Measuring the efficiency of the Indonesian Air Police using Data Envelopment Analysis with BCC Model

Andyas Mukti Pradanarka*[1], Isna Nugraha[2], Iffad Rakhmanhuda[3]
Universitas Pembangunan Nasional Veteran Jawa Timur, Surabaya, +62318706369,
E-mail : dyasmukti.ft@upnjatim.ac.id[*1]*, isna.nugraha.ti@upnjatim.ac.id*[2]*,*
iffad.rakhmanhuda.ft@upn.ac.id[3]
**Corresponding author*
Received 18 July 2025; Revised 2 August 2025; Accepted 10 August 2025

Abstract - As part of the Indonesian National Police, one of the tasks of the Air Police is to support the Ministry of Environment and Forestry in preventing deforestation. With the available resources, the Air Police must be able to carry out their duties efficiently. This study measures the efficiency of the support performance of ten Air Police under the Control of the Regional Police covering ten provinces to prevent deforestation. Each operations control (OC) represents a Decision-Making Unit (DMU). Using Data Envelopment Analysis (DEA) with the Banker, Charnes, Cooper (BCC) model, the results showed that two OCs (Bali and North Sulawesi) were identified as efficient, while eight OCs were inefficient.

Keywords - deforestation, efficiency, DEA, BCC, VRS

1. INTRODUCTION

Domestic security based on Law Number 2 of 2002 concerning the Indonesian National Police is the main requirement in supporting the realization of a just, prosperous, and civilized civil society based on Pancasila and the 1945 Constitution of the Republic of Indonesia. A situation marked by the assurance of security and public order, as well as the enforcement of the law and the implementation of protection and services to the community [1]. Based on the main tasks and functions of the National Police in accordance with Police Regulation Number 5 of 2019 concerning the Organizational Structure of the Police Work Procedure, one of the elements in the police that has the authority to carry out security maintenance is the Air Police [2]. The Air Police, following their main duties and functions, carry out all functions of the Air Police throughout the territory of the Republic of Indonesia, both in the context of providing operational support to the National Police Headquarters and regional units, as well as providing support for all functions of the Police, regions, and ministries or institutions [3]. One of the Air Police's supports to the Ministry is cooperation in supporting the prevention of illegal logging or deforestation with the Ministry of Environment and Forestry.

The forest area in Indonesia is 125,797,052 hectares with the realization of the determination until December 2021 covering an area of 90,233,159 hectares with a total of 2,157 decrees. A significant increase in the area of forest area designation in the last 10 years to 72% of the total forest area in Indonesia [4]. This can result in increased deforestation. Regarding deforestation, to find out the existence and area of land cover, both forested and non-forested, both within forest areas (conservation, protection, and production forest) and outside forest areas (areas of other uses), the Ministry of Environment and Forestry must always conduct monitoring and supervision. In this case, good performance from the Air Police is needed to be able to support the duties of the Ministry of Environment regarding deforestation. One way to assess performance is to measure efficiency, whereby the resources (input) owned by the Air Police can produce the highest possible output, which in this case is countermeasures against deforestation. One of the methods used in measuring performance efficiency is data envelopment analysis (DEA).

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI : 10.62411/tc.v24i3.13770

DEA is a linear programming (LP) method that combines effort (input) and performance (output) to streamline each homogeneous decision-making unit (DMU) [5]. The application of DEA specifically in the military or police field can be used to measure the efficiency of the performance of the Police station [6], main duties and functions [7], such as preventing crime [8] and traffic accidents [9], to the analysis of office facilities and service performance [10] as the basis for allocating funds and resources from the government. In a military operation situation, the DEA can be used to measure how efficient the absorption of the state budget on defence is against the operational activities of the armed forces [11], as well as the efficiency of selecting military transportation routes [12] and war schemes [13] as recommendations in determining the success or failure of an operation in a war situation. In terms of operational equipment, DEA can be applied to measure the efficiency of selecting military vehicles based on mobility in military operations activities [14], and from the defence industry side, it can be used as a basis for the allocation of R&D funds in producing weapons systems [15]. With the limited resources owned by Air Police, and with different locations (both regions and characteristics) of each Regional Police Operational Control (OC), this study will measure the performance efficiency of each OC in preventing deforestation by using DEA. This is intended to guide the Air Police's efforts to improve operational efficiency.

While numerous existing studies have examined the performance of general police stations, military logistics, and defence operations, limited scholarly attention has been given to the role of specialised units—such as the Air Police—in environmental protection initiatives. In particular, there is a noticeable gap in the literature concerning the application of Data Envelopment Analysis (DEA) to assess the operational efficiency of the Air Police in the context of deforestation prevention. This gap is especially pronounced when considering the diverse characteristics and resource constraints of regional operational controls (OCs).

This study seeks to address this research gap by employing DEA to evaluate the efficiency of each Air Police OC in supporting deforestation mitigation efforts. The novelty of this research lies in three key aspects: its focus on a specialised law enforcement entity (the Air Police), its alignment with environmental objectives (specifically deforestation prevention), and its consideration of spatial heterogeneity across operational regions. By integrating these dimensions, the study aims to generate strategic insights that can inform performance improvement and optimised resource allocation within the Air Police organisation.

2. RESEARCH METHOD

DEA tries to maximize the efficiency of organizational units, expressed as a comparison between outputs and inputs, by comparing the efficiency of a particular unit with the performance of a group of similar service units that provide the same performance. In the process, if there is a unit that achieves 100 percent efficiency, it is called a relatively efficient unit, while a unit with an efficiency value of less than 100 percent is called an inefficient unit [16]. The DEA linear programming model was formulated according to Charnes, Cooper, and Rhodes in 1978 [17], and is referred to as the CCR Model. The CCR model is also called the constant return to scale (CSR) model because it has the assumption that the addition of input and output is the same, which means that if there is an additional input of n, the output variable also gets the same amount of addition. Thereafter in 1984, Banker, Charnes, and Cooper [18] developed the CCR model into the BCC Model. The opposite of CCR, in the BCC Model, if there is an additional input of n then it has no impact on the addition of the output or is called return to scale variable (VRS). Due to differences in resources, locations, and characteristics of each DMU, the analysis is input-oriented and carried out locally with the assumption that each DMU is not operating optimally. Therefore, this study uses the BCC Model.

In using DEA, the first thing to do is define input and output variables. And in this study, we use data on regional operations that have been carried out by the Air Police as input. The

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI : 10.62411/tc.v24i3.13770

operation of the area consists of the number of air patrols and flying hours in 2021. And the amount of deforestation recorded by the Ministry of Environment and the Indonesian Central Statistics Agency in 2021 is an output (Ha/Year). While the DMU is the Regional Police OC supported by the Air Police. The size of the DMU used is twice the number of input and output. This study uses ten DMUs in North Sumatra, Riau (covering the Riau Islands), South Sumatra, West Kalimantan, Central Kalimantan (covering South Kalimantan), North Kalimantan (covering East Kalimantan), Bali (covering West and East Nusa Tenggara), North Sulawesi (covering North Maluku), South Sulawesi (covering West Sulawesi), and Southeast Sulawesi (covering Central Sulawesi). The input and output variables can be seen in Table 1.

Table 1. Input and Output Variables

		Variables	Data Sources (2021)
Input	(I_1)	Air patrol (times/year)	Air Police of the Republic of Indonesia
	(I_2)	Flight hours (hours/year)	
Output	(O_1)	Deforestation rate (Ha/Year)	Ministry of Environment and Forestry

The second step is to develop an objective function to find the set of O coefficients associated with each output and I coefficients associated with each input, which will later be evaluated to maximize the efficiency of DMU as high as possible. The objective function and all constraints are ratios rather than linear functions and the equation is restated as a linear function by arbitrarily scaling the inputs for the unit under evaluation to a sum of 1.0. The objective function with the BCC model is stated in equation (1) with limitations in equations (2) to (4),

$$MAX.\text{Eff}_e = u_1 O_{1e} + u_2 O_{2e} + \ \dots \ + \ u_M O_{Me} \quad (1)$$

Subject to the constraint that

$$v_1 I_{1e} + v_2 I_{2e} + \ \dots \ + \ v_N I_{Ne} = 1 \quad (2)$$

Let $\mathrm{E_e}$ as efficiency ratio, $\mathrm{u_M}$ and $\mathrm{v_N}$ are the coefficients of the output and input, then $\mathrm{O_{Me}}$ and $\mathrm{I_{Ne}}$ are the values of the input and output. For each DMU is subject to the constraint that

$$(\mathrm{u_1 O_{1k}} + u_2 O_{2k} + \ \dots \ + \ u_{\mathrm{M}} O_{\mathrm{Mk}}) - (\mathrm{v_1 I_{1k}} + v_2 I_{2k} + \ \dots \ + v_{\mathrm{N}} I_{\mathrm{Nk}}) \le 0, k = 1, 2, \dots, n \quad (3)$$

where

$$u_j \ge 0, j = 1, 2, \dots, M \quad (4)$$

$$v_i \ge 0, i = 1, 2, \dots, N \quad (5)$$

and the stages of this study are described in a flow chart which can be seen in Figure 1.

The study begins by outlining its scope, objectives, and relevance, focusing on the operational efficiency of the Air Police in combating deforestation. A literature review follows, establishing a theoretical foundation by examining prior research on law enforcement efficiency, DEA applications, and the Air Police's environmental role. The problem is then defined as the lack of systematic, data-driven evaluation of Air Police performance in deforestation prevention. Input and output variables are identified for the DEA model (Table 1), including resources such as personnel, flight hours, and budget, and outcomes like patrol coverage and deforestation incidents prevented.

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI : 10.62411/tc.v24i3.13770

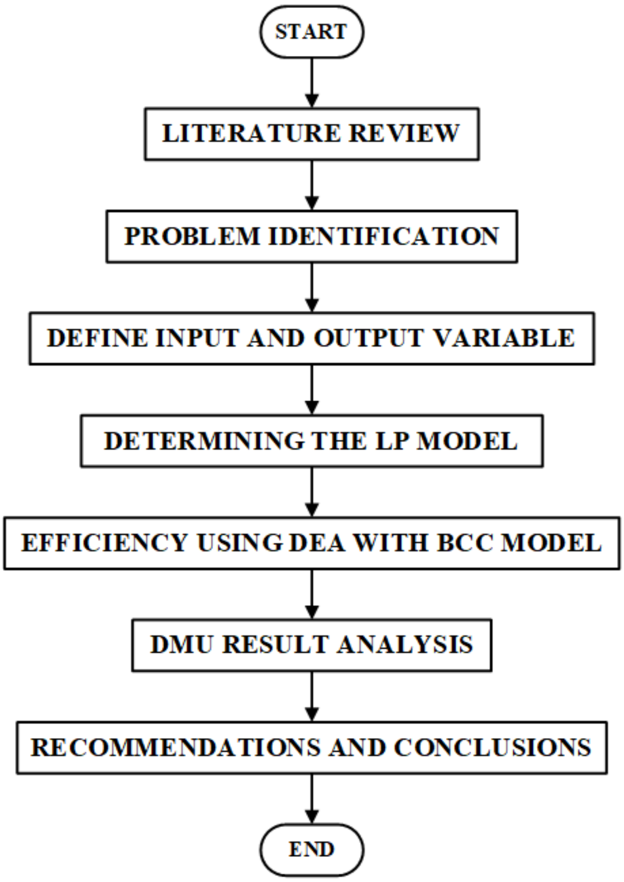

Figure 1. Flowchart of Research Methodology

A suitable linear programming model is then developed, using the BCC DEA approach to account for variable returns to scale. This enables fair comparison across units with diverse regional conditions. The resulting efficiency scores are analysed to identify high- and low-performing Decision-Making Units (DMUs), along with performance drivers. The study concludes with strategic recommendations to improve operational efficiency and resource allocation.

3. RESULTS AND DISCUSSION

In the application of the DEA method, DMU is said to have been efficient if it reaches a value of 1 which means 100%. The calculation of DEA with the BCC Model in this study was carried out with the help of RStudio version 1.1.456 software. Table 2 shows the results of DEA calculations in measuring the efficiency of Air Police support for preventing cases of illegal logging or deforestation.

3.1. Implementation of DEA Framework

Following the identification of the problem—namely, the lack of performance evaluation of Air Police support in deforestation prevention—the study defined key input and output variables. Inputs included air patrol rate and flight hours, while outputs were represented by the deforestation rate. These variables were selected based on operational relevance and data availability across ten provinces. The DEA analysis was conducted using an input-oriented BCC model, which allows for variable returns to scale and is suitable for comparing units with differing operational capacities. The model decomposes inefficiency into radial and slack components.

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI : 10.62411/tc.v24i3.13770

Radial values indicate the proportion of input redundancy, while slack values reflect allocation inefficiencies that must be addressed to achieve optimal performance.

3.2. Efficiency Scores and Benchmarking

The DEA results revealed that only DMU 7 (Bali) and DMU 8 (North Sulawesi) achieved full efficiency scores of 1.00, positioning them on the efficiency frontier. These units serve as benchmarks for the remaining eight DMUs, which exhibited varying degrees of inefficiency. For instance, North Sumatra (DMU 1) recorded the lowest efficiency score of 0.25, with a deviation of 0.75, indicating that its inputs must be reduced by 75% or its outputs increased proportionally to reach efficiency. Similarly, South Sulawesi (DMU 9) and Riau (DMU 2) showed low efficiency scores of 0.28 and 0.34, respectively, suggesting significant operational gaps.

Moderately inefficient units such as West Kalimantan (DMU 4) and Central Kalimantan (DMU 5) had efficiency scores of 0.64 and 0.60, with deviations of 0.36 and 0.40. These results imply that while these units are closer to the efficiency frontier, improvements are still necessary.

Table 2. DEA Result

DMU	Variables	Eff.	Original Val.	Movements		Projected Val.	References	
				Radial	Slack		Peers	λ weight
(1) North Sumatra	Air patrol rate	0.25	57	6.035	0	8	8	1
	Flight hours		196.15	0	0	48.3		
	Deforestation rate		1,233.6	0	775.6	2009.6		
(2) Riau	Air patrol rate	0.34	76	13.872	0	11.644	7	0.3037
	Flight hours		243.4	0	0	81.721	8	0.6963
	Deforestation rate		7,880.6	0	0	7,880.6		
(3) South Sumatra	Air patrol rate	0.36	58	12.654	0	8.187	7	0.0157
	Flight hours		139.205	0	0	50.023	8	0.9843
	Deforestation rate		2,312	0	0	2,312		
(4) West Kalimantan	Air patrol rate	0.64	62	22.726	0	16.891	7	0,741
	Flight hours		203.2	0	0	129.843	8	0.259
	Deforestation rate		16,334.5	0	0	16,334.5		
(5) Central Kalimantan	Air patrol rate	0.6	64	22.588	0	15.727	7	0.644
	Flight hours		199.05	0	0	119.17	8	0.356
	Deforestation rate		14,459.5	0	0	14,459.5		
(6) North Kalimantan	Air patrol rate	0.48	28	0	0	13.369	7	0.4475
	Flight hours		206.3	0.961	0	97.545	8	0.5525
	Deforestation rate		10,660.5	0	0	10,660.5		
(7) Bali	Air patrol rate	1	20	0	0	20	1	1
	Flight hours		158.35	0	0	158.35		
	Deforestation rate		21,342.4	0	0	2,1342.4		
(8) North Sulawesi	Air patrol rate	1	8	0	0	8	1	1
	Flight hours		48.3	0	0	48.3		
	Deforestation rate		2,009.2	0	0	2,009.2		
(9) South Sulawesi	Air patrol rate	0.28	60	8.732	0	8	8	1
	Flight hours		173.2	0	0	48.3		
	Deforestation rate		1,134.8	0	874.4	2,009.2		
(10) Southeast Sulawesi	Air patrol rate	0.63	40	10.703	0	14.627	7	0.5523
	Flight hours		172.25	0	0	109.083	8	0.4477
	Deforestation rate		12,687.5	0	0	12,687.5		

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI : 10.62411/tc.v24i3.13770

In DEA, the calculation of efficiency is done on a relative basis. The two efficient DMUs from the efficiency frontier will serve as a benchmark for the other DMUs. The deviation of the inefficient DMUs to the efficiency frontier can be seen in Table 3. The largest deviation is in DMU 1, namely North Sumatra by 0.75. This means that the input in DMU 1 must be reduced by 0.75 to achieve its efficiency or increase to 1. Figure 2 shows the DMU benchmarking graph, where the input variables owned by the two DMUs are considered to provide the best results among other DMUs, so that it can be said to be best practice.

Table 3. Deviation from Inefficient DMU

DMU		Efficiencies	Deviations
1	North Sumatra	0.25	0.75
2	Riau	0.34	0.66
3	South Sumatra	0.36	0.64
4	West Kalimantan	0.64	0.34
5	Central Kalimantan	0.60	0.40
6	North Kalimantan	0.48	0.52
9	South Sulawesi	0.28	0.72
10	Southeast Sulawesi	0.63	0.47

Therefore, DMUs 7 and 8 can be used as a reference for other DMUs that have not yet achieved an efficiency score of 1, to improve their efficiency.

3.3. Slack and Radial Analysis

The benchmarking graph (Figure 2) illustrates the relationship between efficient and inefficient DMUs. Efficient units (DMUs 7 and 8) are connected to all others, indicating their role as reference models. Inefficient DMUs exhibit slack values, which represent the need to adjust input allocation or increase output effectiveness. For example, North Sumatra's slack in air patrol rate suggests that its current resource deployment is not yielding proportional outcomes.

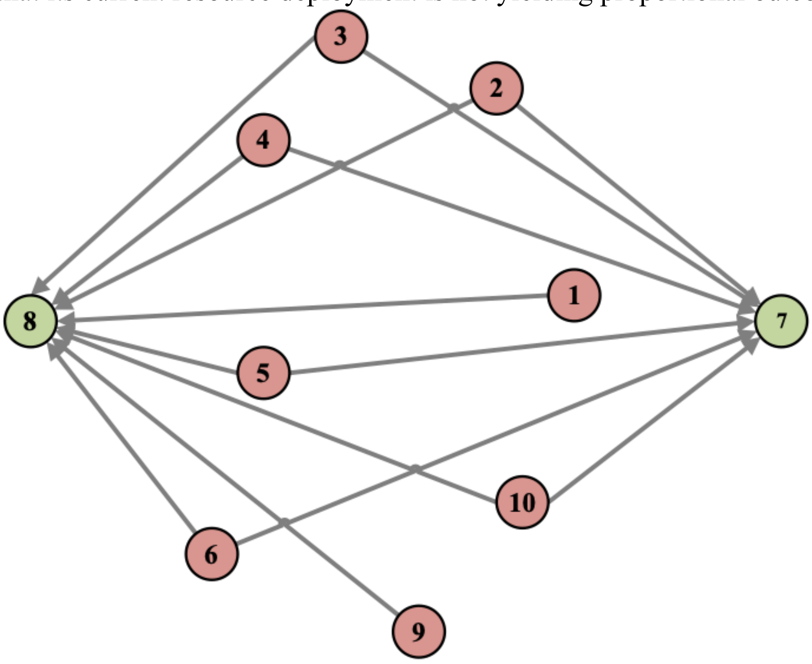

Figure 2. DMU Benchmarking Graph

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI : 10.62411/tc.v24i3.13770

This study uses a DEA input-oriented BCC model with the result that the target input is divided into slack and radial. DMUs that have inefficient performance always result in slack, namely improvements by adding output or reducing input required by a DMU to achieve an efficient level of performance. If one of the models produces a score of 1 (efficient) then the slack value is zero. Slack can be seen as an allocation inefficiency in the DMU. While radial is the target of redundant input, in order to achieve relative efficiency, the input to the DMU must be reduced. Radial values further indicate the extent of input redundancy. In regions with high radial values, such as Riau and South Sumatra, operational restructuring may be necessary to optimise resource use. These insights are critical for guiding strategic decisions in resource allocation and operational planning.

4. CONCLUSION

The efficiency of the Air Police in preventing deforestation crimes is measured using the DEA with the BCC model. The focus of this research is on the institutional support of the Air Police to the Ministry of Environment and Forestry in preventing deforestation in Indonesia. Ten provinces were analyzed to pursue the level of research validity, of which two DMUs were identified as efficient so that they could be used as benchmarks for eight inefficient DMUs. The contribution of this study is to present a measure of technical efficiency to analyze which support has been efficient and which is inefficient. Then, from the support that has not been efficient, it can be used for improvements that refer to the support of the Air Police which is already efficient. The methods and results of this study can be used as recommendations in measuring efficiency in the Air Police institution. Moreover, the DEA results can inform policy-level decisions regarding budget allocation, equipment deployment, and personnel distribution. By identifying specific inefficiencies, the study provides actionable recommendations for enhancing the effectiveness of Air Police support in environmental protection.

Efficiency measurement using DEA is highly dependent on input and output variables. And to avoid less important findings, the selection of input and output variables must be identified carefully. In addition, because the calculation of efficiency using DEA is relative, hence, if there is an additional DMU, it is necessary to re-calculate the DEA to determine the efficiency value of each DMU. Therefore, for future studies, the application of DEA combined with Machine Learning can be applied to build a predictive model or estimation of efficiency measurement in the event of an additional DMU.

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e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI : 10.62411/tc.v24i3.13770