07	2.28	0	0.75	0	1.49	0	0
DMU08	1.1	0.7	0	0	0.89	0	0.81
DMU09	0	1.22	0	0.57	0.49	0.43	0.6
DMU10	0	0.4	0.72	0	0.66	0.34	0
DMU11	1.74	0.42	0	0.67	0	1.1	0.69
DMU12	0	0.08	1.81	0.45	0	1.74	0
DMU13	2.57	0	0	0.99	0	0.86	0
DMU14	0	1.24	0	0.73	0.59	0.45	0
DMU15	0	1.16	0.04	1	0	0	0
DMU16	0.46	0.88	0	0.51	0.43	0.43	0.63
DMU17	0	0.6	0.92	1	0	0	0
DMU18	1.61	0	0.9	0	0.98	0.58	0.43
DMU19	0.43	0.01	1.41	0.54	0.44	1.09	0
DMU20	1.55	0.6	0	0.68	0.55	0.61	0.71
DMU21	0	0.75	0.96	0.63	0	1.44	0.43
DMU22	2.62	0	0.78	0	0	1.88	0.85
DMU23	0	0.6	0.92	1	0	0	0
DMU24	0	0.53	0.96	0	0.87	0.46	0
Total	24.36	12.79	12.04	12.37	11.28	15.93	7.18

Carefully in Table 5.5 and what was described above, except for input 1, the other variables are involved in evaluating the efficiency of the DMU1. For DMU 16, only input 3 and for DMU 19 are the only outputs 4 that do not play a role in evaluating the efficiency of DMU. In other DMUs, there are more variables that do not play a role in evaluating DMU. For DMUs 2, 7, 13, 15, 17 and 23, out of 7 variables, 4 variables do not play a role in evaluating the efficiency of DMU, which is actually more than the rest of DMU. Among the variables, input 2 (number of doctors and nurses) is the best because it does not only affect the performance evaluation of 4 DMUs. Then there is output 3 (the time interval between patients leaving the emergency room) which does not play a role in evaluating 5 DMU. The worst variable is output 4 (patient waiting for the first doctor's visit), which is ineffective in evaluating the performance of 13 DMU. Then there is input 1 (total number of CPRs) which is ineffective in evaluating 12 DMU. The results of Table 5.5 are very efficient. In fact, for example, in DMU2, only input 1 affects the DMUs. This means that the number of CPRs and other inputs is ineffective. Or, for example, for the DMU 15, only output 1, ie the number of successful CPRs, is effective. In general, any variable with zero weight per unit of a decision means that the variable does not help to evaluate its DMU performance. Therefore, with this awareness of generalization, the variables that are important in evaluating the performance of each of the remaining DMUs (in Table 5.5) can be identified based on their non-weighted weight value.

In evaluating the efficiency of each of the 24 DMUs shown in the table above, it can be seen that Input2 (the number of nurses and physicians) is the most important variable used in evaluating the overall efficiency of DMUs, and output 3 (the average time patients leave the emergency room) is the most important. The variable used is in the output section, and in fact, input 1 (number of CPRs) and output 4 (waiting for the patient for the first doctor's visit) are of the least importance.

5.4 Target of CCR

Our main goal in this research is to improve the performance of the emergency department. Considering what has been explained in the previous chapters and what has been achieved so far this season from the results of the software, in order to improve the performance of the hospital, the efficiency of DMUs should be increased. In fact, by reducing the quantity of inputs or the weight of the inputs or increasing the performance of the outputs, the efficiency of a DMU can be increased. Tables 5.5 and 5.6 show the weight of inputs and outputs, the target weight of each input and output, and the gain of each input and output for each DMU obtained by the software.

Table 5.6: Target of CCR for Input

	input1 Value	input1 Target	input1 Gain(%)	Input2 Value	Input2 Target	Input2 Gain(%)	Input3 Value	Input3 Target	Input3 Gain(%)
DMU01	0.61	0.35	-42.93	0.95	0.58	-38.53	0.78	0.48	-38.53
DMU02	0.17	0.17	0	0.88	0.88	0	0.77	0.77	0
DMU03	0.17	0.08	-49.32	0.89	0.45	-49.32	0.75	0.32	-57.54
DMU04	0.08	0.08	0	0.95	0.95	0	0.74	0.74	0
DMU05	0.64	0.64	0	0.95	0.95	0	0.71	0.71	0
DMU06	1	0.35	-65.07	0.95	0.61	-35.36	0.61	0.4	-35.36
DMU07	0.25	0.19	-25.39	0.83	0.6	-28.17	0.58	0.43	-25.39
DMU08	0.33	0.17	-50.03	0.9	0.45	-50.03	0.69	0.27	-61.2
DMU09	0.86	0.4	-53.6	0.82	0.68	-16.75	0.71	0.48	-31.77
DMU10	0.5	0.5	0	0.83	0.83	0	0.93	0.93	0
DMU11	0.39	0.27	-29.32	0.78	0.55	-29.32	0.9	0.41	-54.73
DMU12	0.64	0.49	-23.46	0.96	0.75	-21.16	0.51	0.4	-21.16
DMU13	0.39	0.36	-7.15	0.96	0.73	-24.49	1	0.49	-50.76
DMU14	0.5	0.22	-55.32	0.81	0.39	-51.45	0.99	0.31	-68.32
DMU15	0.58	0.58	0	0.83	0.83	0	0.9	0.9	0

DMU16	0.42	0.42	0	0.92	0.92	0	0.24	0.24	0
DMU17	0.72	0.72	0	0.96	0.96	0	0.46	0.46	0
DMU18	0.33	0.2	-40.93	1	0.41	-58.63	0.52	0.3	-40.93
DMU19	0.47	0.47	0	0.87	0.87	0	0.56	0.56	0
DMU20	0.33	0.26	-23.14	0.81	0.62	-23.14	0.65	0.46	-28.65
DMU21	0.61	0.45	-25.71	0.83	0.79	-4.6	0.4	0.38	-4.6
DMU22	0.25	0.2	-21.79	0.89	0.52	-41.27	0.44	0.35	-21.79
DMU23	0.47	0.47	0	0.84	0.84	0	0.54	0.54	0
DMU24	0.5	0.5	0	0.96	0.96	0	0.51	0.51	0
Total	11.21			21.37			15.89		

Table 5.6 shows the weight of the target that the inputs of each DMU should reach in order to improve the performance of the DMU and the percentage of this change. As you can see, for DMU 1, the input weight is 0.61, but the optimal input weight 1 for DMU improvement is 0.35. So the input 1 must be reduced to 35.0 to get the DMU1 to perform better. The percentage of this change is 42.93. A negative sign indicates a decrease in input weight. In fact, input 1 should be reduced by 42.93%. For input 2, we have to reduce 38.53 per cent, and for input 3, it reduces the DMU reduction by 38.53 per cent to the desired performance. In fact, the overall reduction in these three inputs brings the DMU1 closer to optimal performance. In fact, reducing the number of CPRs, reducing the number of nurses and physicians, and reducing the number of patients waiting to see a DMU1 doctor (April 2018) brings them closer to optimal performance.

This percentage reduction for other DMUs is also shown in Table 5.6, which is similar to the DMU 1 analysis. Imam, as you can see, for some DMUs, this percentage change is equal to 0! In fact, these are the same DMUs that were selected as criteria, and their efficiency was 100%. In fact, the weight of each input for them is equal to the ideal weight that the software calculates for each input, so the percentage change is zero.

The lowest percentage change in each input indicates that the input is closer to the efficient boundary line. It should be noted that the DMU21, as we saw in Table 5.3, was 95% closer to the efficient boundary line. In fact, it is clear from this that the DMU 21 is the closest DMU to the optimal performance boundary line.

Table 5.7: Target of CCR for Output

	Out1 Value	Out1 Target	Out1 Gain	Out2 Value	Out2 Target	Out2 Gain	Out3 Value	Out3 Target	Out3 Gain	Out4 Value	Out4 Target	Out4 Gain
DMU01	0.25	0.25	0	0.5	0.5	0	0.35	0.35	0	0.29	0.29	0
DMU02	0.25	0.25	0	0.33	0.33	0	0.21	0.21	0	0.25	0.25	0
DMU03	0	0.03	2.7E+308	0.25	0.25	0	0.13	0.13	0	0.23	0.23	0
DMU04	0	0	2.7E+308	0.5	0.5	0	0.25	0.25	0	0.38	0.38	0
DMU05	0.75	0.75	0	0.25	0.25	0	0.21	0.21	0	0.87	0.87	0
DMU06	0.25	0.25	0	0.5	0.5	0	0.33	0.33	0	0.17	0.31	77.66
DMU07	0	0.17	2.7E+308	0.5	0.5	0	0.11	0.17	49.55	0.15	0.22	44.45
DMU08	0	0.14	2.7E+308	0.33	0.33	0	0.11	0.12	9.37	0.25	0.25	0
DMU09	0.5	0.5	0	0.5	0.5	0	0.25	0.25	0	0.33	0.33	0
DMU10	0	0	2.7E+308	1	1	0	1	1	0	0.17	0.17	0
DMU11	0.25	0.25	0	0.33	0.38	13.28	0.33	0.33	0	0.25	0.25	0
DMU12	0.5	0.5	0	0.33	0.38	13.26	0.32	0.32	0	0.35	0.39	11.39
DMU13	0.75	0.75	0	0.25	0.29	14.24	0.22	0.22	0	0.12	0.26	121.38
DMU14	0.25	0.25	0	0.33	0.33	0	0.24	0.24	0	0.12	0.12	3.26
DMU15	1	1	0	0.25	0.25	0	0.23	0.23	0	0.13	0.13	0
DMU16	0.25	0.25	0	0.33	0.33	0	0.23	0.23	0	1	1	0
DMU17	1	1	0	0.33	0.33	0	0.26	0.26	0	0.35	0.35	0
DMU18	0	0.05	2.7E+308	0.33	0.33	0	0.28	0.28	0	0.23	0.23	0
DMU19	0.5	0.5	0	1	1	0	0.27	0.27	0	0.29	0.29	0
DMU20	0.25	0.25	0	0.5	0.5	0	0.27	0.27	0	0.23	0.23	0
DMU21	0.5	0.5	0	0.25	0.36	42.24	0.29	0.29	0	0.52	0.52	0
DMU22	0	0.06	2.7E+308	0.33	0.34	0.85	0.27	0.27	0	0.33	0.33	0
DMU23	1	1	0	0.33	0.33	0	0.26	0.26	0	0.31	0.31	0
DMU24	0.25	0.25	0	1	1	0	0.27	0.27	0	0.27	0.27	0
Total	8.5			10.55			6.69			7.59		

Table 5.7 shows the weight of the outputs. As can be seen, for the outputs we have to increase the weight of the outputs in order to achieve the desired performance for the DMUs. Here, too, if the weight gain is 0, it indicates that the DMU is at the highest performance level for that output. But in outputs where we have a positive increase percentage, that means that rooster needs to be improved to get the DMU closer to optimal performance. For example, output 4 for the DMU 6 needs a 77.66 per cent increase, meaning that the average patient waiting time for the first visit needs to be improved to bring the DMU 6's performance closer to the desired performance. In the next chapter, we will discuss the results of this chapter.

5.5 Sensitivity Analysis

According to Table 5.5 and from the sum of the weights for each input and output, we find that the maximum weight between the inputs for input 1 is 24.36 and the maximum weight between the outputs is output 3 with the value of 15.93. Therefore, the most important input between inputs is input 1, which is the number of CPR patients. As a result, this input is of great importance, after which output 3 is next in importance, which is the time interval between patients' emergencies and emergencies. From this point of view, in order to achieve the best emergency performance, it is necessary to pay more attention to input 1 and output 3. Table 5.6 and Table 5.7 also show that inputs 1 and output 3 are more efficient. After input 1 and output 3, input 2 means the number of doctors and nurses in the next priority. Then output 1 means successful CPR, input 3 is the number of patients per triage level, the output is 2 median time to determine patients' assignments, and finally, output 4 is the average duration of each triage level.

5.6 Forecasting

Regarding the projected numbers for 2021, it is worth noting that the numbers that worked were taken into account, but for those factors that did not work, the average of the previous data was used. According to the results obtained in the previous sections, if the inputs and outputs of 2021 are the same numbers, the result is that it is efficient. Also, if the 2021 numbers are predicted to be a multiple of these numbers, the result is that it works and is efficient.

Table 5.8: Forecasting

2021							
	Input 1	Input 2	Input 3	Output 1	Output 2	Output 3	Output 4
DMU01	0.35	0.65	0.48	0.25	0.5	0.35	0.29
DMU02	0.17	0.88	0.77	0.25	0.33	0.21	0.25
DMU03	0.33	0.64	0.61	0.03	0.25	0.13	0.23
DMU04	0.08	0.95	0.74	0.1	0.5	0.25	0.38
DMU05	0.64	0.95	0.71	0.75	0.25	0.21	0.87
DMU06	0.34	0.51	0.35	0.25	0.5	0.33	0.27
DMU07	0.36	0.73	0.49	0.17	0.5	0.22	0.25
DMU08	0.21	0.53	0.36	0.14	0.33	0.19	0.25
DMU09	0.42	0.73	0.43	0.5	0.5	0.25	0.33
DMU10	0.5	0.83	0.93	0.1	1	1	0.17
DMU11	0.37	0.69	0.47	0.25	0.35	0.33	0.25
DMU12	0.49	0.85	0.45	0.5	0.69	0.32	0.33

Chapter 6

CONCLUSION AND RECOEMMENDATION

In this part of the research, the performance of the hospital emergency department is evaluated based on hospital emergency indicators. Data analysis used data envelopment analysis method and the conclusion was based on the results obtained using the CCR model as a method of data analysis from a hospital emergency.

6.1 Conclusion

One of the most important parts of the health system is hospitals. The hospital is a combination of several different systems for providing services and training positions for specialized and sub-specialized human resources of the health system, and since all these systems are obliged to cooperate with each other in this large unit, it is prone to all kinds of performance overlaps. It should not be forgotten that the emergency room of a hospital is a showcase of services and the first entry point for patients and their companions with the medical system, and in other words, the mental image of the clients is formed there.

Therefore, the application of any continuous monitoring mechanism on the process of providing services, reviewing the results of activities within the framework of key performance and quality indicators (efficiency, effectiveness, safety, access, continuity, patient-centred, work environment and fitness) and monitoring the satisfaction of all stakeholders. It is able to provide a good picture of how to manage treatment and to be useful in responding to the key part of the vital needs of society in providing and maintaining the desired level of personal and social health. The topics discussed in Chapter 2 are based on findings from researchers in the past. Some findings on the practical applications of data envelopment analysis, which is the method used in this study, were also discussed in Chapter 2. The basic concept of the method used in this study was explained in Chapter 3, and the procedures used to quantify and obtain each of the variable data in Chapter 4 were explained. The data obtained in this study were solved using PIM-DEA software based on CCR model as a method that is one of the techniques of data envelopment analysis and also analysis of results in the previous chapter (Chapter 5).

According to the data and analysis in the previous chapter, according to the inputs and outputs of this study and from Table 5.2, the highest returns for DMU 2 (May 2018), DMU 4 (July 2018), DMU 5 (August 2018), DMU 10 (January 2019), D MU15 (June 2019), DMU 16 (July 2019), DMU 17 (August 2019), DMU 19 (October 2019), DMU 23 (February 2020), DMU 24 (March 2020) was obtained. These DMUs have the highest performance and efficiency among others. In fact, these DMUs have the highest number of successful CPRs, the best time to allocate patients, the best time for patients to leave the emergency room, and the shortest waiting time to see a doctor at the triage level. These DMUs are used as an efficient criterion for comparison with all DMUs.

Also, as mentioned in the previous chapter, from Table 5.5 and the weight of inputs and outputs for each DMU and finally from the total weights for each input and output, it was determined that the maximum weight for input 1 and then the maximum weight for output 3 is. In fact, in order to achieve the best performance in the emergency department of the hospital, each of the inputs and outputs in this study has a priority, and according to the results of the previous chapter, the highest weight is given to input 1, ie the number of CPR patients. In fact, from the point of view of this research, the most important priority is the number of CPR patients. With this in mind, it is possible to focus on accepting CPR patients in order to increase the level of emergency function. The next most important factor is the average time the patient leaves the hospital. Of course, in fact, in talking to the hospital's experts, they also mentioned that the time when the patient leaves the hospital is a very important indicator because considering the hospital's capacity and the number of staff, the lower the average time the patient leaves the hospital, the higher the work efficiency. We also saw from the previous chapter that the number of doctors and nurses is the next priority, which is very important in reality because it increases the capacity of the hospital and also lowers the average time to determine the patient's task and the average time to leave it. The successful CPR of the emergency department is the next priority indicator, which is also very important in reality. The number of patients at each level of triage and the average time to determine patients' tasks are the last priority. Therefore, based on the results of this research and by improving each of the inputs and outputs based on their priorities, the efficiency and performance of the hospital emergency department can be improved.

6.2 Recommendation

According to what has been said, the most important indicator from the perspective of this research is the number of CPR patients. Patients who are waiting for ICU services and staying in the emergency room are usually among the patients who may have CPR, which raises the CPR rate. In fact, the average time patients leave the hospital emergency room is, as mentioned, the next important indicator. Therefore, it is recommended that researchers in future research address CPR in emergency departments of hospitals as it is important to improve hospital emergency performance. In fact, researchers in future research can work on the average time patients leave the emergency room because in addition to the results of this study from the perspective of health experts, this is one of the most important things in improving emergency performance. Because the higher the average time of the patient's presence in the emergency room, the lower the capacity of the emergency room and the lower the efficiency of the emergency room with the involvement of nurses and doctors.

The next priority is the number of doctors and nurses, and successful CPRs. This can be explored in future research, and in fact, the impact of the number of physicians and nurses on the successful emergency CPRs can be examined directly and separately. Also, one of the important indicators that are suggested to be researched separately and completely is the average time of determining the patients' duties in the emergency room. Because this index also affects emergency performance and is related to other indicators.

It is also recommended that the emergency departments of the hospital, due to the difficulty of extracting data from the patient's file, as well as the problems related to the registration of data in hospitals, design electronic patient files with the help of IT engineers in programs and work priorities. Short-term, doctor's instructions, the time of the doctor's first visit based on the hospital's order and assignment of the patient during emergency discharge should be recorded on the computer and with the coordination of computer engineers in the hospital, the necessary reports should be extracted from HIS system. In this way, indicators can be examined to improve the performance of the emergency department.

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APPENDIX

Formulas

$Vitual\ Input\colon\ X_k = v_1 X_{1k} + v_2 X_{2k} + \cdots + v_m X_{mk} = \sum_{i=1}^{m} v_i X_{ik}$

(3.1)

$Vitual\ Output\colon\ Y_k = u_1 Y_{1k} + u_2 Y_{2k} + \cdots + u_n Y_{nk} = \sum_{i=1}^{n} u_r Y_{rk}$

(3.2)

$$Max\ \ r_k\colon \quad r_k = \frac{\sum_{i=1}^{s} u_r Y_r}{\sum_{i=1}^{m} v_i X_i} \tag{3.3}$$

$$\frac{\sum_{r=1}^{s} u_r Y_{rj}}{\sum_{i=1}^{m} v_i X_{ij}} \leq 1 \qquad ; j = 1,2, \ldots, n \tag{3.4}$$

$u_r \geq 0 \quad ; r = 1,2, \ldots, s \qquad\qquad v_i \geq 0 \quad i = 1,2, \ldots, m$

$$Max\colon \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \tag{3.5}$$

$s.t.$

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, r = 1,2, \ldots, s \tag{3.6}$$

$u_r \geq 0, v_i \geq 0$

$Min\ \theta$

Subject to:

$$\sum_{j=1}^{n} x_{ij}\lambda_j \leq \theta_k x_{ik}$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j \geq y_{rk}$$

$$\lambda_j \geq 0$$

$$Max \sum_{r=1}^{s} u_r y_{r\circ} \tag{3.7}$$

$$s.t.: \sum_{i=1}^{m} v_i x_{i\circ} = 1 \tag{3.8}$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \qquad j = 1, \ldots, n \tag{3.9}$$

$$u_r \geq 0 \qquad v_i \geq 0$$

$$Min \sum_{i=1}^{m} V_i x_{io} \tag{3.10}$$

$$s.t. \sum_{r=1}^{s} u_r y_{ro} = 1 \tag{3.11}$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \quad j = 1, \dots, n$$

(3.12)

$u_r \geq 0 \quad v_i \geq 0$

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

(3.13)

$s.t.$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq m$$

(3.14)

$u_r \geq 0, v_i \geq 0, m \geq 0$

$$\frac{\sum_{r=1}^{s} u_r y_{ro} - \sum_{i=1}^{m} v_i x_{io}}{max\{\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij}\}}, j = 1,2 \dots, n$$

(3.15)

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

(3.16)

$s.t.$

$$\sum_{r=1}^{s} \frac{u_r}{m} y_{rj} - \sum_{i=1}^{m} \frac{v_i}{m} x_{ij} \leq 1$$

(3.17)

$u_r \geq 0, v_i \geq 0, m \geq 0$

$$Max \sum_{r=1}^{s} u_r^{'} y_{ro} - \sum_{i=1}^{m} v_i^{'} x_{io}$$

(3.18)

$$s.t. \sum_{r=1}^{s} u_r^{'} y_{rj} - \sum_{i=1}^{m} v_i^{'} x_{ij} \leq 1$$

(3.19)

$$u_r^{'} \geq 0, v_i^{'} \geq 0$$

$$Min\ \ E = \sum_{j=1}^{n} \quad (a_j p_j + b_j \eta_j)$$

(3.20)

$$s.t.: \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} = \rho_j - \eta_j$$

(3.21)

$$\sum_{i=1}^{m} v_i x_{ij} = 1$$

(3.22)

$$u_r, v_i, \rho_j, \eta_j \geq 0$$

$$\sum_{r=1}^{s} u_r y_{ro} = \rho_o - \eta_o + \sum_{i=1}^{m} v_i x_{io} = 1 + \rho_o - \eta_o$$

(3.23)

The applied parameters in the formulas are as follows:

r_k= Efficiency

$m = Number\ of\ inputs\ used\ in\ each\ decision\ making\ units (DMUs)$

$s = Number\ of\ Outputs\ produced\ in\ each\ Decision\ making\ units (DMUs)$

$u_r = Output\ weight\ \ (r = 1, 2, 3 \ldots s)$

$v_i = Input\ weight\ \ (i = 1, 2, 3 \ldots .m)$

y_{rk} = Amount of output r produced the observed DMU_o

x_{ik} = Amount of input i used by the observed DMU_o

y_{rj} =Amount of output i produced by DMU_j

x_{ij} = Amount of input i used DMU_j

$n = Number\ of\ decision\ making\ units\ (DMUs)$