A Slack-Based Measures within Group Common Benchmarking using DEA for Improving the Efficiency Performance of Departments in Universitas Malikussaleh

Dahlan Abdullah[1*], *Muhammad* Zarlis[2], *Darmawan* Napitupulu[3], *Hartono* Hartono[4], *S* Sriadhi[5], *Cut Ita* Erliana[6], *Rohman* Dijaya[7], *Yulian* Findawati[7], *Heri* Nurdiyanto[8], *Robbi* Rahim[9], and *Ansari Saleh* Ahmar[10]

[1]Universitas Malikussaleh, Department of Informatics, Aceh, Indonesia
[2]Universitas Sumatera Utara, Department of Computer Science, Medan, Indonesia
[3]Lembaga Ilmu Pengetahuan Indonesia, Jakarta, Indonesia
[4]STMIK IBBI, Department of Computer Science, Medan, Indonesia
[5]Universitas Negeri Medan, Department of of Electrical Engineering, Indonesia
[6]Universitas Malikussaleh, Department of Industrial Engineering, Aceh, Indonesia
[7]Universitas Muhammadiyah Sidoarjo, Department of Informatics, Sidoarjo, Indonesia
[8]STMIK Dharma Wacana, Department of Informatics, Lampung, Indonesia
[9]Universiti Malaysia Perlis, School of Computer and Communication Engineering, Kubang Gajah, Malaysia
[10]Universitas Negeri Makassar, Departement of Statistics, Makassar, Indonesia

Abstract. Measurement of the efficiency of the university performance. Data Envelopment Analysis (DEA) is a data-based performance evaluation method used when multiple inputs and outputs are represented in the Decision-Making Unit (DMU) set. In DEA, when there is a value of Non-Zero Input and Output Slacks then this often means inefficiency. This scalar measure directly with the input of surplus and the output of the short decision of the decision-making unit (DMU). DEA Structure usually apply in general settings, actually DMUs can fall into distinct groups whose members experience similar circumstances. The targets of the Ministry of Research, Technology and Higher Education of the Republic of Indonesia (KEMENRISTEKDIKTI), one of which is the measurement of the efficiency based on the number of lecturers' research, the efficient use of resources. This study will group each department at the Universitas Malikussaleh using the Group Common Benchmarking approach and then provide suggestions for improvements to each group by using Slack-Based Measures.

1 Introduction

Data Envelopment Analysis (DEA) is an optimization framework proposed to measure the relative performance of a set of Decision Making Units (DMUs) [1]. In recent years, educational institutions such as universities have increasingly focused on improving quality as an effort to improve their prestige. Within the university, the study program is also increasingly focused on ranking especially related to the quality of publications and graduates [2]. The result of benchmarking that get from the DEA method in the form of benchmarking values can be studies as a pattern when there is a new data can be directly predicted [3]. Data Envelopment Analysis (DEA) is a mathematical model for evaluating Decision Making Units (DMUs) that have multiple inputs and multiple outputs. Note that adding or removing an inefficient DMU will not necessarily change the efficiency of DMU and efficient frontier. Inefficiency scores can only be changed if the efficient frontier is changed. The performance of each DMU depends on the identification of the Efficient Frontier expressed through slack measurement [4]. In DEA, when there is a value of Non-Zero Input and Output Slacks then this often means inefficiency [5]. If there is a DMU with an efficiency score of one even if it has a zero slack value, it remains categorized as having the same efficiency level as an efficient DMU, even if it is inefficient [4].

Slack Based Measure can measure the efficiency of each department in University and if there is an inefficient department then it will be measured based on slack-based measures to advise aspects that need attention so that the department can be efficient [6]. In the DEA Method, we can identify the Efficient Frontier based on a certain subset of efficient DMU, which can be viewed as a common reference set and will minimize the pareto-efficient frontier [7]. From this new efficient frontier this will find the closest targets to each of DMU [8]. This study will group each department at the Universitas Malikussaleh using the Group Common Benchmarking approach and then provide suggestions for improvements to each group by using Slack-Based Measures. In grouping based on efficient frontier it is necessary to pay attention to the quality of grouping [9] and need to pay

* Corresponding author: dahlan@unimal.ac.id

attention to the new patterns that will emerge based on the trend patterns that exist in the process of grouping [10]. The results of the study using Slack Based Measure and Group Common Benchmarking are expected to be the entire study program available at Malikussaleh University to be efficient.

2 Related works

Data Envelopment Analysis (DEA) is a method of performance evaluation and benchmarking of a collection of Decision Making Units (DMU) that are settlement-based with mathematical programming methods[11]. O'Neal et al. [12] proposed DMU exclusion of indefinite data to calculate efficiency. This affects the relative effectiveness of other DMU. Undetected data in DEA can use stochastic approaches. Stochastic programming has undergone many theoretical developments since the 1950s, beginning with the pioneering work in Dantzig[13]. A Common Set of Weights is the basis for comparing and ranking all decision-making units under the same conditions[14]. While CSW and DEA offer two "opposite" approaches to analyzing efficiency, in some situations would be desirable intermediate access between them. For example, Cook and Zhu [15] claim that in many real-world applications where DEA is used, DMUs can be grouped into groups whose members have similar circumstances, and therefore each DMU as a separate entity may not be suitable. Cook et al. [7] develop models that are based on the idea of minimizing distance from the DMU group to the DEA effective limit. On the other side, Tone [5] proposed a method to evaluate the effectiveness based on the deceleration values, a measure based on free movement (SBM) was introduced. When using SBM to evaluate the context, we can have a reasonable stratification of the DMU performance levels.

3 Methodology

Linear programming model of DEA proposed by CCR can be written as follows.

$$Maximize \quad \beta = \sum_{r=1}^{k} u_r y_{rj}$$

Subject to

$$\sum_{s=1}^{l} v_s x_{sj} = 1; \tag{1}$$

$$\sum_{r=1}^{k} u_r y_{rj} - \sum_{s=1}^{l} v_s x_{sj} \le 0; \qquad \forall j$$

$$u_r, v_s \ge 0 \qquad \forall r, \forall s$$

3.1 Slack based measures

We will deal with n DMUs (Decision Making Units) with the input and output matrices $X = (\chi_{ij}) \in R^{mxn}$ and $Y = (y_{ij}) \in R^{sxn}$, respectively. We assume that the data set is positive, i.e., $X > 0$ and $Y > 0$. The production possibility set P is defined as

$$P = \{(x, y) \mid x \ge X\lambda, y \le Y\lambda, \lambda \ge 0\} \tag{2}$$

We consider an expression for describing a certain DMU (x_0, y_0) as

$$x_0 = X\lambda + S^-$$
$$y_0 = Y\lambda - S^+ \tag{3}$$

3.2 Slack Based Measures in Linear Programming

With $\lambda \ge 0, s^- \ge 0$ and $s^+ \ge 0$. The values $s^- \in R^m$ and $s^+ \in R^s$ indicate the input surplus and output shortage of this expression, respectively, and are called slacks. From the conditions $X > 0$ and $\lambda \ge 0$, it holds

$$x_0 \ge s^- \tag{4}$$

using s^- and s^+, we define an index ρ as follows,

$$\rho = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{io}}{1 + \frac{1}{s}\sum_{i=1}^{s} s_i^+ / y_{io}} \tag{5}$$

It can be verified that ρ satisfies the properties P1 (unit invariant) and P2 (monotone). Furthermore from (5), it holds

$$0 < \rho \le 1 \tag{6}$$

Then, Slack-Based Measure become the following linear program in t, S^-, S^+, and Λ :

$$\begin{aligned} &min\ \tau = t - \tfrac{1}{m}\textstyle\sum_{i=1}^{m} S_i^- / x_{io} \\ &subject\ to\ 1 = t + \tfrac{1}{s}\textstyle\sum_{i=1}^{s} s_i^+ / y_{io} \\ &tx_0 = X\Lambda + S^- \\ &ty_0 = Y\Lambda - S^+ \\ &\Lambda \ge 0, S^- \ge 0, S^+ \ge 0, t > 0 \end{aligned} \tag{7}$$

3.3 Group common benchmarking in linear programming

Group common benchmarking model will find the closest targets for the DMU in a given group by minimizing globally weighted distance to their actual inputs and outputs.

$$\begin{aligned} &Min \sum_{j \in J_g} ||(X_j, Y_j) - (\hat{X}_j, \hat{Y}j\ )||_1^{\omega} \\ &s.t.: \\ &\sum_{k \in E} \lambda_{kj} X_k = \hat{X}_j \quad j \in J_g \\ &\sum_{k \in E} \lambda_{kj} Y_k = \hat{Y}_j \quad j \in J_g \\ &-v' X_k + u' Y_k + d_k = 0 \quad k \in E \\ &\bar{X} v \ge 1_m \\ &\bar{Y} u \ge 1_s \\ &d_k \le M b_k \quad k \in E \\ &\sum_{j \in J_g} \lambda_{kj} \le M(1 - b_k) \quad k \in E \\ &d_k \ge 0, b_k \in \{0,1\}\, k \in E \\ &\lambda_{kj} \ge 0, \hat{X}_j \ge 0_m, \hat{Y}_j \ge 0_s \quad \forall k, j \end{aligned} \tag{8}$$

4 Experimental process

4.1 Data Description

Universitas Malikussaleh has 30 Departments with around 20000 students. The data of 19 Departments (DMU) with two outputs and two inputs is shown in Table1. There are 11 departments are still new, therefore they do not have graduates yet. As a consequence, these 11 departments are not included in Table 1.

Table 1. List of DMU with input and output data.

DMU	INPUT		OUTPUT	
	Number of Lecturers	Number of Students	Number of Research	Number of Graduates
Information Technology	17	588	5	610
Civil Engineering	26	747	5	533
Architectural Engineering	15	396	5	195
Industrial Engineering	17	467	5	300
Chemical Engineering	25	348	5	252
Mechanical Engineering	23	499	5	224
Electrical Engineering	19	420	5	326
Agribusiness	17	689	5	273
Agro-Technology	34	822	5	284
Aquaculture	10	501	5	204
Communication Science	11	719	5	273
Political Science	11	262	5	183
Sociology	13	487	5	204
Anthropology	9	173	5	116
Jurisprudence	50	1096	10	467
Medicine	30	278	4	257
Management	48	1265	5	1302
Economic Development	11	853	5	290
Accounting	23	1127	5	417

Using (1), we can calculate the efficiency score of each DMU. The result can be seen in Table 2.
Using (1), we can calculate the efficiency score of each DMU. The result can be seen in Table 2. For example for DMU1 (Department of Information Technology), the linear programming model can be written as follows.
Maximize 610 U1 + 5 U2
Subject to
17 V1 + 588 V2 = 1
610 U1 + 5 U2 - 17 V1 - 588 V2 <= 0
533 U1 + 5 U2 - 26 V1 - 747 V2 <= 0
195 U1 + 5 U2 - 15 v1 - 396 V2 <= 0
300 U1 + 5 U2 - 17 V1 - 467 V2 <= 0
252 U1 + 5 U2 - 25 V1 - 348 V2 <= 0
224 U1 + 5 u2 - 23 V1 - 499 V2 <= 0
326 U1 + 5 U2 - 19 V1 - 420 V2 <= 0
273 U1 + 5 U2 - 17 V1 - 689 V2 <= 0
284 U1 + 5 U2 - 34 V1 - 822 V2 <= 0
204 U1 + 5 U2 - 10 V1 - 501 V2 <= 0
273 U1 + 5 U2 - 11 V1 - 719 V2 <= 0
183 U1 + 5 U2 - 11 V1 - 262 V2 <= 0
204 U1 + 5 U2 - 13 V1 - 487 V2 <= 0
116 U1 + 5 U2 - 9 V1 - 173 V2 <= 0
467 U1 + 5 U2 - 50 V1 - 1096 V2 <= 0
257 U1 + 5 U2 - 30 V1 - 278 V2 <= 0
1302 U1 + 5 U2 - 48 V1 - 1265 V2 <= 0
290 U1 + 5 U2 - 11 V1 - 852 V2 <= 0
417 U1 + 5 U2 - 23 V1 - 1127 V2 <= 0
U1, U2, V1, V2 >= 0
END
We use software LINDO Release 6.1 Demo Version.
The expression (3) is in LINDO format.
The result is as follows.
OBJECTIVE FUNCTION VALUE
1) 1.000000

VARIABLE	VALUE	REDUCED COST
U1	0.001639	0.000000
U2	0.000000	0.000000
V1	0.058824	0.000000
V2	0.000000	0.000000

It can be seen that DMU1 is efficient, as the value of β is 1. The score of efficiency for all DMUs can be found in Table 2.

Table 2. Efficiency Score of Each DMU Using DEA

NO	DMU	DEA SCORE
1	Information Technology	1.0
2	Civil Engineering	0.6982436
3	Architectural Engineering	0.6818709
4	Industrial Engineering	0.7045490
5	Chemical Engineering	0.8069085
6	Mechanical Engineering	0.5265533
7	Electrical Engineering	0.8263003
8	Agribusiness	0.6639550
9	Agrotechnology	0.3810771
10	Aquaculture	1.0
11	Communication Science	0.9912544
12	Political Science	0.9152225
13	Sociology	0.7845375
14	Anthropology	1.0
15	Jurisprudence	0.4226586
16	Medical	1.0
17	Management	0.9921286
18	Economic Development	1.0
19	Accounting	0.5871874

4.2 Linear programming with slack based measures

From Table 2 we would be able to observe that DMU1, DMU10, DMU14, DMU16, and DMU18 are efficient. For DMU 2, DMU 3, DMU 4, DMU5, DMU6, DMU7, DMU8, DMU11, DMU12, DMU13, DMU15, DMU17, and DMU19. Slack value for Infefficient DMU can be seen in Table 3.

Tabel 3. Slack value for inefficient DMU.

NO	DMU	SLACK VALUE
1	Civil Engineering	0.301756
2	Architectural Engineering	0.318129
3	Industrial Engineering	0.295451
4	Chemical Engineering	0.228036
5	Mechanical Engineering	0.473447
6	Electrical Engineering	0.173700
7	Agribusiness	0.336045
8	Agrotechnology	0.618923
9	Communication Science	0.008746
10	Political Science	0.084778
11	Sociology	0.215462
12	Jurisprudence	0.577341
13	Management	0.007871
14	Accounting	0.412813

4.3 Slack based measure within common group benchmarking

Using (8) we can calculate the distance to their paretto efficient frontier for each DMU. For each in efficient DMU, we calculate the distance for input and output. We assume that the DMU Information Technology as the best DMU. The Result can be seen in Table 4.

Table 4. Distance to paretto efficient frontier.

DMU	Distance		Distance	
	Number of Lecturers	Number of Students	Number of Research	Number of Graduates
Civil Engineering	9	159	0	77
Architectural Engineering	2	192	0	415
Industrial Engineering	0	121	0	310
Chemical Engineering	8	240	0	358
Mechanical Engineering	6	89	0	386
Electrical Engineering	2	168	0	284
Agribusiness	0	101	0	337
Agro-Technology	17	234	0	326
Communication Science	6	131	0	337
Political Science	6	326	0	427
Sociology	4	101	0	406
Jurisprudence	33	508	5	143
Management	31	677	0	692
Accounting	6	539	0	193

According to (8) the minimum distance to paretto efficient frontier are Input Number of Lecturers and Output Number of Research. For the input we use the maximum distance to subtract with its slack value and the output we use the minimum distance to add with its slack value.

For example we can see the DMU Civil Engineering with the slack value 0.301756. We can increase the output of U_2 (Number of Research) according to the slack value using (4)

$U_2 = 5 + 5*0.301756 = 7$

We can decrease the input of V_2 (Number of Students) according to the slack value using (4)
$V_2 = 747 - 747*0.301756 = 522$

The result of Recomendation of Input and Output for become efficient can be seen in Table 5.

Table 5. Recomendation of input and output for every DMU to become efficient.

DMU	INPUT		OUTPUT	
	Number of Lecturers	Number of Students	Number of Research	Number of Graduates
Civil Engineering	26	522	7	533
Architectural Engineering	15	270	8	195
Industrial Engineering	17	329	7	300
Chemical Engineering	25	268	6	252
Mechanical Engineering	23	262	8	224
Electrical Engineering	19	347	6	326
Agribusiness	17	407	9	273
Agro-Technology	34	313	8	284
Communication Science	11	712	6	273
Political Science	11	239	6	183
Sociology	13	382	7	204
Jurisprudence	50	463	8	467
Management	48	1255	6	1302
Accounting	23	561	10	417

5 Conclusion

First, the Common Group Benchmarking can be used to determine the minimum value of each input and the inefficient output to the paretto efficient frontier value so that it can be used as a basis for using slack based measure. Second, slack based measure can be used to reduce the maximum value of inputs based on Common Group Benchmarking and can also increase the minimum value of output based on Common Group Benchmarking. Third, the results show that each department can be efficient if we increase the output and reduce the input according to the slack value. Future research is expected that the developed DEA model can be applied to ensure quality of data in the process of efficiency measurement especially if there is a lot of uncertainty data.

References

1. M. Ehrgott, A. Holder, O. Nohadani, Uncertain Data Envelopment Analysis, Eur. J. Oper. Res., **268**, 1, 231–242 (2018)
2. E. C. Rosenthal, H. J. Weiss, A data envelopment analysis approach for ranking journals, *Omega*, **70**, 135–147 (2017)
3. D. Abdullah, Tulus, S. Suwilo, S. Effendi, Hartono, DEA Optimization with Neural Network in Benchmarking Process, *IOP Conf. Ser. Mater. Sci. Eng.*, **288**, 012041 (2018)
4. H. Morita, K. Hirokawa, J. Zhu, A slack-based measure of efficiency in context-dependent data envelopment analysis, *Omega*, **33**, 4, 357–362 (2005)
5. K. Tone, A slacks-based measure of eficiency in data envelopment analysis, Eur. J. Oper. Res., 12 (2001)
6. D. Abdullah, Tulus, S. Suwilo, S. Efendi, Hartono, C. I. Erliana, A Slack-Based Measures for Improving the Efficiency Performance of Departments in Universitas Malikussaleh, Int. J. Eng. Technol., **7**, 2, 491–494 (2018)
7. W. D. Cook, J. L. Ruiz, I. Sirvent, J. Zhu, Within-group common benchmarking using DEA, Eur. J. Oper. Res., **256**, 3, 901–910 (2017)
8. J. L. Ruiz, J. V. Segura, I. Sirvent, Benchmarking and target setting with expert preferences: An application to the evaluation of educational performance of Spanish universities, Eur. J. Oper. Res., **242**, 2, 594–605 (2015)
9. Hartono, D. Abdullah, A. S. Ahmar, A New Diversity Technique for Imbalance Learning Ensembles, Int. J. Eng. Technol., **7**, 2, 478–483 (2018)
10. H. Hartono, O. S. Sitompul, T. Tulus, E. B. Nababan, Optimization Model of K-Means Clustering Using Artificial Neural Networks to Handle Class Imbalance Problem, *IOP Conf. Ser. Mater. Sci. Eng.*, **288**, 012075 (2018)
11. M. Zahedi-Seresht, G. -R. Jahanshahloo, J. Jablonsky, A robust data envelopment analysis model with different scenarios, *Appl. Math. Model.*, **52**, 306–319 (2017)
12. P. V. O'Neal, Y. A. Ozcan, Y. Ma, Benchmarking Mechanical Ventilation Services in Teaching Hospitals, J. Med. Syst., **26**, 3, 227–240 (2002)
13. G. B. Dantzig, Linear Programming Under Uncertainty, *Stochastic Programming,* 1-11 (Springer, New York, NY, 2010)
14. M. Salahi, N. Torabi, A. Amiri, An optimistic robust optimization approach to common set of weights in DEA, *Measurement*, **93**, 67–73 (2016)
15. W. D. Cook, J. Zhu, Within-group common weights in DEA: An analysis of power plant efficiency, Eur. J. Oper. Res., **178**, 1, 207–216 (2007)