Efficiency measurement of transjakarta corridors towards people activities using DEA method (study case: corridor 1 and corridor 2)

Andryan Suhendra, Eduardi Prahara, Putri Arumsari, Titut Wulandari*, Juliastuti

Civil Engineering Department, Faculty of Engineering, Bina Nusantara University Jakarta, Indonesia 11480

Corresponding author: titutparamitha@gmail.com

Abstract. Increasing population every year in DKI Jakarta cause higher mobility. Transjakarta is the solution of the problem in this metropolitan city. This study aims to measurements of the efficiency Transjakarta corridors based on the level efficiency in each bus station by applying the Data Envelopment Analysis method CCR model and to make recommendation for future improvement. DEA was used because it allowed multiple input and multiple output. In this study the ridership of public transportation is considered as direct output characteristic of efficiency and four indicators are selected as input. From the result, corridor 4 has higher efficiency than corridor 1 and 2 by using the output orientation, all corridors have to improve the performance for increasing the ridership

Keywords: Efficiency, Transjakarta Corridors, Data Envelopment Analysis, CCR, Output Orientation

1. Preliminary

Jakarta as central administration and economic in Indonesia, causes the population increasing every year. The population in Jakarta was 9,607,787 people with 1.41 percent/year of growth rate in 661.52 km² areas (1). The increasing population every in Jakarta causes higher mobility. That’s why transportation is the most important things. However, private vehicles are still a major interest for the people. Based on data from Inrix Traffic Score 2017 quoted on Kompas.com, Jakarta is ranked 12th as a city with high congestion levels. Whereas when compared with other Asian countries, Jakarta is ranked 2nd. To overcome this problem, the Provincial Government of DKI Jakarta began operating a bus-based transit (BRT) system called Transjakarta.

This transportation system was first operated in 2004. This transportation system adopted from Transmilenio in Bogota. Bus Rapid Transit is a high quality, high capacity bus-based mass transit option for rapidly growing cities (2). BRT delivers fast, reliable and cost-effective mobility through the provision of segregated lanes, enclosed stations, rapid and frequent operations. This transportation
system always connects with transit station (station) as a node. Shelters as supporting facilities are needed to facilitate passengers in using mass transportation so that traffic disruption can be minimized (3). Based on data taken from the Jakarta Open Data, Transjakarta currently has 260 stations.

As long as the bus system is implemented in Jakarta, many evaluations have been carried out with the aim of increasing the number of Transjakarta users. A similar study was conducted, namely comparing the level of technical efficiency of the Transjakarta corridor with the DEA method. In the results of the analysis it was found that corridor four is the corridor with the highest level of efficiency. While corridor one has a sufficient level of efficiency compared to corridor two which has a low level of efficiency (4).

Based on previous research it has been known that corridor four is efficient because it reaches 100% while corridor one has sufficient efficiency compared to corridor two which has not been efficient (4). This is what underlies this research, which is done because the population continues to increase of course it is expected that there will be an increase in bus station users for each corridor.

2. Research Method

The initial stage in this study was to formulate a problem that can be used as a research objective while determining the location of research so that the objectives in the study can be achieved. After finding the problems that emerged in this study, conducted a literature study of the results of the research that had been carried out conducting a literature study related to the problems and methods that will be used in this study. The type of data used in this study is secondary data and primary data. For secondary data was obtained from the Dinas Cipta Karya, the Dinas Perhubungan and PT. Transportasi Jakarta. Whereas, for primary data a survey was carried out at stations in corridors one, two and four. Serata, on the road that passes through the corridors.

The methodology in this study is using Data Envelopment Analysis (DEA). Data Envelopment Analysis (DEA) is a linear program method that uses multiple inputs and multiple outputs to determine the relative efficiency of a unit (Decision Making Unit or DMU). Efficiency in this method is relative, if a unit has higher efficiency than other units (5). DEA evaluates certain units then compared with other units with good performance. The productivity of each unit is determined based on the input and output of each unit. In a production each DMU has a different level of input and output (6).

In measuring and analyze the efficiency of the Transjakarta corridor using DEA, a Decision Making Unit is needed in this study the intended DMU is bus stations along corridors one, two and three. The next stage is processing and recapitulating the data and determining the input and output variables and indicators used in the analysis using the DEA method. Determining the input and output variables and indicators used in the analysis using the DEA method.

Table 1 Variable and Indicator DEA

| No | Variable                  | Unit |
|----|---------------------------|------|
| 1  | Ridership                 | Person | Y |
| 2  | Population (Kelurahan)    | Person | X₁ |
| 3  | Trip Generation           | Person | X₂ |
| 4  | Headway AM                | Sec   | X₃ |
| 5  | Headway PM                | Sec   | X₄ |

a. Ridership (Y)

The number of users used was the average number of users per day on commuters per station (7). So that in this study the number of users used is the number of bus stations per day obtained from PT. Transjakarta in 2018.

b. Population (X₁)
The density, diversity and design (3D) become a framework in TOD. The input used was population density (person / km²). The DMU that was used so that the input used in this study was the total population per village that had the same village as the research station and also who had the potential to use a bus station (7).

c. Trip Generation ($X_2$

The diversity is diversity in the form of developing land use functions (8).

d. Headway Morning & Evening ($X_3$ dan $X_4$

Headway is as an input variable is because the service problems often faced by Transjakarta, namely the time between buses that are not really well scheduled (9).

In this study to measure efficiency using DEA method will focus on the CCR model with output orientation. The choice of the model is because each DMU will be compared to all DMUs in the sample assuming that the DMU's internal and external conditions are the same. And also, the selection of output orientation because in the use of units it is desirable that output results increase with the number of inputs fixed or decreasing. In this study the CCR or BCC model will be completed with DEAP V 2.1. The equation of the linear program used for this model is as follows:

\[
\begin{align*}
\text{Max} & \quad \theta_k(h_k) = \sum_{i=1}^{m} U_r Y_{ij} \\
\text{S.t} & \quad \sum_{i=1}^{m} V_i X_{ij} \leq 0 \quad j = 1,2,\ldots, n \\
& \quad Ur, Vi > 0; r = 1,2,\ldots,s \quad i = 1,2,\ldots m
\end{align*}
\]

$\theta_k$ : relative efficiency of DMU  
$Y_{ij}$ : r is the total number of output from DMU  
$X_{ij}$ : I is the total number of input from DMU I  
$n$ : the number of DMU  
$m$ : number of input  
$s$ : number of output  
$Ur$ : the weight of output  
$Vi$ : the weight of input
3. DEA FRAMEWORK

The IRS (Increasing Return to Scale) condition if an increase in input causes the output to rise more than proportionally. The second condition is CRS (Constant Return to Scale) is a condition where when the input increases by x, the output will increase by x. whereas, in the condition of DRS (Decreasing Return to Scale) is a condition where if the input increases by x then the output increases smaller than x (10). The determination of the three efficiency conditions is as follows (11):

a. IRS condition if the value of \( \sum \lambda < 1 \) from CCR \( \lambda \)
b. CRS condition if the value of CCR = 1 atau \( \sum \lambda = 1 \) for CCR model.
c. DRS condition if the value of \( \sum \lambda > 1 \) dari model CCR.

4. RESULTS AND DISCUSSION

4.1. General Characteristics of Research Sites

Corridor one has 18 station with a distance between station is 650 meters. This corridor connects Blok M to the city by crossing 5 road segments and is integrated with two commuter line stations, namely Sudirman station and Kota station. Corridor two has 24 stations with an average distance between 700-800 meters. The length of the route taken by this corridor is 14.3 km this corridor connects Pulogadung with Harmoni by crossing 13 road segments. Corridor four has 17 stations with a
distance between 700 - 800 meters. The track length passed by corridor 4 is 11.85 km. This corridor connects Pulo Gadung with Upper Hamlet 2 by crossing 6 road segments.

4.2. Descriptive Statistic Sample

Descriptive statistics sample provide an overview of the data that will be used in measuring efficiency using DEA, it is necessary to know the maximum, minimum, average and standard deviations of each variable studied. In this sub-chapter consists of descriptive statistics of sample input variables (X) and descriptive statistics of sample variable output (Y).

4.3. Variable Output (Y)

The ridership of Transjakarta station illustrates the number of people using Transjakarta station seen from the number of people who do tap in gate in one day.

Table 2 Comparison of the Number of Bus Stops in Various Corridors (in number of people)

| Variable Output (Y) | Minimum | Maximum | Mean  | Std. Dev |
|---------------------|---------|---------|-------|----------|
| Ridership (Person)  |         |         |       |          |
| Halte Transjakarta  | 1,487   | 8,185   | 3,600 | 1,661    |
| Koridor 1           |         |         |       |          |
| Halte Transjakarta  | 162     | 4464    | 1456  | 1377     |
| Koridor 2           |         |         |       |          |
| Halte Transjakarta  | 353     | 2688    | 1120  | 665      |
| Koridor 4           |         |         |       |          |

(Source: PT. Transportasi Jakarta 2018)

4.4. Variable Input (X)

In Table 3 provides an overview of the variable output data (x) that will be used in measuring efficiency in the DEA method. The output variable is the number of population, number of trip generation, morning headway and afternoon headway. On Table 3 shows the minimum, maximum, average and standard deviations of the parameters used. Table 3 provides a comparison of input variables on corridor stations one, two and four.

Table 3 Comparison of Variable Inputs on Corridors One, two and four station

| Location     | Ridership (Person) | Trip Generation (Person) | Headway AM | Headway P |
|--------------|--------------------|--------------------------|------------|-----------|
| Halte Koridor 1 | Minimum 2049       | 4,164                    | 120        | 228       |
|               | Maximum 21,247      | 38,163                   | 180        | 306       |
|               | Mean 7645          | 20,241                   | 154        | 209       |
|               | Std.Deviasi 6173    | 10,638                   | 16         | 24        |
| Halte Koridor 2 | Minimum 2145       | 1,033                    | 222        | 234       |
|               | Maximum 28,992      | 62,921                   | 276        | 306       |
|               | Mean 13,446         | 11,793                   | 248        | 260       |
|               | Std.Deviasi 10,867  | 13,285                   | 14         | 17        |
| Halte Koridor 4 | Minimum 2386        | 924                      | 257        | 166       |
|               | Maximum 29,454      | 17,741                   | 302        | 314       |
4.5. Result and Discussion

Efficiency Measurement in Corridor 1 Using DEA

The results of efficiency measurements at stations in corridor one show differences in the level of efficiency in both models, namely BCC (VRS) and CCR (CRS). This is due to the underlying assumptions on the two models. The efficiency score of the BCC model which assumes that every increase or decrease in the number of inputs does not produce a proportional increase in output. This implies that an increase or decrease in the level of efficiency can occur.

| Location          | Ridership (Person) | Trip Generation (Person) | Headway AM | Headway P |
|-------------------|---------------------|--------------------------|------------|------------|
| Mean              | 19688               | 4,648                    | 280        | 262        |
| Std.Deviasi       | 8490                | 4,115                    | 13         | 30         |

Table 4 Result Efficiency Measurement in Corridor 1

| No | DMU (Halte)       | CRS  | VRS  | Scale Efficiency | RTS |
|----|-------------------|------|------|------------------|-----|
| 1  | Blok M            | 1.000| 1.000| 1.000            | -   |
| 2  | Masjid Agung      | 0.445| 1.000| 0.445            | irs |
| 3  | Bundaran Senayan  | 0.569| 0.749| 0.760            | irs |
| 4  | Gelora Bung Karno | 0.531| 1.000| 0.531            | irs |
| 5  | Polda Metro       | 0.518| 1.000| 0.518            | irs |
| 6  | Bendungan Hilir   | 0.691| 1.000| 0.691            | irs |
| 7  | Karet Sudirman    | 0.984| 1.000| 0.984            | irs |
| 8  | Dukuh Atas        | 0.544| 1.000| 0.544            | irs |
| 9  | Tosari            | 0.625| 0.869| 0.719            | irs |
| 10 | Sarinah           | 0.513| 0.526| 0.976            | drs |
| 11 | Bank Indonesia    | 0.292| 0.294| 0.933            | irs |
| 12 | Monas             | 1.000| 1.000| 1.000            | -   |
| 13 | Harmoni           | 0.711| 0.793| 0.897            | irs |
| 14 | Sawah Besar       | 0.485| 0.598| 0.812            | irs |
| 15 | Mangga Besar      | 0.360| 0.434| 0.830            | irs |
| 16 | Olimo             | 0.261| 1.000| 0.261            | irs |
| 17 | Glodok            | 0.266| 0.276| 0.966            | drs |
| 18 | Kota              | 1.000| 1.000| 1.000            | -   |

a. The efficiency measurement of the Constant Return to Scale (CRS) model assumption resulting in 3 stations that have operated efficiently, namely Blok M station, Monas station, and Kota station.
b. The efficiency measurement of the Variable Return to Scale (VRS) model assumption resulting in 10 stations that have operated efficiently, namely Blok M station, Great Mosque station, Bung Karno bus station, Polda Metro Jaya station, Bendungan hilir station, Karet Sudirman station, Dukuh Atas station, Monas station, Olimo station and Kota station. Efficiency scores generated by the BCC model are higher than the CCR model where lower number of outputs is considered more efficient (4).
c. In the condition of efficiency each unit has 13 stations that are in an increasing return to scale condition, 2 stations are in a decreasing return to scale condition and 3 stations are in a constant return to scale condition.

d. Determining the efficiency conditions of IRS, DRS and CRS based on $\Sigma \lambda$ or total benchmark weights on inefficient stations (12). If $\Sigma \lambda < 1$ of the CCR model, the DMU is in the IRS condition whereas if $\Sigma \lambda > 1$ then the DMU is in an efficient DRS condition (Siswandi and Arafat, 2000 in Akbar, 2010). For example, based on benchmark weights for the Masjid Agung station in table 5 then $\Sigma \lambda = 0.973$ so that $\Sigma \lambda < 1$, therefore the efficiency conditions at the Masjid Agung station are Increasing Return to Scale. These results are obtained by summing the weight of the city station (0.035) + Monas station (0.938). This also applies to other stations.

| Table 5 Benchmark for Station in Corridor 1 |
| No | DMU | Skor | Rank | Benchmark | Benchmark Weight |
|-----|-----|------|------|-----------|------------------|
| 1   | Blok M | 1.000 | 1    | Blok M    | 1.000            |
| 2   | Masjid Agung | 0.445 | 12   | Kota; Monas | 0.035; 0.938 |
| 3   | Bundaran Senayan | 0.569 | 6    | Kota; Blok M ;Monas | 0.082; 0.598; 0.193 |
| 4   | Gelora Bung Karno | 0.531 | 8    | Blok M    | 0.885            |
| 5   | Polda Metro | 0.518 | 9    | Monas; Kota; Blok M | 0.325; 0.145; 0.384 |
| 6   | Bendungan Hilir | 0.691 | 4    | Blok M; Kota | 0.563; 0.191 |
| 7   | Karet Sudirman | 0.984 | 2    | Kota; Monas; Blok M | 0.035; 0.480; 0.331 |
| 8   | Dukuh Atas | 0.544 | 7    | Kota; Monas; Blok M | 0.096; 0.320; 0.411 |
| 9   | Tosari | 0.625 | 5    | Blok M    | 0.889            |
| 10  | Sarinah | 0.513 | 10   | Kota; Blok M; Monas | 0.185; 0.837; 0.022 |
| 11  | Bank Indonesia | 0.292 | 14   | Monas; Kota; Blok M | 0.300; 0.028; 0.584 |
| 12  | Monas | 1.000 | 1    | Monas    | 1.000            |
| 13  | Harmoni | 0.711 | 3    | Blok M; Kota | 0.334; 0.568 |
| 14  | Sawah Besar | 0.485 | 11   | Kota; Blok M | 0.520; 0.363 |
| 15  | Mangga Besar | 0.360 | 13   | Blok M; Kota | 0.423; 0.464 |
| 16  | Olimo | 0.261 | 15   | Kota; Blok M | 0.593; 0.261 |
| 17  | Glodok | 0.266 | 16   | Blok M; Kota | 1.029; 0.009 |
| 18  | Kota | 1.000 | 1    | Kota    | 1.000            |

4.6. Result and Discussion Efficiency Measurement in Corridor 2 using DEA

The table below will show the results of measuring the efficiency of corridor 2 in each station. The measurement results in this table show differences in the level of efficiency of the two models and the scale of efficiency in station corridor 2.
Tabel 6 Result Efficiency Measurement in Corridor 2

| No | DMU               | CRS   | VRS   | Scale Efficiency | RTS |
|----|------------------|-------|-------|------------------|-----|
| 1  | Pulogadung 1     | 0.885 | 0.893 | 0.990            | irs |
| 2  | Bermis           | 0.705 | 1.000 | 0.705            | irs |
| 3  | Polumas          | 0.436 | 0.444 | 0.982            | drs |
| 4  | Asmi             | 0.362 | 1.000 | 0.362            | irs |
| 5  | Pedongkelan      | 0.278 | 1.000 | 0.278            | irs |
| 6  | Cempaka Timur    | 0.713 | 1.000 | 0.713            | irs |
| 7  | Rumah Sakit Islam| 0.300 | 0.305 | 0.983            | drs |
| 8  | Cempaka Tengah   | 0.182 | 0.236 | 0.772            | irs |
| 9  | Pasar Cempaka Putih| 0.230 | 0.538 | 0.426            | irs |
| 10 | Rawa Selatan     | 0.407 | 0.991 | 0.411            | irs |
| 11 | Galur            | 0.362 | 1.000 | 0.362            | irs |
| 12 | Senen            | 1.000 | 1.000 | 1.000            | -   |
| 13 | Atrium           | 0.130 | 0.208 | 0.625            | irs |
| 14 | Rspad            | 0.109 | 0.641 | 0.171            | irs |
| 15 | Deplu            | 0.045 | 1.000 | 0.045            | irs |
| 16 | Gambir 1         | 0.219 | 1.000 | 0.219            | irs |
| 17 | Istiqlal         | 0.047 | 0.215 | 0.218            | irs |
| 18 | Juanda           | 1.000 | 1.000 | 1.000            | -   |
| 19 | Pecenongan       | 0.216 | 0.220 | 0.982            | drs |
| 20 | Harmoni          | 1.000 | 1.000 | 1.000            | -   |
| 21 | Monas            | 1.000 | 1.000 | 1.000            | -   |
| 22 | Balai kota       | 0.207 | 0.216 | 0.959            | irs |
| 23 | Gambir 2         | 0.158 | 1.000 | 0.158            | irs |
| 24 | Kwitang          | 0.197 | 1.000 | 0.197            | irs |

a. The efficiency calculation uses the Constant Return to Scale (CRS) assumption resulting in 4 stations that have been operating efficiently, namely the Senen station, Juanda station, Harmoni bus station and Monas station.

b. The efficiency calculation uses the Variable Return to Scale (VRS) assumption resulting 13 stations that have operated efficiently, namely Kwitang station, Gambir station, Monas station, Cempaka Timur station, Pedongkelan station, ASMI station, and Bermis station, Harmoni, station, Juanda station, Gambir 1 station, Deplu station, Senen station, and Galur bus station. Efficiency scores produced by the BCC model are higher than the CCR model, where lower outputs are considered more efficient (4).

c. In the condition of efficiency experienced by each unit there are 17 stations that are in an increasing return to scale condition, 3 stations are in a decreasing return to scale condition and 4 stations are in a constant return to scale condition.

d. Determining the efficiency conditions of IRS, DRS and CRS based on Σλ or total benchmark weights on inefficient stations (12). If Σλ <1 of the CCR model then the DMU is in the IRS condition whereas if Σλ> 1 then the DMU is in the condition of the DRS (11). For example, based
on benchmark weights for Pulo Gadung 1 station in table 7 then $\Sigma \lambda = 0.987$ so that $\Sigma \lambda < 1$, therefore the efficiency condition at the Pulo Gadung station is Increasing Return to Scale. The results are obtained by summing the weights from the Harmoni station (0.0.531) + Juanda station (0.456). This also applies to other stations.

**Tabel 7 Benchmark for Station in Corridor 2**

| No | DMU       | Skor | Rank | Benchmark       | Benchmark Weight |
|----|-----------|------|------|-----------------|------------------|
| 1  | Pulogadung| 0.887| 2    | Harmoni; Juanda | 0.531; 0.456     |
| 2  | Bermis    | 0.784| 3    | Juanda          | 0.272            |
| 3  | Polumas   | 0.441| 7    | Harmoni; Juanda | 0.157; 0.864     |
| 4  | Asmi      | 0.920| 5    | Juanda          | 0.338            |
| 5  | Pedongkelan| 0.275| 11   | Juanda          | 0.277            |
| 6  | Cempaka Timur | 0.752| 4    | Harmoni; Juanda | 0.766; 0.118     |
| 7  | Rumah Sakit Islam | 0.292| 10   | Harmoni; Juanda | 0.657; 0.351     |
| 8  | Cempaka Tengah | 0.132| 15   | Senen           | 1.024            |
| 9  | Pasar Cempaka Putih | 0.227| 12   | Harmoni; Juanda | 0.122; 0.802     |
| 10 | Rawa Selatan | 0.486| 6    | Juanda          | 0.563            |
| 11 | Galur     | 0.348| 8    | Harmoni; Juanda | 0.425; 0.522     |
| 12 | Senen     | 1.000| 1    | Senen           | 1.000            |
| 13 | Atrium    | 0.122| 16   | Senen           | 0.976            |
| 14 | Rspad     | 0.117| 17   | Juanda; Harmoni; Monas | 0.460; 0.124; 0.353 |
| 15 | Deplu     | 0.050| 19   | Juanda; Harmoni; Monas | 0.479; 0.113; 0.319 |
| 16 | Gambir 1  | 0.279| 9    | Juanda; Monas   | 0.065; 0.733     |
| 17 | Istitqlal | 0.047| 20   | Senen; Monas    | 0.389; 0.554     |
| 18 | Juanda    | 1.000| 1    | Juanda          | 1.000            |
| 19 | Pecenongan| 0.214| 12   | Juanda; Harmoni; Monas | 0.255; 0.738; 0.030 |
| 20 | Harmoni   | 1.000| 1    | Harmoni         | 1.000            |
| 21 | Monas     | 1.000| 1    | Monas           | 1.000            |
| 22 | Balaikota | 0.270| 13   | Senen           | 0.873            |
| 23 | Gambir 2  | 0.149| 14   | Senen           | 0.873            |
| 24 | Kwitang   | 0.117| 18   | Senen           | 0.881            |

**Conclusion and Suggestion**

Based on the results of efficiency measurements with the DEA method the CCR model obtained efficiency of corridor 1 of 0.600 (60%) with a total of 3 of the 18 stations that had optimal efficiency. In corridor 2 the efficiency obtained is equal to 0.452 (42.5%) with a total of 4 from 24 stations that have optimal efficiency. Whereas, when compared with the BCC efficiency model in corridor 1 the efficiency obtained is 0.808 (80.8%) with 11 of the 18 stations operating optimally. In corridor 2 the efficiency obtained is 0.689 (68.9%) with 12 of the 24 stations that have optimal efficiency. When
compared to the results of efficiency with the CCR model, the efficiency value of the BCC model tends to be higher. The evaluation results also show that the three corridors have the same problem, namely headway scheduling. The existing headway is still considered too long to meet user needs. Therefore, it is necessary to repair and reschedule the headway at each bus station. As well, from the evaluation results it was seen that the number of Transjakarta users at each bus station has the potential to increase the number of users. Based on the results of the correlation analysis of the input variables most related to the increase in the number of Transjakarta users at each bus station is the total trip generation and morning headway.

The suggestion from this study for Transjakarta and to conduct a feasibility study at each Transjakarta Station and need to increase efficiency in each corridor in order to achieve optimal efficiency. Based on the third conclusion regarding the evaluation of input and output variables in the inefficient unit, suggestions can be recommended, namely the need for a time keeper in each bus station, strict guarding on the busway lane must be increased again. From the evaluation results, it can be used as a target for the number of users that Transjakarta can reach in the future.

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