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MEASURING THE PERFORMANCE OF MALAYSIAN UNIVERSITIES USING CHARNES, COOPER AND RHODES (CCR) AND SLACK-BASED MEASURE (SBM) MODELS

(Pengukuran Kecekapan Universiti di Malaysia Menggunakan Model Charnes, Cooper dan Rhodes dan Model Ukuran Bersandarkan Slek)

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ABSTRACT

The efficiency and productivity of the higher education sector play an important role in the development and growth of a nation, both as a major source of human capital and the main driver of the country's economic growth. Public higher education is under tremendous pressure worldwide to improve its performance and quality. This paper examines the efficiency scores of 20 public universities in Malaysia using the Charnes, Cooper, and Rhodes model (CCR) and Slack-Based Measure model (SBM). Three inputs and five outputs are determined to measure the performance of the university through the graduate student's marketability. The findings show that out of 20 public universities, 11 public universities are efficient with an efficiency score equal to 1. Meanwhile, the remaining nine public universities showed inefficient score results. Suggestions and improvements are identified to improve the efficiency of those universities in the future. To overcome the inefficient universities, the use of the SBM model provides recommendations to consider in measuring efficiencies which are number of postgraduate students enrolled, number of undergraduate students enrolled, and number of academic staff as the inputs and number of postgraduates, number of undergraduates, number of graduates working, number of graduates who choose to further studies and number of graduates choose to develop skills as the outputs. All the criterias need to consider for the improvement for the universities to be more efficient.

Keywords: Charnes, Cooper and Rhodes model; efficiency; Slack-Based Measure model

ABSTRAK

Kecekapan dan produktiviti sektor pendidikan tinggi memainkan peranan penting dalam pembangunan dan pertumbuhan sesebuah negara sebagai model insan dan pemacu utama dalam pertumbuhan ekonomi negara. Pendidikan tinggi awam berada pada tahap tekanan yang luar biasa di seluruh dunia untuk meningkatkan prestasi dan kualitinya. Kajian ini mengkaji skor kecekapan 20 universiti awam di Malaysia menggunakan model Charnes, Cooper dan Rhodes (CCR) dan juga model Ukuran Bersandarkan Slek (SBM). Terdapat tiga input dan lima output yang ditentukan untuk mengukur prestasi universiti melalui kebolehpasaran siswazah. Daripada 20 universiti awam, sebelas universiti awam adalah cekap dengan memberi nilai skor kecekapan adalah sama dengan 1. Sementara itu, sembilan universiti awam yang selebihnya memberi keputusan nilai skor tidak cekap. Cadangan dan penambahbaikan dibuat untuk memastikan bahawa universiti yang tidak cekap akan efisien pada masa akan datang. Untuk mengatasi ketidakcekapan universiti, penggunaan model SBM dapat memberikan cadangan yang perlu dipertimbangkan dalam mengukur kecekapan iaitu bilangan pelajar pascasiswazah mendaftar, bilangan pelajar prasiswazah mendaftar dan bilangan staf akademik sebagai input dan seterusnya bilangan pascasiswazah, bilangan mahasiswa, bilangan graduan yang bekerja, bilangan graduan memilih untuk melanjutkan pelajaran dan bilangan graduan yang memilih untuk membangunkan kemaharian sebagai output. Kesemua kriteria ini perlu dipertimbangkan untuk proses penambahbaikan agar universiti menjadi lebih cekap.

Kata kunci: model Charnes, Cooper dan Rhodes; kecekapan; model Ukuran Bersandarkan Slek

1. Introduction

Higher Education Institutions (HEIs) is an organization that provides and offers higher, post-secondary, tertiary, and third-level education. It also provides a chance for all citizens to further their studies at a higher level. In Malaysia, public universities, private universities, community colleges, polytechnics, and skill-oriented colleges are among the classifications of a Higher Education Institution. According to Irliana *et al.* (2014), numerous educational institutions reflect the government's intention to provide sufficient HEIs for Malaysians and foreigners to further their studies. This shows that education and skills are highly emphasized and significant to accomplish a better living standard in Malaysia. HEIs play significant roles in contributing to the growth of skilled and knowledgeable citizens (Grapragasem *et al.* 2014). This means that HEIs should pay more attention to providing sufficient knowledge and skills to Malaysians. The performance of Malaysian Public Universities can be measured by looking at how public universities effectively manage all resources to generate the required output. The performance of HEIs determines their ability to sustain themselves in the higher sector (Volchik & Maslyukova 2017). Fundamentally, this is to produce high-quality and versatile Malaysian students in the field after graduation.

Furthermore, there are 20 public universities in Malaysia and these universities are outstanding and still spearheading the higher education landscape in this country. Likewise, every year the government provides a certain budget for research grants to the public university. Thus, evaluating the performance of public universities is equally important. Besides, the higher education sector is still striving to strengthen and develop performance while enhancing the quality of its activities as indicated by Nazarko and Saparauskas (2014). According to Chuanyi *et al.* (2016), Malaysian society has become highly concerned about the internal operation and structure of the education sector and showed keen interest in the performance and efficiency of higher education. Efficiency is the level of performance that illustrates the least number of inputs to gain the highest number of outputs. An efficient public university makes a significant contribution to the economic growth in any region. An efficient study of HEIs such as public universities will allow the decision-making units to decide policies and guidelines that can increase redirecting policies, quality, and decision-making to increase performance based on the research analysis. This can be translated into actions according to proven empirical evidence, and not only rely on the assumptions or beliefs of the educational sector's faculty or management's guidelines.

The process of measuring the performance of the higher education sector such as public universities is complicated. According to Johnes (2003), there has been limited analysis to compare the performance using various techniques in public universities to overcome these difficulties. Many researchers or analysts have done measuring the relative efficiency of higher education institutions in previous years (Chuanyi *et al.* 2016; Flegg *et al.* 2004; Iddrisu *et al.* 2019; Irliana *et al.* 2014; Johnes 2003; Katharaki & Katharakis 2010). Data Envelopment Analysis (DEA) is a non-parametric model that uses linear programming techniques for measuring the relative efficiency of Decision-Making Units (DMUs) in the presence of multiple inputs and multiple outputs to establish an efficiency frontier. Initially DEA was used to investigate the relative efficiency of the not-for-profit organization (Göksen *et al.* 2015), only to spread to the profit-making organizations. The basic DEA model was the CCR model, originally presented by Charnes, Cooper, and Rhodes (CCR) in 1978s. In 1984, the BCC model was suggested to improve the CCR model in evaluating the efficiency of DMUs.

Some previous studies from other authors and the models in determining the efficiency of higher learning sectors are shown in Table 1.

Table 1: Authors and models in determining the efficiency of universities

Authors	Model of Efficiency
Irliana *et al*. (2014)	CCR, KAM CRS and BCC
Flegg *et al*. (2004)	DEA technical and scale efficiency (CCR)
Katharaki and Katharakis (2010)	CCR
Johnes (2003)	Variable return to scale (VRS)
Göksen *et al.* (2015)	CCR and CRS efficiency
Kuah and Wong (2011)	BCC
Abdullah *et al.* (2018)	CCR, BCC and SBM

The main objective of DEA is to measure the efficiency of the Decision-Making Unit (DMU) by a scalar measure ranging between zero (the worst) and one (the best). DEA has already successfully applied in such institutions as schools, hospitals, courts, airports, and banks (Chuanyi *et al.* 2016; Göksen *et al.* 2015; Irliana *et al*. 2014; Othman *et al.* 2016; Malik *et al* 2018; Miszczynska & Miszczyński 2021). Therefore, it has been a reason why DEA used to evaluate the effectiveness of universities across the world in different countries (Chuanyi *et al.* 2016). According to Göksen *et al.* (2015), DEA can measure the performance of non-profit organizations like universities that have voluminous inputs and outputs, whose model cannot be linear due to its structure. Efficiency is measured on a scale of 0 to 1, where a value of 1 indicates the unit is relatively efficient, and a value less than 1 indicates the unit is inefficient. The efficiency score of a unit will vary according to the factors and DMUs included in the analysis. The goal of this research is to use the CCR and SBM models to determine the performance of public universities. The CCR model proposed in this research assesses the efficiency score of Malaysia's public universities, while the SBM model is used to improve the inefficient public universities in Malaysia. SBM model will assist in identifying the sources input and output of inefficiencies and make a suggested improvement for inefficient DMUs as it considers the resulting amount of slacks for inputs and outputs. In this study, there are 20 public universities in Malaysia namely DMUs that were suggested to improve their efficiencies.

2. Method of Study

There are two types of models in DEA which are radial and non-radial. The radial model was represented by the CCR model. They deal with proportional charges of input or output. The CCR score reflects the proportional maximum input (output) reduction (expansion) rate, which is common to all inputs (outputs). The non-radial SBM models put aside the assumption of proportionate changes in input and output and deal with slack directly. This may discard varying proportions of original input and output directly. In this research, there are two types of DEA for evaluating efficiency in public universities. Since 1978s, CCR has proposed the DEA to determine the effectiveness of managerial units with numerous inputs to assemble numerous outputs (Abdullah *et al.* 2018; Kuah & Wong 2011; Martic´ *et al.* 2009; Sengupta 1992). The efficiency of the unit under evaluation is the proportion of the total amount of its weight outputs to the total amount of its weight inputs defined by CCR (Martic *et al.* 2009). This technique can help users to evaluate the proportional efficiency of business organizations. Moreover, DEA is used to determine a unit's efficiency according to its inputs and outputs and compare it to other units in the analysis, as a technique of mathematical programming. Then, the SBM model is proposed by Tone (2011). From the study of Visbal-Cadavid *et al.* (2017), the researchers mentioned that this model was developed by Tone (2011) to make an adjustment for the basic CCR model. Visbal-Cadavid *et al.* (2017) stated that the SBM considers straight with input excess and output shortfall. The difference between the CCR and BCC measures depends on the proportional reduction (enlargement) of input (output) vectors. This section shows the

procedure to complete this project where the model of CCR and SBM from the DEA approach was used to measure the efficiency of 20 public universities in Malaysia. Figure 1 below shows the process of this study.

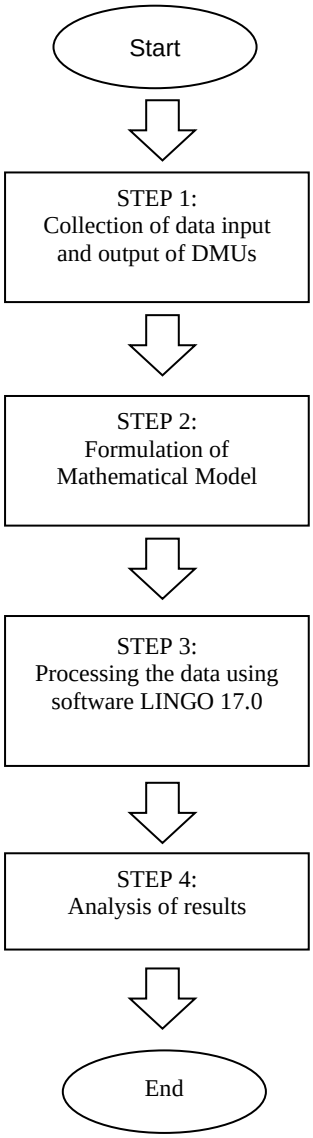

Figure 1: Flowchart of the methodology

2.1 *Charnes, Cooper, and Rhodes (CCR) and Slack-Based Measure (SBM) model*

There are two models used to measure the efficiency of public universities in Malaysia, which are the CCR model and the SBM model.

Model 1: Charnes, Cooper and Rhodes (CCR) model

The CCR model for DMU_0 set up, respectively, as:

$$\text{Minimum } \tau = t$$

$$\text{subject to } \sum_{j=i}^{n} x_{ij}u_j + t_i^- \le tx_{i0}$$

$$\sum_{j=1}^{n} y_{rj}u_j - t_r^+ \le y_{r0}$$

$$u_j \ge 0, t_r^+ \ge 0, t_i^- \ge 0$$

where n is the number of DMU, y_{r0} is the output of DMU_0, y_{rj} is the output of DMU_j, x_{i0} is the input of DMU_0 and x_{rj} is the input of DMU_j.

Model 2: Slack-Based Measure (SBM) model

The Slack-Based Model that used to evaluate the efficiency of DMU_0 is defined as follows:

$$\text{Minimum } \tau = t - \frac{1}{m}\sum_{i=1}^{m}\frac{S_i}{x_{i0}}$$

$$\text{subject to } 1 = t + \frac{1}{s}\sum_{r=1}^{s}\frac{S_r^+}{y_{r0}}$$

$$tx_{i0} = \sum_{j=1}^{n} x_{ij}L_j + S_i^-$$

$$ty_{r0} = \sum_{j=1}^{n} y_{rj}L_j - S_r^+$$

$$L \ge 0,\ S^- \ge 0,\ S^+ \ge 0,\ t \ge 0 \text{ with } S^- = ts^-,\ S^+ = ts^+, \text{ and } tL = tl$$

where S_i^- the slack in the i^{th} input and S_r^+ is the slack in the r^{th} output. Efficiency is measured by additional variables s^+ and s^-. Based on Vincová (2005), the researcher demonstrated that the SBM efficiency rate is always less than or equal to the efficiency rate of the CCR model. This means that a unit rated as SBM efficient is CCR efficient at the same time. In this model, n is the number of DMU, $r = 1,\ldots,s$ is the total number of the output, and $i = 1,\ldots,m$ is the total number of the input. Hence, x_{i0} and y_{r0} are the input and the output for a particular DMU respectively.

2.2 *Data description*

The data from Irliana *et al.* (2014) examined the relative efficiency of 20 public universities in Malaysia and stated as Decision Making Unit (DMU). The data of Public Universities in Malaysia are shown in Table 2.

Table 2: Data of public universities in Malaysia for the year 2011

	DMU	Code
Universiti Malaya	1	UM
Universiti Sains Malaysia	2	USM
Universiti Kebangsaan Malaysia	3	UKM
Universiti Putra Malaysia	4	UPM
Universiti Teknologi Malaysia	5	UTM
Universiti Utara Malaysia	6	UUM
Universiti Islam Antarabangsa Malaysia	7	UIAM
Universiti Malaysia Sarawak	8	UNIMAS
Universiti Malaysia Sabah	9	UMS
Universiti Perguruan Sultan Idris	10	UPSI
Universiti Teknologi MARA	11	UITM
Universiti Sultan Zainal Abidin	12	UNISZA
Universiti Malaysia Terengganu	13	UMT
Universiti Sains Islam Malaysia	14	USIM
Universiti Tun Hussein Onn Malaysia	15	UTHM
Universiti Teknikal Melaka	16	UTEM
Universiti Malaysia Pahang	17	UMP
Universiti Malaysia Perlis	18	UNIMAP
Universiti Malaysia Kelantan	19	UMK
Universiti Pertahanan Nasional Malaysia	20	UPNM

The main problem in determining the effectiveness of public institutions in the selection of input and output variables for the model. The comparative evaluation focused on ratio analysis that allows initial comparisons and some early conclusions to reach based on performance indicators. These indicators reflect mainly on human resources involved in supporting institutional services and the number of outcomes produced. Based on Irliana *et al.* (2014) higher education institutions employ academic staff to educate the students enrolled to produce graduates with a certain level of quality. Hence, teaching effectiveness is referring to the teaching performance of universities in delivering knowledge to undergraduate and postgraduate students. The quality of students' state as input is based on a general assumption that better entry qualifications will produce better quality graduates. The outputs of teaching activities are concentrated on graduates. Intuitively, technical efficiency is a measure of the extent to which an institution efficiently allocates the physical input at its disposal for a given level of output. Table 3 shows a summary of some input and output used in previous studies using a few criteria to measure the performance of higher education in several countries.

Table 3: The lists of selected input and output by the authors from previous research

Input and Output/Authors	Irliana *et al*. (2014)	Flegg *et al*. (2004)	Katharaki and Katharakis (2010)	Iddrisu *et al*. (2019)	Johnes (2003)
Input:					
Number of academic staff	√	√	√	√	√
Number of non-academic staff			√	√	
Number of postgraduate students enrolled	√	√	√		√
Number of undergraduate students enrolled	√	√			√
Aggregate departmental expenditure		√		√	
Operating expenses			√		
Output:					
Number of postgraduates	√	√	√	√	√
Number of undergraduates	√	√	√	√	√
Number of graduates working	√		√	√	
Number of graduates who choose to further studies	√			√	√
Number of graduates choose to develop skills	√	√	√	√	√
Income from research and consultancy		√	√		√

Table 4: List of DMU with input and output data (Irliana *et al.* 2014)

DMUs	Input			Output				
	Postgraduate students enrolled	Undergraduate students enrolled	Academic Staff	Postgraduates	Undergraduates	Graduates working	Graduates who choose to further studies	Graduates choose to develop skills
UM	2471	3502	2076	1799	4127	3818	255	105
USM	2048	5635	2031	1121	4471	3236	387	31
UKM	2872	3168	2158	1278	5086	4185	272	73
UPM	3208	5030	1524	1736	4201	4313	597	52
UTM	2975	5176	2007	791	3821	3272	894	58
UUM	1651	5645	1215	1445	6358	5361	154	118
UIAM	902	4347	2135	591	2868	2149	251	306
UNIMAS	213	4154	709	122	1229	801	62	45
UMS	261	4311	896	62	3570	2284	118	73
UPSI	545	10050	609	334	3077	1141	20	7
UNISZA	39	1331	406	1	440	281	310	7
UMT	88	2301	383	79	1617	776	194	24
USIM	117	2505	478	44	1120	682	45	43
UTHM	739	4010	676	165	1832	1174	277	32
UTEM	270	2552	656	100	1082	701	259	28
UMP	80	2102	583	29	716	650	154	21
UNIMAP	76	2125	630	43	952	501	172	28
UMK	96	1104	215	3	266	137	6	6
UPNM	15	580	213	0	406	177	15	24

In this study, the secondary data used from the article "Relative Efficiency of Public Universities in Malaysia" by Irliana *et al.* (2014). The data consists of the relative efficiency of 20 public universities of Malaysia in the students' transition process in 2011. There are three

inputs and five outputs selected to determine the effectiveness of the public universities based on the demand of the graduated students. The three inputs and five outputs are considered in measuring efficiencies: number of postgraduate students enrolled, number of undergraduate students enrolled and number of academic staff as the inputs and number of postgraduates, number of undergraduates, and number of graduates working, number of graduates who choose to further studies and number of graduates choose to develop skills as the outputs. Then, these data were analysed using LINGO 17.0 that generated the efficiency scores. The input and output data of the universities can be referred to in Table 4.

3. Results and Discussions

Measuring efficiency is a means rather than an end and its goal is to find the direction for each DMU to make improvements. The efficiency score of 20 DMUs in this study were measured using the CCR and SBM models. Table 5 shows the efficiency score obtained using CCR and SBM models.

Table 5: CCR and SBM score for 20 public universities in Malaysia

DMUs	Code	CCR Score	SBM Score
1	UM	1.0000	1.0000
2	USM	0.7221	0.3677
3	UKM	1.0000	1.0000
4	UPM	1.0000	1.0000
5	UTM	0.7319	0.5025
6	UUM	1.0000	1.0000
7	UIAM	1.0000	1.0000
8	UNIMAS	0.7198	0.2622
9	UMS	1.0000	1.0000
10	UPSI	1.0000	1.0000
11	UITM	1.0000	1.0000
12	UNISZA	1.0000	1.0000
13	UMT	1.0000	1.0000
14	USIM	0.8697	0.4206
15	UTHM	0.6533	0.4288
16	UTEM	0.5489	0.4968
17	UMP	0.8908	0.5534
18	UNIMAP	0.8414	0.6828
19	UMK	0.3145	0.0565
20	UPNM	1.0000	1.0000

According to Table 5, eleven DMUs are efficient with the efficiency scores of the DMUs being equal to 1 and it has no input excess and no output shortfall. Based on Tone (2011), a DMU is efficient for the SBM model if the CCR score is efficient. The list of efficient universities is UM, UKM, UPM, UUM, UIAM, UMS, UPSI, UITM, UNISZA, UMT, and UPNM with the efficiency score equal to 1. The remaining nine inefficient universities with a score efficiency below 1 are USM, UTM, UNIMAS, USIM, UTHM, UTEM, UMP, UNIMAP, and UMK. Both models indicate the same result whereby eleven universities are efficient

while another nine universities are inefficient. However, the SBM model provides more detailed and accurate results for inefficiency scores from the perspective of input excess and output shortfall. The result of score efficiency with input excess and output shortfall in percentages of the DMUs are shown in Table 6.

Table 6: Result of score efficiency with input excess and output shortfall in public universities

No	**DMUs**	ρ	s_1^-	s_2^-	s_3^-	s_1^+	s_2^+	s_3^+	s_4^+	s_5^+
1	UM	1.0000	0	0	0	0	0	0	0	0
2	USM	0.3678	28.85%	0	0	0	11.98%	25.68%	0	691.07%
3	UKM	1.0000	0	0	0	0	0	0	0	0
4	UPM	1.0000	0	0	0	0	0	0	0	0
5	UTM	0.5025	63.88%	0	14.16%	0	12.45%	5.19%	0	218.53%
6	UUM	1.0000	0	0	0	0	0	0	0	0
7	UIAM	1.0000	0	0	0	0	0	0	0	0
8	UNIMAS	0.2622	0	30.82%	0.12%	0	61.44%	52.94%	200.70%	0
9	UMS	1.0000	0	0	0	0	0	0	0	0
10	UPSI	1.0000	0	0	0	0	0	0	0	0
11	UiTM	1.0000	0	0	0	0	0	0	0	0
12	UNISZA	1.0000	0	0	0	0	0	0	0	0
13	UMT	1.0000	0	0	0	0	0	0	0	0
14	USIM	0.4206	0	37.25%	0	20.31%	0	0	100.94%	0
15	UTHM	0.4288	51.62%	40.51%	0	39.40%	0	24.10%	214.97%	29.45%
16	UTEM	0.4968	24.99%	30.40%	18.63%	0	11.28%	33.16%	209.20%	4.51%
17	UMP	0.5334	0	5.76%	42.16%	138.76%	90.04%	4.40%	21.77%	0
18	UNIMAP	0.6829	0	8.40%	39.75%	39.50%	43.45%	31.73%	0	0
19	UMK	0.0564	53.40%	64.46%	45.15%	136.37%	0	50.52%	0	7.75%
20	UPNM	1.0000	0	0	0	0	0	0	0	0

For example, DMU 2 was inefficient with an efficiency score of 0.3678 measured by using the SBM model. Table 7 below shows the recommendation to improve the efficiency of DMU 2, USM.

Table 7: Score of DMU 2

DMU 2: USM ρ = 0.3678				
Slack	Values	Percentage%		
s_1^-	590.885	(-28.85%)	Number of postgraduate students enrolled	Input excess
s_2^-	0.000	0.00%	Number of undergraduate students enrolled	
s_3^-	0.000	0.00%	Number of academic staff	
s_1^+	0.000	0.00%	Number of postgraduates	Output shortfall
s_2^+	535.637	(+11.98%)	Number of undergraduates	
s_3^+	931.109	(+25.68%)	Number of graduates working	
s_4^+	0.000	0.00%	Number of graduates who choose to further studies	
s_5^+	214.231	(+691.07%)	Number of graduates choose to develop skills	

In order to be efficient, USM should minimize the input excess and maximize the output shortfall as illustrated in Table 7. The number of postgraduate students enrolled should decrease

by 28.85 % of input excess. On the other hand, the output shortfall of the number of undergraduates who graduate should increase by 11.98%, the number of graduates working should increase by 25.68 % and the number of graduates who choose to develop skills should increase by 691.07%. By using this recommendation for improving the efficiency of each input and output, inefficient DMU 2 can be efficient. Furthermore, the SBM model gives the input excess and output shortfall of inefficient DMU. The non-zero input and output slacks mean that the university is inefficient. SBM model can provide suggestions and recommendations that require attention and improvement to the input and output of the universities to become efficient**.** For further analysis of the inefficient universities can refer to Table 6 which has the results in percentage to improve and consider the input and output of inefficient DMUs.

4. Conclusion

DEA is used to measure efficiency and comparable DMUs relative to one another. This study proposes a method to compare the performance of public universities in Malaysia by using CCR and SBM models. The finding of this study will help to analyze the performance and productivity change in the higher education sectors such as public universities. This is because it will give valuable information to produce better-educated, skilled workers and achieve the nation's aspiration to become a developed country. Another significance of this finding is it will help the management of public universities which can be exposed to the measurability performance of universities that would provide them with the better understanding to maintain the efficiency of the universities which will maximize its performance. Besides that, future studies should investigate different fields such as hospitals, schools, airports, business firms, bank branches, military services, agriculture, retail outlets, and others to evaluate the performance. Moreover, in future studies, the suggestion of the Banker, Charnes, and Cooper (BCC) model can apply to determine the efficiency of public or non-profit organizations.

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