EASTJ Engineering, Agriculture, Science and Technology Journal

e-ISSN: 2948-4065
Volume 2 Number 1 August 2023, 75 ~ 86
DOI: https://doi.org/10.37698/eastj.v2i1.205
❐ 75

Discrete-Event Simulation (DES) and Banker, Chames and Cooper Data Envelopment Analysis (BCC-DEA) Models in Improving the Allocation Officers in Outpatient Department

Siti Nur Fadhilah Masrom[1], Phang Yook Ngor[1], Ruzanita Mat Rani[1]
[1]Universiti Teknologi Mara, Malaysia

ARTICLE INFO

Article history:

Received June 01, 2023
Revised June 13, 2023
Accepted June 23, 2023

Keywords:

Public Healthcare,
Discrete-Event Simulation,
Banker, Chames and Cooper Data Envelopment Analysis,
Resource Allocation,
Arena Software,
Lingo Software

Conflict of Interest:

None

Funding:

None

ABSTRACT

This study aims to propose an improvement model for the queuing system and determine the best and most appropriate allocation suggestion for officers at the outpatient department of a public clinic in Johor. In this study, Arena Simulation Software and Lingo Software were used. Discrete-Event Simulation (DES) and Banker, Chames, and Cooper Data Envelopment Analysis (BCC-DEA) models were used to determine the best improvement model across various alternatives. The Min-Max of officers was suggested as an improvement model. The mathematical formulation has been programmed and tested in the Lingo 19.0 software, and Decision-Making Units (DMU) would be suggested. After that, each DMUs were run in Arena Simulation Software. Then, the input and output of each DMUs were determined. The researcher used BCC Model Input-Oriented to reduce the input required to produce the optimal output. The mathematical formulation has been programmed again and tested in the Lingo 19.0 software. Based on the results, DMU is considered an efficient choice if the value θ_0 is one (θ_0= 1). DMU is considered an inefficient alternative if the value θ_0 is not one (θ_0 ≠ 1). The input-oriented BCC model needs to identify the most effective and efficient DMU because they have multiple DMUs that are rated as efficient. So, the Super Efficiency model was used to identify the most efficient and suitable DMU. The mathematical formulation has been programmed again and tested in the Lingo 19.0 software to identify the Super Efficiency model.

Corresponding Author: Phang Yook Ngor, Universiti Teknologi Mara, Cawangan Melaka, 110 Off Jalan Hang Tuah, 75350 Melaka, Malaysia. Tel. +6017-6997228. E-mail: phang@uitm.edu.my

1. Introduction

Forming a healthier nation requires a healthcare system that is both equitable and effective. A healthier population leads to greater productivity, and a more effective healthcare system can boost economic growth. Over the past few years, society's healthcare services have shown remarkable improvement. Khairy Jamaluddin, Malaysia's Minister of Health, has proposed six new initiatives to improve the country's healthcare system, which would cost RM3.4 billion to be included in the 2023 Budget. The six initiatives include strengthening healthcare and wellness programs, improving and refurbishing the ministry's health facilities, increasing the effectiveness of healthcare treatment, replacing critical and obsolete medical assets, digitizing healthcare services, and offering appreciation incentives for medical staff (Bernama, 2022).

It is important to keep people happy with a functioning healthcare system. Efforts to increase productivity, decrease expenses, and implement cutting-edge technological advancements will all have that effect (Ibrahim & Daneshvar, 2018). Along with the increase in population density, it is important for the healthcare system to operate efficiently to handle the increase in healthcare demand. The national health policy identifies health service delivery and strengthening the role of the Ministry of Public Health as top priorities in the health sector.

Providing health care to every citizen is a huge step toward social change. Therefore, it is imperative that the healthcare system function effectively to guarantee universal health coverage. Improving the effectiveness and functionality of the current healthcare system will influence the quality of healthcare provided.

2. Data Envelopment Analysis (DEA)

According to Azadeh et al. (2007), Emrouznejad et al. (2010), Rani et al. (2014) and Wan Mohd Aminuddin et al. (2018), Data Envelopment Analysis (DEA) is a nonparametric method. It is a linear programming-based technique for determining the relative efficiency of a set of entities, called decision-making units (DMUs), using predetermined inputs and outputs. It was first introduced into the operational research and management science literature by Charnes, Cooper, and Rhodes (Azadeh et al., 2007; Charnes et al., 1978). According to Vincová (2005), the purpose of DEA models in measuring the efficiency of producing units DMU is to maximize their efficiency rate. The models must incorporate all the characteristics under evaluation, meaning the weights of all inputs and outputs must be larger than zero.

According to Weng et al. (2011), there are some advantages of utilizing DEA, such as (a) the ability to assume a deterministic connection between inputs and outputs, as well as the efficiency with which the efficiency scale may be estimated, (b) the ability to handle numerous inputs and outputs simultaneously without the need to assume the functional form of the relationship between inputs and outputs as regression methods do, and (c) the ability to compare with peers or a combination of peers simultaneously without the need for sensitive information such as price.

The BCC-DEA model was introduced by Banker, Chames, and Cooper in 1984 and is used to assess Technical Efficiency as the convexity constraint and assures that the composite unit is of the same scale size as the unit being measured. The resulting efficiency must have at least one, and efficient DMUs have the lowest input or greatest output levels (Sreedevi, 2016).

BCC Formulation (Sreedevi, 2016; Vincová, 2005)

$$Z\,(BCC) = \text{Min}\ \lambda \qquad 1$$

Subject to

$$\sum_{j=1}^{n} \lambda_i x_{ii} \leq \lambda x_{io} \quad i=1,2 \ldots\ldots m \qquad 2$$

$$\sum_{j=1}^{n} \lambda_i \mu_{ri} \geq \mu r_o \quad r=1,2 \ldots\ldots s$$

$$\sum_{j=1}^{n} \lambda_i = 1 \quad \lambda_i \geq 0$$

Where,

Z (BCC) = efficiency measure corrected for scale differences

n= decision-making units

m= inputs

s= output

3. BCC-DEA Input-Oriented Model

There are two types of BCC models: input- and output-oriented. The input-oriented model reduces the amount of input required to produce optimal output. The output-oriented model maximises the required output by using a quantity of no more than the given input source (Wan Mohd Aminuddin et al., 2018).

So, in this study, the input-oriented BCC model was more appropriate than the output-oriented one because it had limited resources of officers and doctors in health clinics while being able to produce better output and quality services. Other than that, used Banker, Chames and Cooper Data Envelopment Analysis (BCC-DEA) input oriented provides high-quality services while using minimum resources (Mohd Yusoff et al., 2021).

$$Max_s \theta_0 = \sum_{j=1}^{m} u_j y_{j0} + u_0 \qquad 3$$

Subject to

$$\sum_{i=1}^{s} v_i x_{i0} = 1 \qquad 4$$

$$\sum_{j=1}^{m} u_j y_{jk} - \sum_{i=1}^{s} v_i x_{ik} + u_0 \leq 0, k = 1, \ldots, n$$

$$u_j \geq 0$$

$v_i \geq 0$
$i = 1,2, \ldots, m,$
$j = 1,2, \ldots, n,$
Where;

u_0 = unconstrained in sign

θ_0 = relative efficiency for DMU_0

x_{i0} = input vector of DMU_0

y_{j0} = output vector of DMU_0

x_{ik} = actual value of input i of DMU_k

y_{jk} = actual value of output j of DMU_k

u_j = the weight given to output j

v_i = the weight given to input i

n = the output number

m = the input number

Based on the equation above, if the value of θ_0 is one ($\theta_0 = 1$), then DMU is an efficient choice. If the value of θ_0 is not one ($\theta_0 \neq 1$), then DMU is an inefficient alternative.

4. Super Efficiency

However, there are certain drawbacks to employing this BCC-DEA. According to some researchers, there is an inability to discern between efficient DMUs and an unrealistic distribution of input and output weights (Lawrence & Zhu, 1999; Mohd Yusoff et al., 2021). Inefficient DMUs receive a score of less than one, while efficient DMUs receive a score equal to one. So, while inefficient DMUs are ranked, efficient DMUs are not. Therefore, various improvements for ranking efficient DMUs with crisp data are proposed to overcome this issue (Azadeh et al., 2007; Wan Mohd Aminuddin et al., 2018). Among the proposed improvements are Reference Sets, Cross-Efficiency and Super-Efficiency. So, in this study, the researcher used Super-Efficiency.

According to Andersen & Petersen (1993), Lawrence & Zhu (1999) and Rani et al. (2014), Super-Efficiency is applied to rank improvement models and choose the best improvement model among various DMUs given by the BCC-DEA model.

$$\varpi_0 = \min \sum_{i=1}^{m} v_{ik} x_{ijo} - v_0 \quad 5$$

$$s.t. \begin{cases} \sum_{r=1}^{s} u_r y_{rj0} = 1 \\ \sum_{r=1}^{s} u_r y_{jr} - \sum_{i=1}^{m} v_{ik} x_{ij} + v_0 \leq 0 \\ v_0\, free, u_r, v_i \geq \varepsilon, r = 1, \ldots, s_i = 1, \ldots, m_j = 1, \ldots, n \end{cases} \quad 6$$

The Super Efficiency-BCC score should be obtained from

$$\left(\frac{\mathbf{1}}{\boldsymbol{\varpi_0}}\right) > \mathbf{1} \quad 7$$

The highest Super Efficiency-BCC score is considered the best DMU

5. Methodology

5.1 Research Framework

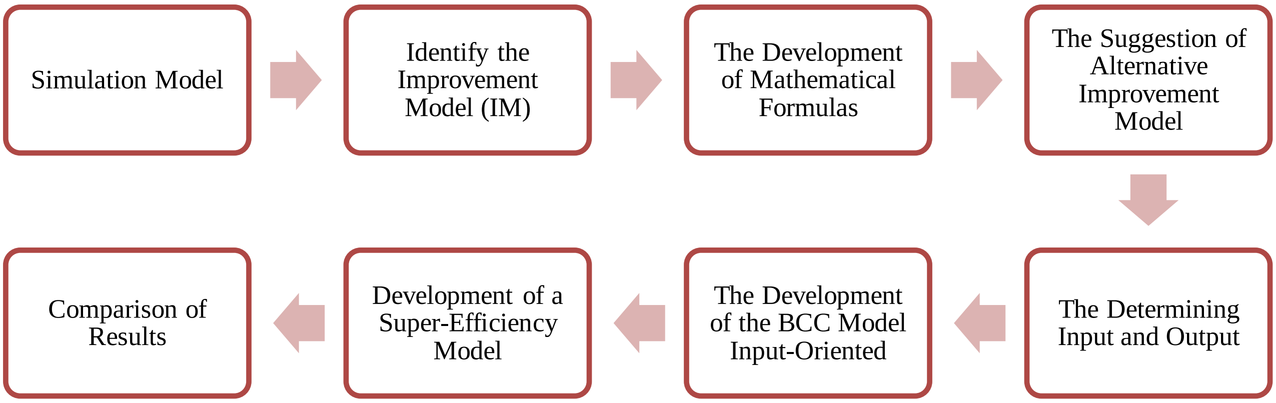

Figure 1. Research Framework

5.2 Simulation Model

Patients arrived at the health clinic at 8.00 a.m. There were two types of patients. Express patients include pregnant women, children under one year, elderly, disabled patients, or emergency cases. Regular patients are other than those classified as express patients. Express patients entered the express route, while regular patients entered the regular route. The entrance for express patients is right in front of the triage counter. This is to make it easier for the patient to enter the clinic. Meanwhile, regular patients must go through a slightly longer line. At the triage station, the nurse suggested which patients needed to go. Patients would go to an isolation clinic if the patients had symptoms such as fever, cough, or flu. Outpatients went to the outpatient department, while others went to the non-outpatient department.

The outpatient went to the registration station. Some of them had to take blood pressure. Some were not. Afterwards, they went to the doctor, laboratory, radiology, dressing, or pharmacy route. At the doctor's station, the patients took numbers first. There was an express counter and express doctor room for express patients and a regular counter and doctor room for regular patients. Express patients got speciality which was their line quicker than the regular line.

At the laboratory station, the patients needing the simple test took numbers and waited for the blood, urine, or sputum tests. While at the radiology unit, the patients took the number and the X-ray. After settling, they take an X-ray, and the patients must wait until they get the result. Some patients went to the dressing station. Lastly, the patients had to go to the pharmacy station. The same goes for doctor stations; there was an express search drug and pharmacy counter for express patients and a regular search drug and pharmacy counter for regular patients.

The first phase of simulation model development involves data collection. The simulation of the outpatient department is designed in ARENA software. An input Analyzer collects and fits all data to select the most suitable probability distribution for the modelling process. After the verification tests and validation of the simulation model were completed, outpatient department bottlenecks were identified

The table below is a simulation report from ARENA software.

Table 1. Number In, Number Out, and Patients Remain in System of Simulation Report

	Express Patient (Person)	Regular Patient (Person)	Total (Person)
Number in	196	202	398
Number out	194	183	377
In system	2	19	21

The total time in the system has been set for 9 hours, based on the operation hour of the clinic, which is from 8.00 a.m. to 5.00 p.m. The replication was already set as 30 replications. According to the table above, 196 patients were express patients entering the system, while 194 patients were express patients leaving the system. There were still 3 individuals in the system. For regular patients, 202 patients were entering the system, while 183 patients were express patients leaving the system. There were still 19 individuals in the system. So, the total number of patients entered the system was 398 patients. The total patient's exit the system was 377. 21 patients remained in the system.

Table 2. Service Time, Waiting Time, Total Time and WIP

	Express Patient (min)	Regular Patient (min)
Service time	19.2695	16.9886
Waiting time	71.6728	133.19
Total time	91.4298	150.91

For express patients, the service time was 19.2695 minutes. The waiting time was 71.6728 minutes. The total time was 91.4298 minutes. For regular patients, the service time was 16.9886 minutes. The waiting time was 133.19 minutes. The total time was 150.91 minutes.

5.3 Identify the Improvement Model (IM)

After verifying and validating the simulation model and analysing the results, the researcher provided some suggestions for modification for improving the simulation model throughout specific stages to achieve the KPI. The modification of the original simulation model is to obtain the best improvement model based on the allocation of doctors, nurses, and staff. To acquire more information about the configuration of the necessary resources, a collaborative discussion with the administration of the health clinic was held. Following discussion and approval from the health clinic, certain suggestions have been made for the allocation officer based on the configuration of the minimum and maximum number of resources required.

Table 3. Min-Max No. of Officer Current and After Improvement

Officer	No. of Current Officer	No. of Officer after Improvement	
		Min	Max
Registration Take Number Officer	1	1	1
Registration Counter Officer	2	2	3
Take Blood Pressure Officer	1	1	1
Doctor Take Number Officer	1	1	1
Express Doctor Officer	3	3	4
Regular Doctor Officer	2	2	3
Lab Officer	1	1	1
Radio Officer	1	1	1
Dressing Officer	1	1	2
Pharmacy Take Number Officer	1	1	1
Express Search Drug Officer	3	2	3
Regular Search Drug Officer	2	2	3
Pharmacist	1	1	1
Total	20	19	25

The equation below shows the min-max officer allocation formulation developed based on the maximum and the minimum number of officers at each station/checkpoint modified by Field Rani et al.

$$\sum_{a=1}^{A}\sum_{b=2}^{B}\sum_{c=1}^{C}\sum_{d=1}^{D}\sum_{e=3}^{E}\sum_{f=2}^{F}\sum_{g=1}^{G}\sum_{h=1}^{H}\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=2}^{K}\sum_{l=2}^{L}\sum_{m=1}^{M} n_a + o_b + p_c + q_d + r_e + s_f + t_g + u_h + v_i + w_j + x_k + y_l + z_m = \bar{X} \quad (10)$$

$$\sum_{\bar{v}}^{\bar{V}} (\bar{X}_{n,o,p,q,r,s,t,u,v,w,x,y,z} \leq 25) = \bar{T} \quad (11)$$

Where;

a is the index for total officers at the registration take number process,

b is the index for total officers at the registration counter process,

c is the index for total officers at the take blood pressure process,

d is the index for total officers at the doctor take number process,

e is the index for total officers at the express doctor process, f is the index for total officers at the regular doctor process,

g is the index for total officers at the lab process,

h is the index for total officers at the radio process,

i is the index for total officers at the dressing process,

j is the index for total officers at the pharmacy take number process,

k is the index for total officers at the express search drug process,

l is the index for total officers at the regular search drug process,

m is the index for total officers at the pharmacy process,

A is the number of total officers at the doctor take number process,

B is the number of total officers at the registration counter process,

C is the number of total officers at the take blood pressure process,

D is the number of total officers at the doctor take number process,

E is the number of total officers at the express doctor process,

F is the number of total officers at the regular doctor process,

G is the number of total officers at the lab process,

H is the number of total officers at the radio process,

I is the number of total officers at the dressing process,

J is the number of total officers at the pharmacy take number process,

K is the number of total officers at the express search drug process,

L is the number of total officers at the regular search drug process,

M is the number of total officers at the pharmacy process,

n is the total officers a at the registration take number process,

o is the total officers b at the take blood pressure process,

p is the total officers c at the take blood pressure process,

q is the total officers d at the doctor take number process,

r is the total officers e at the express doctor process,

s is the total officers f at the regular doctor process,

t is the total officers g at the lab process,

u is the total officers h at the radio process,

v is the total officers i at the dressing process,

w is the total officers j at the pharmacy take number process,

x is the total officers k at the express search drug process,

y is the total officers l at the regular search drug process,

z is the total officers m at the pharmacy process,

$\bar{X}$ is the officer allocation alternative,
$\bar{v}$ is the index for the officer allocation alternative,
$\bar{V}$ is the number of officer allocation alternatives and
$\bar{T}$ is the total number of officer allocation alternatives less or equal to 25 officers.

5.4 The Development of Mathematical Formulas

There have several steps to select the best improvement model. The first phase entailed developing a mathematical formula to list the new resource allocation options suggested in Improvement Models (IM) at outpatient health clinic. This is to facilitate the process of generating all possible resource allocation alternatives. A mathematical formula introduced by Aminuddin & Ismail (2021) has been modified into a new mathematical formula that correlates to the list of new resource allocation possibilities.

$$\bar{X}_{n,o,p,q,r,s,t,u,v,w,x,y,z} \leq \bar{T} \quad (12)$$

Where;

$\overline{X}$ is the officer allocation alternative,

n is the total officers a at the registration take-number process,

o is the total officers b at the registration counter process,

p is the total officers c at the take blood pressure process,

q is the total officers d at the doctor take number process,

r is the total officers e at the express doctor process,

s is the total officers f at the regular doctor process,

t is the total officers g at the lab process,

u is the total officers h at the radio process,

v is the total officers i at the dressing process,

w is the total officers j at the pharmacy take number process,

x is the total officers k at the express search drug process,

y is the total officers l at the regular search drug process,

z is the total officers m at the pharmacy process,

$\overline{T}$ is the maximum number of officer allocation alternatives,

The mathematical formula would be coded and solved in the Lingo 19.0 software to produce resource allocation suggestions for optimising the outpatient queue.

5.5 The Suggestion of an Alternative Improvement Model

Several Decision-Making Units (DMU) would be suggested after the mathematical formulation has been programmed and tested in the Lingo 19.0 software for outpatient health clinics. The results found that 64 DMUs have been proposed for outpatients at health clinics.

Table 4. Min-Max N DMUs of Officers

DMUs	Suggestion of Officers	DMUs	Suggestion of Officers
1(actual system)	(1, 2, 1, 1, 3, 2, 1, 1, 1, 1, 3, 2, 1)	33	(1, 3, 1, 1, 3, 2, 1, 1, 1, 1, 2, 2, 1)
2	(1, 2, 1, 1, 3, 2, 1, 1, 1, 1, 2, 3, 1)	34	(1, 3, 1, 1, 3, 2, 1, 1, 1, 1, 2, 3, 1)
3	(1, 2, 1, 1, 3, 2, 1, 1, 1, 1, 2, 2, 1)	35	(1, 3, 1, 1, 3, 2, 1, 1, 1, 1, 3, 2, 1)
4	(1, 2, 1, 1, 3, 2, 1, 1, 1, 1, 3, 3, 1)	36	(1, 3, 1, 1, 3, 2, 1, 1, 1, 1, 3, 3, 1)
5	(1, 2, 1, 1, 3, 2, 1, 1, 2, 1, 2, 2, 1)	37	(1, 3, 1, 1, 3, 2, 1, 1, 2, 1, 2, 2, 1)
6	(1, 2, 1, 1, 3, 2, 1, 1, 2, 1, 2, 3, 1)	38	(1, 3, 1, 1, 3, 2, 1, 1, 2, 1, 2, 3, 1)
7	(1, 2, 1, 1, 3, 2, 1, 1, 2, 1, 3, 2, 1)	39	(1, 3, 1, 1, 3, 2, 1, 1, 2, 1, 3, 2, 1)
8	(1, 2, 1, 1, 3, 2, 1, 1, 2, 1, 3, 3, 1)	40	(1, 3, 1, 1, 3, 2, 1, 1, 2, 1, 3, 3, 1)
9	(1, 2, 1, 1, 3, 3, 1, 1, 1, 1, 2, 2, 1)	41	(1, 3, 1, 1, 3, 3, 1, 1, 1, 1, 2, 2, 1)
10	(1, 2, 1, 1, 3, 3, 1, 1, 1, 1, 2, 3, 1)	42	(1, 3, 1, 1, 3, 3, 1, 1, 1, 1, 2, 3, 1)
11	(1, 2, 1, 1, 3, 3, 1, 1, 1, 1, 3, 2, 1)	43	(1, 3, 1, 1, 3, 3, 1, 1, 1, 1, 3, 2, 1)
12	(1, 2, 1, 1, 3, 3, 1, 1, 1, 1, 3, 3, 1)	44	(1, 3, 1, 1, 3, 3, 1, 1, 1, 1, 3, 3, 1)
13	(1, 2, 1, 1, 3, 3, 1, 1, 2, 1, 2, 2, 1)	45	(1, 3, 1, 1, 3, 3, 1, 1, 2, 1, 2, 2, 1)
14	(1, 2, 1, 1, 3, 3, 1, 1, 2, 1, 2, 3, 1)	46	(1, 3, 1, 1, 3, 3, 1, 1, 2, 1, 2, 3, 1)
15	(1, 2, 1, 1, 3, 3, 1, 1, 2, 1, 3, 2, 1)	47	(1, 3, 1, 1, 3, 3, 1, 1, 2, 1, 3, 2, 1)
16	(1, 2, 1, 1, 3, 3, 1, 1, 2, 1, 3, 3, 1)	48	(1, 3, 1, 1, 3, 3, 1, 1, 2, 1, 3, 3, 1)
17	(1, 2, 1, 1, 4, 2, 1, 1, 1, 1, 2, 2, 1)	49	(1, 3, 1, 1, 4, 2, 1, 1, 1, 1, 2, 2, 1)
18	(1, 2, 1, 1, 4, 2, 1, 1, 1, 1, 2, 3, 1)	50	(1, 3, 1, 1, 4, 2, 1, 1, 1, 1, 2, 3, 1)
19	(1, 2, 1, 1, 4, 2, 1, 1, 1, 1, 3, 2, 1)	51	(1, 3, 1, 1, 4, 2, 1, 1, 1, 1, 3, 2, 1)
20	(1, 2, 1, 1, 4, 2, 1, 1, 1, 1, 3, 3, 1)	52	(1, 3, 1, 1, 4, 2, 1, 1, 1, 1, 3, 3, 1)
21	(1, 2, 1, 1, 4, 2, 1, 1, 2, 1, 2, 2, 1)	53	(1, 3, 1, 1, 4, 2, 1, 1, 2, 1, 2, 2, 1)
22	(1, 2, 1, 1, 4, 2, 1, 1, 2, 1, 2, 3, 1)	54	(1, 3, 1, 1, 4, 2, 1, 1, 2, 1, 2, 3, 1)
23	(1, 2, 1, 1, 4, 2, 1, 1, 2, 1, 3, 2, 1)	55	(1, 3, 1, 1, 4, 2, 1, 1, 2, 1, 3, 2, 1)
24	(1, 2, 1, 1, 4, 2, 1, 1, 2, 1, 3, 3, 1)	56	(1, 3, 1, 1, 4, 2, 1, 1, 2, 1, 3, 3, 1)
25	(1, 2, 1, 1, 4, 3, 1, 1, 1, 1, 2, 2, 1)	57	(1, 3, 1, 1, 4, 3, 1, 1, 1, 1, 2, 2, 1)
26	(1, 2, 1, 1, 4, 3, 1, 1, 1, 1, 2, 3, 1)	58	(1, 3, 1, 1, 4, 3, 1, 1, 1, 1, 2, 3, 1)
27	(1, 2, 1, 1, 4, 3, 1, 1, 1, 1, 3, 2, 1)	59	(1, 3, 1, 1, 4, 3, 1, 1, 1, 1, 3, 2, 1)
28	(1, 2, 1, 1, 4, 3, 1, 1, 1, 1, 3, 3, 1)	60	(1, 3, 1, 1, 4, 3, 1, 1, 1, 1, 3, 3, 1)

29	(1, 2, 1, 1, 4, 3, 1, 1, 2, 1, 2, 2, 1)	61	(1, 3, 1, 1, 4, 3, 1, 1, 2, 1, 2, 2, 1)
30	(1, 2, 1, 1, 4, 3, 1, 1, 2, 1, 2, 3, 1)	62	(1, 3, 1, 1, 4, 3, 1, 1, 2, 1, 2, 3, 1)
31	(1, 2, 1, 1, 4, 3, 1, 1, 2, 1, 3, 2, 1)	63	(1, 3, 1, 1, 4, 3, 1, 1, 2, 1, 3, 2, 1)
32	(1, 2, 1, 1, 4, 3, 1, 1, 2, 1, 3, 3, 1)	64	(1, 3, 1, 1, 4, 3, 1, 1, 2, 1, 3, 3, 1)

Based on the table above, DMU 1 was the number of resources currently available in the outpatient department. While DMU 2 up to DMU 64 were a new resource distribution alternative proposed to improve the outpatient. This DMU involved a maximum of 25 officers, among them one registration takes number officer, three registration counter officers, one take blood pressure officer, one doctor takes number officer, four express doctor officers, three regular doctor officers, one lab officer, one radio officer, two dressing officers, one pharmacy take number officer, three express search drug officer, three regular search drug officer, and one pharmacist.

After that, each DMU would be run in the simulation model as an input value. As a result, the output value would be obtained.

5.6 The Determining Input and Output

Based on the DMUs, the researcher determined the input and output of each operator allocation alternative. Based on Aminuddin & Ismail (2021) and Rani et al. (2018), the input and output can be determined by a simulation model which was developed using Arena Simulation Software. The following is a list of inputs and outputs in the outpatient department.

Table 5. Input and Output

No	Input	Output
1	Total officers	Average utilization of officers
2	Waiting time express patients	Number of express patients treated
3	Waiting time regular patients	Number of regular patients treated

The total number of DMUs measured must exceed twice the total number of inputs and outputs used; this is one of the requirements to guarantee that the model performs more efficiently.

(Total input + Total output) x 2 13

= (3 + 3) × 2

= 12

According to the Alternative Improvement Model Suggestions table, the total number of DMUs measured is 64 DMUs. The amount is greater than 12, which is more than twice as much input as output. The model thus proved to be more effective.

Table 6. Result of Input and Output of DMUs

	INPUT			OUTPUT		
DMU	Total Officers	WTEP	WTNP	Average Utilization of Officers	NOEP	NONP
1	20	71.6728	133.19	65.8292438	194.1	183.33
2	20	106.01	116.78	66.48407265	181.37	194.8
3	19	106.82	130.46	67.992023	184.33	183.3
4	21	73.4261	116.64	63.39420633	191.9	193.6
5	20	100.53	133.4	65.19541875	182.33	182.57
6	21	101.42	112.44	63.1331521	182.33	193.63
7	21	69.7596	127.6	62.5285161	194.3	183.63
8	22	72.6242	111.26	60.38732414	190.43	193.67
9	20	100.72	126.83	66.74182405	179.63	184.8
10	21	102.54	73.3125	64.00550657	183.77	198.6
11	21	80.8139	129.2	64.58403505	193.47	184.67
12	22	79.495	76.671	62.13670591	194.37	200.67
13	21	103.79	124.5	63.59517962	184.73	184.93
14	22	105.04	70.7129	60.77246073	181.7	197.67
15	22	77.2067	124.98	60.86652168	195.1	186.63
16	23	80.0109	70.5663	58.57172439	200.57	199.63
17	20	100.35	133.59	66.1896862	183.63	183.5
18	21	100.91	112.87	63.497428	181.43	195.47
19	21	52.9109	127.47	63.44213205	197.57	183.37

20	21	55.0323	111.07	64.08727233	195.2	194.6
21	21	96.6509	131.41	62.269514	183.07	184.13
22	22	97.2484	108.83	60.58331086	182.77	193.07
23	22	52.4573	128.2	60.42145259	197.8	184.3
24	23	50.6957	107.26	57.41950348	191.77	190.67
25	21	99.15	122.64	59.2981991	182.1	183.87
26	22	97.8395	69.7798	60.96259914	183.9	197.27
27	22	53.575	121.16	61.08169191	197.77	185.93
28	23	61.5991	77.9817	58.89116922	197.3	196.5
29	22	94.0625	125.42	60.08436582	183.87	184.03
30	23	98.1376	74.1998	58.95640096	185.07	202.07
31	23	52.2745	126.95	58.57748596	194	185.87
32	24	60.1162	79.0649	56.51479488	193.23	199.97
33	20	101.34	128.22	65.5562917	182.93	184.53
34	21	100.46	108.68	62.89204686	182.63	193
35	21	74.2573	127.77	62.74319714	193	184.03
36	22	74.3526	116.09	61.28578377	197.27	192.53
37	21	101.07	127.83	62.86968338	179.17	184.87
38	22	94.998	109.39	60.5519725	183.97	197.5
39	22	70.3546	129.6	60.04237186	193.97	183.07
40	23	74.0482	110.72	58.84750761	194.9	195.37
41	21	102.15	126.03	63.49654519	182.77	185.63
42	22	101.76	69.3975	60.89450927	179.87	201.4
43	22	77.2697	122.76	60.7592695	194	185.77
44	23	78.3556	73.3009	59.12529343	195.33	200.8
45	22	94.7498	125.47	60.40448745	183.47	186.57
46	23	97.3397	68.7257	58.33340309	185.4	200.23
47	23	79.5223	124.36	58.70967257	198.07	183.5
48	24	81.0224	68.7436	57.280529	195.77	201.1
49	21	98.3251	129.18	62.63343519	182.57	184.53
50	22	94.9477	109.22	60.46864218	183.57	194.47
51	22	48.3016	131.39	60.83441495	195.93	181.13
52	23	50.6339	112.66	59.03741009	199	191.8
53	22	96.1722	125.11	60.00789655	185.63	187.93
54	23	96.599	109.84	58.75388352	183.97	193
55	23	43.5157	128.26	57.65260426	199.17	184.07
56	24	47.1413	113.12	56.551899	197.8	194.27
57	22	96.2907	126.89	60.35311541	185.67	183.53
58	23	88.8756	72.924	58.79267491	185.7	199.37
59	23	49.4788	127.17	59.04951157	197.17	185.6
60	24	58.8495	74.9722	56.54560013	197.6	195.13
61	23	97.0987	121.87	58.62451009	183.87	184.33
62	24	95.718	66.7661	56.09305383	184.93	197.2
63	24	45.9737	123.98	56.17532767	196.2	183.57
64	25	57.4013	78.1806	55.07511852	198.27	201.63

5.7 The Development of the BCC Model Input-Oriented

In this study, the researcher used BCC input-oriented model because there had limited resources of officers and doctors in health clinics, but they still needed to provide high-quality services. The suggestion of input and output that 64 DMU is run in the Lingo 19 software based on mathematical formulation.

Table 7. Result of BCC Model Input-Oriented of DMUs

DMU	BCC-DEA	DMU	BCC-DEA	DMU	BCC-DEA	DMU	BCC-DEA
1	1	17	0.9663909	33	0.9709191	49	0.9377082
2	1	18	0.967677	34	0.963597	50	0.9330481
3	1	19	1	35	0.9646399	51	1
4	0.9814263	20	1	36	0.9621826	52	0.9965111
5	0.9663478	21	0.9367089	37	0.9367843	53	0.911235
6	0.9623191	22	0.9280625	38	0.9444781	54	0.8953993
7	0.97044	23	0.9762226	39	0.9308483	55	1
8	0.9467725	24	1	40	0.9228198	56	1

9	0.9731693	25	0.944299	41	0.9378307	57	0.9092708
10	1	26	1	42	1	58	0.9760524
11	0.963472	27	0.9800144	43	0.9378561	59	0.9663069
12	1	28	1	44	0.9980761	60	1
13	0.9380828	29	0.9126727	45	0.912045	61	0.8829716
14	0.9923216	30	0.9654974	46	0.998838	62	1
15	0.9399645	31	0.9189226	47	0.9202231	63	0.98106
16	1	32	0.999523	48	1	64	1

The input-oriented BCC Model evaluates 19 of the 64 DMUs that have been proposed as efficient because the efficiency score value achieved is equal to 1. The DMUs are designated as follows: DMU 1, DMU 2, DMU 3, DMU 10, DMU 12, DMU 16, DMU 19, DMU 20, DMU 24, DMU 26, DMU 28, DMU 42, DMU 48, DMU 51, DMU 55, DMU 60, DMU 62, and DMU 64.

5.8 Development of a Super-Efficiency Model

Based on the table of the BCC Input-Oriented Model demonstrates that multiple DMUs were rated as efficient. Therefore, the input-oriented BCC model could only provide new resource allocation choices; it cannot conclusively identify the most effective and efficient DMU. As a result, the Super Efficiency model, which allows for the precise selection of the most suitable DMU, will be employed as a second method.

The DEA Super-Efficiency Model alters the model by removing constraints pertaining to DMUs that are being assessed (Yusoff et al., 2018).

Table 8. DEA Super-Efficiency Model

DMU	Suggestion of Officers	BCC-DEA	SUPER EFFI	RANKS
1	(1, 2, 1, 1, 3, 2, 1, 1, 1, 1, 3, 2, 1)	1	1.020639	14
2	(1, 2, 1, 1, 3, 2, 1, 1, 1, 1, 2, 3, 1)	1	1.016823	16
3	(1, 2, 1, 1, 3, 2, 1, 1, 1, 1, 2, 2, 1)	1	1.073485	2
10	(1, 2, 1, 1, 3, 3, 1, 1, 1, 1, 2, 3, 1)	1	1.070852	3
12	(1, 2, 1, 1, 3, 3, 1, 1, 1, 1, 3, 3, 1)	1	1.018984	15
16	(1, 2, 1, 1, 3, 3, 1, 1, 2, 1, 3, 3, 1)	1	1.040669	5
19	(1, 2, 1, 1, 4, 2, 1, 1, 1, 1, 3, 2, 1)	1	1.02183	13
20	(1, 2, 1, 1, 4, 2, 1, 1, 1, 1, 3, 3, 1)	1	1.063881	4
24	(1, 2, 1, 1, 4, 2, 1, 1, 2, 1, 3, 3, 1)	1	1.000914	19
26	(1, 2, 1, 1, 4, 3, 1, 1, 1, 1, 2, 3, 1)	1	1.005308	17
28	(1, 2, 1, 1, 4, 3, 1, 1, 1, 1, 3, 3, 1)	1	1.021905	12
42	(1, 3, 1, 1, 3, 3, 1, 1, 1, 1, 2, 3, 1)	1	1.022431	11
48	(1, 3, 1, 1, 3, 3, 1, 1, 2, 1, 3, 3, 1)	1	1.027314	10
51	(1, 3, 1, 1, 4, 2, 1, 1, 1, 1, 3, 2, 1)	1	1.003541	18
55	(1, 3, 1, 1, 4, 2, 1, 1, 2, 1, 3, 2, 1)	1	1.079751	1
56	(1, 3, 1, 1, 4, 2, 1, 1, 2, 1, 3, 3, 1)	1	1.034886	7
60	(1, 3, 1, 1, 4, 3, 1, 1, 1, 1, 3, 3, 1)	1	1.031791	8
62	(1, 3, 1, 1, 4, 3, 1, 1, 2, 1, 2, 3, 1)	1	1.02935	9
64	(1, 3, 1, 1, 4, 3, 1, 1, 2, 1, 3, 3, 1)	1	1.039634	6

The outcomes of 19 different DMU types are displayed in the table above. According to the aforementioned table, DMU 55 was the highest Super Efficiency score, with a reading value of 1.079751, while the scores of the other DMUs were lower. This showed that DMU 55 was more efficient and better than other DMUs.

DMU 55 proposed one registration take number officer, three registration counter officers, one take blood pressure officer, one doctor take number officer, four express doctor officers, two regular doctor officers, one lab officer, one radio officer, two dressing officers, a pharmacy take number officer, three express search drug officers, two regular search drug officers and a pharmacist. So, the total number of officers was 23 officers.

5.9 Comparison of Result

Based on the table of comparison between DMU 1 (original simulation model) and DMU 55 (improvement model), there were several suggestions have been made. The total officers suggested adding three officers: one registration counter officer, one express doctor officer, and one dressing officer. As a result, the waiting time for express patients was lowered from 71.6728 minutes to 43.5157 minutes, the waiting time for regular patients was reduced from 133.19 minutes to 128.26 minutes, the average utilization of officers was reduced from 69.29394084% to 57.65260426%, the number express patient treated was increased from 194.1 patients to 199.17 patients, and the number regular patient treated was increased from 183.33 patients to 184.07 patients.

Table 9. Comparison between DMU 1 and DMU 55

Item	DMU 1	DMU 55
Total Officers	20	23
Suggestion of Officers	(1, 2, 1, 1, 3, 2, 1, 1, 1, 1, 3, 2, 1)	(1, 3, 1, 1, 4, 2, 1, 1, 2, 1, 3, 2, 1)
Waiting Time Express Patients	71.6728 minutes	43.5157 minutes
Waiting Time Regular Patients	133.19 minutes	128.26 minutes
Average utilization of officers	69.29394084 %	57.65260426 %
Number Express Patient Treated	194.1	199.17
Number Regular Patient Treated	183.33	184.07

There are several waiting times targets for each phase to reach KPI for the outpatient department. For registration, the waiting time must be less than 15 minutes. Waiting time at the doctor's room must be less than 30 minutes. Waiting time at the pharmacy must be less than 30 minutes. The total waiting time from registration to the consultation must be less than 90 minutes. The service time for consultation must be between 10 and 20 minutes. The total waiting time in the outpatient department is 60 minutes (Aziati & Hamdan, 2018; Azraii et al., 2017).

Table 10. Comparison between DMU 1, DMU 55 and KPI

Item	DMU 1	DMU 55	KPI
Total officers	20	23	
Waiting time registration counter	32.96	6.778	<15 minute
Waiting time express doctor	47.25	22.14	<30 minute
Waiting time regular doctor	106.27	119.82	<30 minute
Waiting time express patients at pharmacy	1.624	7.079	<30 minute
Waiting time regular patients at pharmacy	30.9	33.42	<30 minute
Total time express patients	91.4298	63.2849	<90 minutes
Total time regular patients	150.91	145.94	<90 minutes
Waiting time express patients	71.6728	43.5157	<60 minutes
Waiting time regular patients	133.19	128.26	<60 minutes
Consultation time express patients	10.0806	10.1604	Between 10 and 20 minutes
Consultation time regular patients	7.2352	7.2711	Between 10 and 20 minutes

According to the table, DMU 55 met most of the checkpoint's KPI or waiting time target especially for express patients. DMU 55 was therefore approved as the suggestion for the allocation of officers.

6. Conclusion

According to the simulation data from the observation, there were some improvements and adjustments to do in this study. The researcher derived mathematical formulas and ran them in the software. 64 DMUs have been suggested, which showed the suggestion of allocation of officers. Then, the input-oriented BCC Model evaluated 19 of the 64 DMUs that have been proposed as efficient because the efficiency score value achieved is equal to 1. After that, the researcher discovered that DMU 55 was the best and most appropriate allocation suggestion for officers after entering the mathematical formula of the super efficiency model in the software to determine which DMU from the other 19 DMUs is most suited.

DMU 55 suggested that the total officers have added three officers: one registration counter officer, one express doctor officer, and one dressing officer. As a result, the waiting time for express patients was lowered from 71.6728 minutes to 43.5157 minutes, the waiting time for regular patients was reduced from 133.19 minutes to 128.26 minutes, the average utilization of officers was reduced from 69.29394084% to 57.65260426%, the number express patient treated was increased from 194.1 patients to 199.17 patients. The number of regular patients treated increased from 183.33 patients to 184.07 patients.

References

Aminuddin, W. M. W. M., & Ismail, W. R. (2021). IMPROVING EMERGENCY DEPARTMENT OVERCROWDING IN MALAYSIAN GOVERNMENT HOSPITAL. *Journal of Quality Measurement and*

Analysis, *17*(1), 19–39.
Andersen, P., & Petersen, N. C. (1993). A Procedure for Ranking Efficient Units in Data Envelopment Analysis. *Management Science*, *39*(10), 1261–1264.
Azadeh, M. A., Anvari, M., & Izadbakhsh, H. (2007). An Integrated FDEA-PCA Method as Decision Making Model and Computer Simulation for System Optimization. *Summer Computer Simulation Conference 2007*, 609–616.
Aziati, A. N., & Hamdan, N. S. B. (2018). Application Of Queuing Theory Model and Simulation to Patient Flow at The Outpatient Department. *Proceedings of the International Conference on Industrial Engineering and Operations Management Bandung, Indonesia*, 3016–3028.
Azraii, A. B., Kamaruddin, K. N., & Ariffin, F. (2017). An Assessment of Patient Waiting and Consultation Time in a Primary Healthcare Clinic. *Malaysian Family Physician of Malaysia*, *12*(1), 14–21.
Bernama. (2022). Health ministry proposes 6 new initiatives worth RM3. 4bil in Budget 2023. *Free Malaysia Today*, 1–2.
Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the Efficiency of Decision-Making Units. *European Journal of Operational Research*, *2*(6), 429–444. https://doi.org/10.1016/j.rser.2016.12.030
Emrouznejad, A., Anouze, A. L., & Thanassoulis, E. (2010). A Semi-Oriented Radial Measure for Measuring the Efficiency of Decision-Making Units with Negative Data, Using DEA. *European Journal of Operational Research*, *200*(1), 297–304. https://doi.org/10.1016/j.ejor.2009.01.001
Ibrahim, M. D., & Daneshvar, S. (2018). Efficiency Analysis of Healthcare System in Lebanon Using Modified Data Envelopment Analysis. *Journal of Healthcare Engineering*, 1–6. https://doi.org/10.1155/2018/2060138
Lawrence, M., & Zhu, J. O. E. (1999). Infeasibility of super-efficiency data envelopment analysis models. *INFOR: Information Systems and Operational Research*, *37*(2), 174–188.
Mohd Yusoff, N. S., Azhar, A., & Rozak, nur athirah che. (2021). *ESTIMATING THE BEST RESOURCE ALLOCATION AT AN EMERGENCY DEPARTMENT' S GREEN ZONE USING BCC SUPER EFFICIENCY AND BI-OBJECTIVE MCDEA BCC MODELS Likewise, similar problems are faced by the Emergency Department' s Green Zone of the capital city of Kelantan*. *17*(1), 153–163.
Rani, R. M., Ismail, W. R., & Ishak, I. (2014). An Integrated Simulation and Data Envelopment Analysis in Improving SME Food Production System. *World Journal of Modelling and Simulation*, *10*(2), 136–147.
Rani, R. M., Ismail, W. R., & Rahman, M. N. A. (2018). A Min–Max Operator Allocation Formulation, Computer Simulation and DEA Cross-Efficiency in Determining the Optimal Operator Allocation. *Advanced Science Letters*, *24*(2), 1519–1523. https://doi.org/10.1166/asl.2018.10782
Sreedevi, R. P. (2016). A Case Study of Minority Institutions by Using BCC Model-DEA Approach. *IOSR Journal of Mathematics*, *12*(3), 66–68. https://doi.org/10.9790/5728-1203026668
Vincová, I. K. (2005). *USING DEA MODELS TO MEASURE EFFICIENCY*. *13*(1), 24–28. https://www.nbs.sk/_img/Documents/BIATEC/BIA08_05/24_28.pdf
Wan Mohd Aminuddin, W. M., Ismail, W. R., & Harunarashid, H. (2018). Penambahbaikan Sumber Jabatan Kecemasan menggunakan Kaedah Simulasi dan Analisis Pengumpulan Data. *Sains Malaysiana*, *47*(9), 2231–2240. https://doi.org/10.17576/jsm-2018-4709-34
Weng, S.-J., Tsai, B.-S., Wang, L.-M., & Chang, C.-Y. (2011). Using Simulation and Data Envelopment Analysis in Optimal Healthcare Efficiency Allocations. *Proceedings of the 2011 Winter Simulation Conference*, 1295–1305.
Yusoff, N. S. M., Liong, C. Y., Noh, A. Y. M., & Ismail, W. R. (2018). Discrete event simulation and data envelopment analysis models for selecting the best resource allocation alternative at an emergency department's green zone. *Sains Malaysiana*, *47*(11), 2917–2925. https://doi.org/10.17576/jsm-2018-4711-35.