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A research level of efficiency treatment of Covid-19 using data envelopment analysis

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Abstract

Coronavirus Disease 2019 (Covid-19) is a collection of viruses that can infect the respiratory system. This virus only causes mild respiratory infections, such as the flu. The process of handling Corona infection patients is indeed much different from other disease patients. Covid-19 can cause various symptoms in its sufferer. These symptoms depend on the type of corona virus that attacks, and how serious the infection is. The design of this application uses DFD and ERD modeling which is built using the web-based PHP programming language and uses a MySQL database. The assessment of the efficiency level of COVID-19 was carried out in one of the provinces in Indonesia, namely in the province of Aceh, using samples from 12 existing hospitals. All the hospitals that we have taken data every day will continue to increase and decrease. This application is built using the Data Envelopment Analysis (DEA) method, where the search process is determined by the lindo software. The input criteria in this application are suspected patients, probable patients, confirmed patients, and patients being treated. While the output of this application is the patient recovers, and the patient dies. All the data we get is real data that we get directly from the hospital and the results are confirmed via the Internet. All calculation processes use predetermined formulas. The computational result obtained from the DEA CCR Model on the 8 DMUs is 1, it is the gain from dividing the output variable by the input variable, then the results obtained from 8 DMUs are efficient and 4 DMUs are inefficient.

Keywords: Data Envelopment Analysis, Efficiency, Covid-19, Hospital.

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1. Introduction

Along with the times, the risk of disease transmission is increasingly massive, the rise of diseases caused by viral and bacterial infections makes most people panic. One example of a deadly case, namely the COVID-19 disease caused by the SARS-CoV-2 virus or often called the Corona virus [12].

Coronavirus Disease 2019 (COVID-19) is a new type of disease that has never been previously identified in humans [4]. Corona virus is zoonotic (transmitted between animals and humans). Research says that SARS was transmitted from civet cats to humans and MERS from camels to humans. Meanwhile, the animal that is the source of COVID-19 transmission is still unknown [8]. Common signs and symptoms of COVID-19 infection include symptoms of acute respiratory distress such as fever, cough and shortness of breath. The average incubation period is 5-6 days with the longest incubation period being 14 days. In severe cases of COVID-19 it can cause pneumonia, acute respiratory syndrome, kidney failure, and even death [2].

Indonesia is also one of the countries experiencing the impact of COVID-19. The first positive case occurred in March 2020, then not long after, April 2020 the pandemic spread to all 34 provinces in Indonesia. The rapid spread of COVID-19 has also affected a number of areas, including the most western part of Indonesia, namely Aceh Province.

Based on May 2021 data, the positive number in Aceh has reached 13,848 cases, with details of 11,121 people recovering, 2,171 people being treated, and 556 deaths (Asmunda, 2021). During the emergency response status for handling Corona Virus Disease 2019 (Covid-19) in Aceh Province, it turned out that the lives of people with disabilities were getting worse in the Veranda of Mecca province.

COVID-19 is in the process of development, its handling causes many social changes and changes in various fields of life which often cause anxiety and fear among the public because of the rapid spread of the process. Through various discussions, trial tests and policies have been carried out to accelerate the handling of the COVID-19 pandemic. The private sector, government, and citizens have flocked to call for the acceleration of handling COVID-19 and make the focus of this pandemic the main focus.

In handling cases of the COVID-19 outbreak, the government is considered to need to refer to the responsibility for implementing efforts to overcome the outbreak. As confirmed in Law no. 4 of 1984, steps that can be taken or need to be carried out can be in the form of epidemiological investigations, examinations, treatment, care, isolation of patients or sufferers, quarantine measures for the incubation period, prevention and immunization with vaccines, extermination of causes of disease, handling of corpses due to epidemics, counseling community, and other countermeasures.

So to measure and compare efficiency between hospitals, a research was conducted using the Data Envelopment Analysis (DEA) method. DEA is a linear programming-based technique to evaluate the relative efficiency of a decision-making unit, by comparing one DMU to another that utilizes the same resources to produce the same output [11].

The basis of efficiency is the ratio of output to input comparison, so we need a method to be able to evaluate the efficiency of the company objectively based on the input expenditure made to obtain an output result. Responding to this concept, Data Envelopment Analysis (DEA) has been recognized as a tool that can represent performance evaluation using a linear program-based technique to measure the efficiency of organizational units called Decision Making Units (DMU) [18].

2. Literature Review

2.1. Handling Covid-19

Covid-19 is a large group of viruses that cause various types of diseases. Starting from coughs and colds to more severe diseases. This disease is in the spotlight because of its emergence at the end of 2019 for the first time in Wuhan, China [16] [12]. The location of its appearance for the first time has made the coronavirus also known as the Wuhan virus [15].
According to data from the Indonesian Ministry of Health, positive confirmed cases of Covid-19 in Indonesia are increasing day by day [24]. This number has increased from previous data, although the recovery rate for Covid-19 infections also continues to increase [17]. The process of handling Corona infection patients is indeed much different from other disease patients. In addition to the fact that there is no cure, Covid-19 is also very easily transmitted, so all processes must be carried out carefully [13].
Corona virus can cause various symptoms in sufferers [10]. These symptoms depend on the type of corona virus that attacks, and how serious the infection is. The main symptoms of corona virus patients are mild flu to pneumonia or pneumonia. Complaints can appear 2-14 days after exposure to the virus [10]. Complaints improve easily in some patients. However, some other patients can experience rapid worsening of symptoms. Other symptoms include disturbances in the sense of smell (anosmia), fever. Chills, dry cough, sore throat, shortness of breath, muscle aches, and fatigue [14].

2.2. Efficiency

Efficiency is a 'measurement' that compares the planned use of inputs with the realization of their use [7]. 100% efficiency is very difficult to achieve, but near 100% efficiency is expected and this concept is more input oriented than output. One method that can be used in measuring efficiency is through the frontier approach [19]. There are two types of this approach, namely:

1. The parametric frontier approach is an approach whose model stipulates the existence of certain conditions on the population parameters that are the source of the research. The parametric frontier approach can be measured by statistical tests using the Stochastic Frontier Analysis (SFA) and Distribution Free Analysis (DFA) methods.
2. The non-parametric frontier approach is an approach that does not set certain conditions on the parameters of the research sample population. The non-parametric frontier approach can be measured using the Data Envelopment Analysis (DEA) method [21] [22].

The simple formula for efficiency is as follows: Efficiency = Output/Input
The basic measure of efficiency used in DEA is the ratio of total output to total input.

$$Efficiency = \frac{Output}{Input} \tag{2.1}$$

The symbols in the formula are used x and y to represent inputs and outputs, i and j to represent specific inputs and outputs. So x_i is the i-th input and y_j is the j-th output of the decision-making unit /DMU. The number of inputs is represented by I and the number of outputs is represented by J, where $I, J>0$. Mathematically it can be described as follows [3]:

$$Virtual\ input = \sum_{i=1}^{I} u_i x_i \tag{2.2}$$

Where u_i is the weight of the input x_i during the accumulation process. The output can be described as follows:

$$Virtual\ Output = \sum_{j=1}^{J} v_j y_j \tag{2.3}$$

Where v_j is the weight of the input y_j during the accumulation process. From the virtual input and output model above, efficiency can be defined as follows:

$$Efficiency = \frac{virtual\ output}{virtual\ input} = \frac{\sum_{j=1}^{J} v_j y_j}{\sum_{i=1}^{I} u_i x_i} \tag{2.4}$$

Information:
U_i= Weight for output i
X_i=i-th output value
V_j= Weight for input j
Y_j= jth input value

2.3. Data Envelopment Analysis

The DEA model used is the CCR model in this model is the main model used to calculate the relative efficiency value of each DMU unit where the efficient DMU (= 1) and not efficient (< 1) [23]. Assuming there are n DMUs consisting of m inputs and s outputs [1]. The relative efficiency value of the DMU sought is obtained from the equation mode as follows [25]:

$$\max \frac{\sum_{k=1}^{s} v_k\ y_{kp}}{\sum_{j=1}^{m} u_j\ x_{jp}} \tag{2.5}$$

s.t.

$$\frac{\sum_{k=1}^{s} v_k\ y_{ki}}{\sum_{j=1}^{m} u_j\ x_{ji}} \leq 1 \tag{2.6}$$

$$v_k, u_j\ \geq\ 0 \tag{2.7}$$

Information:
X_{ji} = j-th input value used by the i-th DMU
Y_{ki} = Output value to $-k$ used by i-th DMU
U_j = weight for input j
V_k= weight for output k
Equations (2.5), (2.6), and (2.7) are non-linear equations or fractional linear equations [9], which are then transformed into linear form so that they can be applied in linear equations as follows [20]:

$$\max \sum_{k=1}^{s} v_k\ y_{kp} \tag{2.8}$$

s.t.

$$\sum_{j=1}^{m} v_j\ x_{jp} = 1 \tag{2.9}$$

$$\sum_{k}^{s} v_k y_{ki} - \sum_{j=1}^{m} u_j\ x_{ji} \leq 0 \tag{2.10}$$

$$v_k, u_j \geq 0 \tag{2.11}$$

The calculation of efficiency using the DEA CCR model to be carried out will determine which DMU-DMU are considered efficient or less efficient by referring to the results of the calculation of the efficient value of the DEA CCR mathematical model where the determination is based on the following provisions [25] [5] [6]: If relative efficiency (hk) = 1 then DMU is declared efficient, whereas if the relative efficiency (hk) < 1 then the DMU is declared inefficient.

3. Method

Data collection is carried out in research to obtain information that is relevant to the problems in the research which will later become input at the data processing stage. In the data collection carried out for this research, there are two ways that can be done to obtain raw data, namely collecting data themselves and obtaining data from other sources. The data collection method used in this study is a literature study method, namely by collecting data obtained from the Ministry of Health website as well as supporting references from several books, journals, as well as online and offline literature that are in accordance with the contents of this research, namely Efficiency, Data Envelopment Methods. Analysis (DEA) and ERD (Entity Relationship Diagram).
The system scheme for the Efficiency Level of Handling Virus Disease 19 (Covid-19) Using the Data Envelopment Analysis (DEA) Method can be seen in the following figure:

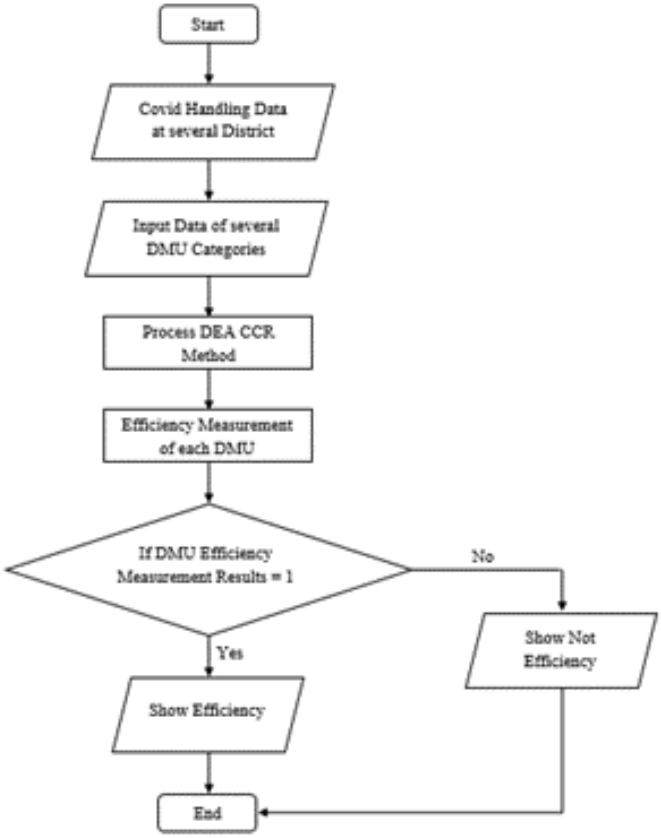

Figure 1: System Schematic

Efficiency Level of Handling Virus Disease 19 (Covid-19) Using Data Envelopment Analysis (DEA) Method in Several Districts. The system schematic that has been mentioned explains the workflow

Table 1: Covid-19 Data for Several Regencies/Cities in Aceh Province

No	City	Suspect	Possible	Confirmed	Under Care	Recover	Died
1	Banda Aceh	984	48	5527	335	5046	146
2	Aceh Utara	399	5	457	121	300	36
3	Pidie	715	50	1302	130	1048	124
4	Bireuen	2191	17	946	70	829	47
5	Aceh Selatan	271	10	401	55	306	40
6	Langsa	527	1	594	108	454	32
7	Aceh Tengah	294	30	629	163	446	20
8	Nagan Raya	270	335	349	139	179	31
9	Aceh Barat Daya	202	51	207	14	177	16
10	Aceh Timur	158	93	298	118	169	11
11	Gayo Lues	60	0	452	87	357	8
12	Aceh Tenggara	306	1	208	45	160	3

of the system to be designed. The steps for the DEA search process on the system to be designed are as follows.

1. The first step begins by inputting data for handling COVID-19.
2. Next is to input data for the DMU (Decission Making Unit) category.
3. The program will perform the search process using the DEA CCR Method. Determine the objective function and the constraint function.
4. To measure the efficiency of each DMU, it will be calculated using the output/input formula
5. If the result of DMU efficiency = 1, then the status of the DMU is efficient
6. If the result of DMU efficiency 1, then the status of the DMU is inefficient.
7. After the system displays the efficiency results, the system workflow is complete.

4. Result and Discussion

Functional requirements analysis describes the system provided. This system calculates the level of efficiency in handling COVID-19. To implement the system, the functional requirements that must be met include:

1. The system requires hospital data in the form of suspected patients, probable patients, confirmed patients, and patients being treated.
2. Data grouping is done based on input and output variables from each DMU.
3. Calculations were carried out using the DEA method assisted by linear programming Lindo 6.1

Non-functional requirements that must be met include the following:

1. The performance of the system to be built produces output in the form of efficiency values for each DMU.
2. This system will display the results of efficient and inefficient handling of COVID-19.
3. The system to be built does not require additional devices that can cost money and is free to use so it is cost-effective.

Table 2: Covid-19 Data After Selection

No	DMU	U1	U2	U3	U4	V1	V2
1	D1	984	48	5527	335	5046	146
2	D2	399	5	457	121	300	36
3	D3	715	50	1302	130	1048	124
4	D4	2191	17	946	70	829	47
5	D5	271	10	401	55	306	40
6	D6	527	1	594	108	454	32
7	D7	294	30	629	163	446	20
8	D8	270	335	349	139	179	31
9	D9	202	51	207	14	177	16
10	D10	158	93	298	118	169	11
11	D11	60	0	452	87	357	8
12	D12	306	1	208	45	160	3

In the data table 1 above, the regency/city attributes and address attributes are not needed during the data processing, so the data can be omitted. The next step is to define the hospital attribute as DMU. For each hospital, it is transformed into D1 to D12. Attributes of suspect, confirmed and under treatment as U1, U2, U3 and U4, respectively. The heal and die attributes as V1 and V2, respectively. The following is the display of the data after the selection process:
After all the data is ready to be processed, it is possible to calculate the weight ratio for each DMU so that the efficiency process can be carried out. The calculation of the weight ratio on the DEA CCR uses Linear Programming, so a supporting software is needed to carry out the process. The software used is LINDO. The Linear Programming for each DMU is as follows:
Linier Programming Weight Ratio DMU 1 (dr. Zainoel Abidin Hospital)
Maximize Z = 5046V1 + 146V2 + 0U1 + 0U2 + 0U3+0U4
Subject to
984U1 + 48U2 + 5527U3 + 335U4 = 1
5046V1 + 146V2 + 984U1 - 48U2 - 5527U3 - 335U4 <= 0
300V1 + 36V2 + 399U1 - 5U2 – 457U3 – 121U4 <= 0
1048V1 + 124V2 + 715U1 - 50U2 – 1302U3 – 130U4 <= 0
829V1 + 47V2 + 2191U1 - 17U2 – 946U3 – 70U4 <= 0
306V1 + 40V2 + 271U1 - 10U2 – 401U3 – 55U4 <= 0
454V1 + 32V2 + 527U1 - 1U2 – 594U3 – 108U4 <= 0
446V1 + 20V2 + 294U1 - 30U2 – 629U3 – 163U4 <= 0
179V1 + 31V2 + 270U1 - 335U2 – 349U3 – 139U4 <= 0
177V1 + 16V2 + 202U1 - 51U2 – 207U3 – 14U4 <= 0
169V1 + 11V2 + 158U1 - 93U2 – 298U3 – 118U4 <= 0
357V1 + 8V2 + 60U1 - 0U2 – 452U3 – 87U4 <= 0
160V1 + 3V2 + 306U1 - 1U2 – 208U3 – 45U4 <= 0
U1 >= 0, U2 >= 0, U3 >= 0, U4 >=0, V1 >= 0, V2 >=0
The output generated from the LINDO program for solving Linear Programming above is:
Model computation results:
LP OPTIMUM FOUND AT STEP 0
OBJECTIVE FUNCTION VALUE

1. 1.000000

VARIABLE	VALUE	REDUCED COST
V1	0.000198	0.000000
V2	0.000000	0.000000
U1	0.000000	1968.000000
U2	0.002810	0.000000
U3	0.000157	0.000000
U4	0.000000	0.000000

The objective function value shown by the LINDO program output is 1.0000000. This value is the maximum result of dr. Zainal Abidin Hospital in Banda Aceh – Indonesia where the weight values are V1 = 0.000198, V2 = 0.000000, U1 = 0.000000, U2 = 0.000000, U3 = 0.000181 and U4 = 0.000000.

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	0.000000	1.000000
3)	0.000000	1.000000
4)	0.026130	0.000000
5)	0.136615	0.000000
6)	0.031557	0.000000
7)	0.030226	0.000000
8)	0.005814	0.000000
9)	0.094373	0.000000
10)	0.960564	0.000000
11)	0.140643	0.000000
12)	0.274499	0.000000
13)	0.000000	0.000000
14)	0.003659	0.000000
NO. ITERATIONS=	0	

The above section shows that the active constraints are in rows 2 and 3 with a Dual Prices value of 1. This value indicates that the reduction of each unit value of the right-hand side of these constraints will cause the value of the objective function to increase by 1. equal to zero indicates that the resource is in an inactive or excess constraint status, wherein addition or decrease in the supply of the resource will not affect the value of the objective function.

RANGES IN WHICH THE BASIS IS UNCHANGED:

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
V1	5046.000000	INFINITY	0.000000
V2	146.000000	0.000000	INFINITY
U1	0.000000	1968.000000	INFINITY
U2	0.000000	0.000000	INFINITY
U3	0.000000	INFINITY	0.000000
U4	0.000000	0.000000	INFINITY

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	1.000000	INFINITY	1.000000
3	0.000000	0.041824	1.000000
4	0.000000	INFINITY	0.023232
5	0.000000	INFINITY	0.027882
6	0.000000	INFINITY	0.006871
7	0.000000	INFINITY	0.011911
8	0.000000	INFINITY	0.017500
9	0.000000	INFINITY	0.025418
10	0.000000	INFINITY	0.027671
11	0.000000	INFINITY	0.002375
12	0.000000	INFINITY	0.020425
13	0.000000	INFINITY	0.011031
14	0.000000	INFINITY	0.005925

The weight data above is entered into the weight data table of dr. Zainoel Abidin Hospital in Banda Aceh, as follows:

Table 3: Data Weight of dr. Zainoel Abidin Hospital

Input				Output	
U1	U2	U3	U4	V1	V2
0	0	0.000181	0	0.000198	0

After getting the weight values for each DMU, the next step is to calculate the input and output for each DMU using the following formula:

$$Virtual\ input = \sum_{i=1}^{I} u_i x_i$$

$$Virtual\ Output = \sum_{j=1}^{J} v_j y_j$$

Input and Output Calculation DMU 1

INPUT

984(0) + 48(0.002810) + 5527(0.000157) + 335(0)

= 0 + 0.13488 + 0.867739 + 0

= 1

OUTPUT

5046(0.000198) + 146(0)

= 0.999108 + 0

= 1

After getting the input and output values for each DMU, the next step is to calculate the efficiency for each DMU using the following mathematical equation:

$$Efisiensi = \frac{virtual\ output}{virtual\ input} = \frac{\sum_{j=1}^{J} v_j y_j}{\sum_{i=1}^{I} u_i x_i}$$

Efficiency DMU 1 :

$$\frac{1}{1} = 1$$

The following is a table of data on the efficiency of handling covid 19 in several districts in Aceh from searches that have been carried out previously:

Table 4: Data on the Efficiency of Handling Covid 19

No	DMU	Hospital Name	Efficiency Value
1	Banda Aceh	dr. Zainoel Abidin	1
2	North Aceh	Cut Mutia	1
3	Pidie	Tgk Chik Di Tiro	1
4	Bireuen	dr. Fauziah	1
5	South Aceh	dr. H. Yuliddin Away	1
6	Langsa	Langsa	1
7	Central Aceh	Datu Beru	0.792502
8	Nagan Raya	Nagan Raya	0.890475
9	Southwest Aceh	Tgk Peukan Abdya	1
10	East Aceh	dr. Zubir Mahmud	0.645841
11	Gayo Lues	Gayo Lues	1
12	Southeast Aceh	H Sahuddin	0.89648

From table 4 above, it can be seen that the handling of covid 19 in Aceh Province is efficient. Of the 12 regencies/cities that have referral hospitals, only 4 regencies are not yet efficient. The 4 districts/cities are Central Aceh District, Nagan Raya District, East Aceh District and Southeast Aceh District.

Conclusion

The conclusions from the results of the research that the author did can be described as follows:

1. Application of the efficiency level of handling Coronavirus Disease 2019 (Covid-19) using the Data Envelopment Analysis (DEA) method was built using DFD (Data Flow Diagram) modeling.
2. From the results of efficiency measurements using the DEA CCR Model, it is found that the DMU rated Relative Efficiency is 1. While the DMU whose relative value is less than 1 is categorized as inefficient. The computational result of the DEA CCR model for the 8 DMUs is 1, it is the result of dividing the output variable by the input variable, so the results of 8 DMUs are efficient and 4 DMUs are inefficient.

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