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DEA Optimization with Neural Network in Benchmarking Process

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Abstract. The object of research that will be examined in this study is the problem of benchmarking by using Data Envelopment Analysis (DEA). The result of benchmarking obtained through the DEA method in the form of benchmarking values should be studied as a pattern when there is a new data can be directly predicted. On this side required a well-known application of Artificial Neural Networks in studying existing patterns. The results of this study are in the form of optimization is performed on DEA method to guarantee the principle of quality assurance in detecting early the quality of a new pattern emerging. Based on the result of the research, we can predict emerging new patterns that become in efficient.

1. Introduction

Research on benchmarking is now evolving as a follow-up to the improvement process, quality assurance, evaluation and performance improvement [1]. Data Envelopment Analysis (DEA) is a linear programming approach proposed by [2] Is widely used as a framework for efficiency and measurement evaluation, which has also been refined by [3] and [4]. The results of benchmarking obtained through the DEA method in the form of benchmarking values should be studied as a pattern when there is a new data can be directly predicted benchmarking results that exist. On this side required a well-known application of Artificial Neural Networks in studying existing patterns.

This pattern recognition method with ANN is trained with a set of data to be able to recognize and identify data patterns or curves. This training process is often called the learning stage. So that learning process becomes an important part also in this method. The selection of algorithms and their corresponding parameters and determining how many data devices are required in this learning process is critical to determining the accuracy of the resulting forecasting [5].

In principle there are two ways to train the neural network with supervised learning and unsupervised learning. In unsupervised learning, the neural network is given only input data but how the output is not specified. As the data entered increases, the neural network will categorize or group the input data. In supervised learning, a neural network is assigned a pair of training data consisting of input and target data. So, when the inclusion of data increases the neural network will change its internal characteristics to produce as much as possible the output as the target. Thus, the way of learning that can be used for pattern recognition is the supervised learning because the data to be



trained is a pair of input and target data [5].

Our main contributions in this paper are: (a) we adapted Artificial Neural Network for studying existing pattern of the result of benchmarking by using DEA (b) to determine the weight value of Artificial Neural Network for recognizing the existing pattern that be obtained from benchmarking using DEA, and (c) to combine the points (a) and (b) in order to optimizing DEA for predict emerging new patterns that become inefficient. Reichmann et al [6] used the DEA method for benchmarking of university libraries. Research conducted by [7] introduces an expert system that can be used to evaluate benchmarking processes using the Small and Medium Size Enterprise (SMEs) method. [1] proposed a Benchmarking Knowledge Based System (BKBS) method for benchmarking, performance evaluation and improvement process that incorporates the KBS methodology with DEA.

Research conducted by [1] has produced an excellent model for benchmarking processes. The BKBS method proposed by [1] can still be refined for real applications especially relating to efficiency measurement and inefficiency of Data Measurement Unit (DMU), because in DEA method it is assumed that random error is zero so it can not be estimated inefficiency problem. Research that has been done by some researchers can not predict emerging new patterns that become inefficient.

The results of this study are in the form of optimization is performed on DEA method to guarantee the principle of quality assurance in detecting early on the quality of a new pattern emerging.

2. Methods

The case study in this study is the benchmarking of the use of Hand Tractor for farmers. The Decision-Making Unit for Input is Variable Cost, Machine Cost, and Age of Tractor. While Decision Making Unit for Output is Total Income, Income from Planting, and Revenue from Renting a Tractor [8].

The working procedure conducted by the researchers of this study can be seen as a whole in Figure 1.

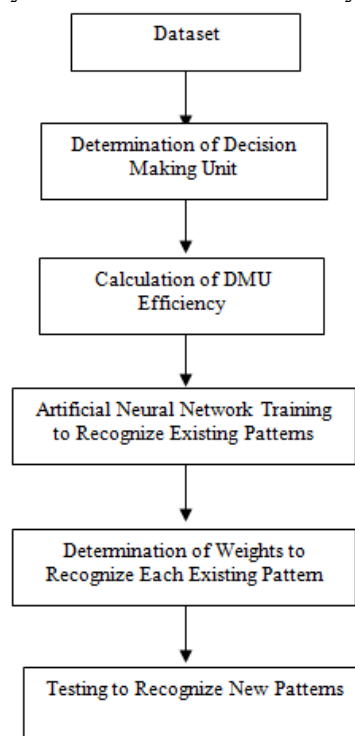


Figure 1. Stages of Research Methods

From the Figure 1, it can be seen that the process will begin with determined the dataset that will be used in this research. After we have a dataset, the next process is determined the Decision-Making Unit (DMU) in input and output. Based on the DMU Input and Output, the research will be continued with calculating the efficiency of the DMU. Artificial Neural Network will study the existing patterns

in the form of the result of benchmarking using DEA. The result of Artificial Neural Network in the form of the weight will be used in testing to recognize the new patterns.

2.1. Data envelopment analysis

In DEA, an entity or unit of production is called a Decision-Making Units. The efficiency or performance of the DMU is calculated from the ratio of decision unit inputs to its outputs (Banker, 1984). The basis of efficiency measurement used in DEA is the ratio of total output to total input, where multiple inputs and multiple outputs are added linearly using weighted average. The DMU to k efficiency is defined as the ratio of the overall output to the overall input shown in Equation 1.

$$\text{Efficiency} = \frac{\text{Total output}}{\text{Total input}} = \frac{\sum_{j=1}^s w_j y_{jk}}{\sum_{i=1}^r v_i x_{ik}} \dots\dots\dots(1)$$

Y_j is the output to j , x_i is the input to i , v_i is the input weight and w_j is the output weight. In DEA, DMU is compared to the most efficient unit or DMU with the best performance.

The DMU used in this calculation can be seen in Table 1 [8].

Table 1. DMU Used in The Research

	Variable	Cost and revenue analysis	Analysis of tractor lifetime
Output	Total Income		*
	Income from Planting	*	
	Revenue from Renting a Tractor	*	
Input	Variable Cost	*	
	Machine Cost	*	*
	Age of Tractor		*

From the Table 1. [8] it can be seen that the DMU that used in the research can be divide become DMU Output and DMU Input. The DMU Output consists of Total Income, Income from Planting, and Revenue Form Renting a Tractor. The DMU input consists of Variable Cost, Machine Cost, and Age of Tractor. Total Income, Machine Cost, and Age of Tractor will be used in Analysis of Tractor Lifetime. Income from Planting, Revenue from Renting a Tractor, Variable Cost, and Machine Cost will be used in Cost and Revenue Analysis.

In this research we will focus on benchmarking for cost and revenue analysis. Thus, DMU for input is Variable Cost and Machine Cost whereas DMU for output is Income from Planting and Revenue from Renting a Tractor. To simplify our calculations, it is assumed that the weights for each input and output are equal, ie 0.5. DMU is said to be efficient if it can achieve the efficiency level $> = 0.33$ (assuming the tractor's lifetime is 3 years).

For example, suppose data from farmers are as can be seen in Table 2.

Table 2. Example of DMU Input and Output

Farmer	Income from Planting	Revenue from Renting a Tractor	Variable Cost	Machine Cost
1	100	50	30	200
2	75	45	27	205
3	40	20	40	210
4	50	40	60	220
5	65	50	30	190
6	45	30	30	200
7	70	60	30	190
8	40	30	50	180
9	100	45	30	200
10	70	30	30	200

The efficiency level for each farmer from the Table 2. is as follows.

$$\text{Efficiency of Farmer 1} = \frac{0.5 \times 100 + 0.5 \times 50}{0.5 \times 30 + 0.5 \times 200} = \frac{75}{115} = 0.65 \text{ (Efficient)}$$

$$\text{Efficiency of Farmer 2} = \frac{0.5 \times 75 + 0.5 \times 45}{0.5 \times 27 + 0.5 \times 205} = \frac{60}{116} = 0.52 \text{ (Efficient)}$$

$$\text{Efficiency of Farmer 3} = \frac{0.5 \times 40 + 0.5 \times 20}{0.5 \times 40 + 0.5 \times 210} = \frac{30}{125} = 0.24 \text{ (Inefficient)}$$

$$\text{Efficiency of Farmer 4} = \frac{0.5 \times 50 + 0.5 \times 40}{0.5 \times 60 + 0.5 \times 220} = \frac{45}{140} = 0.32 \text{ (Inefficient)}$$

$$\text{Efficiency of Farmer 5} = \frac{0.5 \times 65 + 0.5 \times 50}{0.5 \times 30 + 0.5 \times 190} = \frac{57.5}{110} = 0.52 \text{ (Efficient)}$$

$$\text{Efficiency of Farmer 6} = \frac{0.5 \times 45 + 0.5 \times 30}{0.5 \times 30 + 0.5 \times 200} = \frac{37.5}{115} = 0.32 \text{ (Inefficient)}$$

$$\text{Efficiency of Farmer 7} = \frac{0.5 \times 70 + 0.5 \times 60}{0.5 \times 30 + 0.5 \times 190} = \frac{65}{110} = 0.59 \text{ (Efficient)}$$

$$\text{Efficiency of Farmer 8} = \frac{0.5 \times 40 + 0.5 \times 30}{0.5 \times 50 + 0.5 \times 180} = \frac{35}{115} = 0.3 \text{ (Inefficient)}$$

$$\text{Efficiency of Farmer 9} = \frac{0.5 \times 100 + 0.5 \times 45}{0.5 \times 30 + 0.5 \times 200} = \frac{72.5}{115} = 0.63 \text{ (Efficient)}$$

$$\text{Efficiency of Farmer 10} = \frac{0.5 \times 70 + 0.5 \times 30}{0.5 \times 30 + 0.5 \times 200} = \frac{50}{115} = 0.43 \text{ (Efficient)}$$

From the Table 2, the Efficiency of each DMU has been calculated. The efficiency of Farmer 1, 2, 5, 7, 9, and 10 according to DEA process is efficient, but the efficiency of Farmer 3, 4, 6, and 8 according to DEA process is in efficient. The pattern of the result of the benchmarking using DEA can be studied using Artificial Neural Network with the assumption that the efficiency of every farmer will set to 1 if efficient and will set to 0 if inefficient.

2.2. Perceptron algorithm

Perceptron algorithm in this research is done by assuming data included in efficient category as 1 and data are not efficient as 0. Based on the result of benchmarking using DEA in Table 2, we can be training the Perceptron Algorithm of Artificial Neural Network in recognizing the existing pattern.

The form of training conducted can be seen in Table 3.

Table 3. Training with Perceptron Algorithm for each DMU

Input				Target	Weight				Actual	Error	Final Weight			
X1	X2	X3	X4		W1	W2	W3	W4			W1	W2	W3	W4
100	50	30	200	1	0	0	0	0	0	-1	-10	-5	-3	-20
75	45	27	205	1	-10	-5	-3	-20	0	-1	-17.5	-9.5	-5.7	-40.5
40	20	40	210	0	-17.5	-9.5	-5.7	-40.5	0	-1	-21.5	-11.5	-9.7	-61.5
50	40	60	220	0	-21.5	-11.5	-9.7	-61.5	0	-1	-26.5	-15.5	-15.7	-83.5
65	50	30	190	1	-26.5	-15.5	-15.7	-83.5	0	-1	-33	-20.5	-18.7	-102.5
45	30	30	200	0	-33	-20.5	-18.7	-102.5	0	-1	-37.5	-23.5	-21.7	-122.5
70	60	30	190	1	-37.5	-23.5	-21.7	-122.5	0	-1	-44.5	-29.5	-24.7	-141.5
40	30	50	180	0	-44.5	-29.5	-24.7	-141.5	0	-1	-48.5	-32.5	-29.7	-159.5
100	45	30	200	1	-48.5	-32.5	-29.7	-159.5	0	-1	-58.5	-37	-32.7	-179.5
70	30	30	200	1	-58.5	-37	-32.7	-179.5	0	-1	-65.5	-40	-35.7	-199.5

From the Table 3., the process of Training with Perceptron Algorithm for each DMU can be explain as follows.

$\alpha = 0.1$ (Learning Rate)

$$\begin{aligned}\text{Actual} &= X1.W1 + X2.W2 + X3.W3 + X4.W4 \\ &= 100*0 + 50*0 + 30*0 + 200*0 \\ &= 0 + 0 + 0 + 0 = 0\end{aligned}$$

$$\begin{aligned}\text{Error} &= \text{Target} - \text{Aktual} \\ &= 0 - 1 = -1\end{aligned}$$

$$\begin{aligned}\Delta W1 &= \alpha * \text{Error} * X1 \\ &= 0.1 * -1 * 100 \\ &= -10\end{aligned}$$

$$\begin{aligned}W1 (2) &= W1 + \Delta W1 \\ &= 0 + -10 \\ &= -10\end{aligned}$$

$$\begin{aligned}\Delta W2 &= \alpha * \text{Error} * X2 \\ &= 0.1 * -1 * 50 \\ &= -5\end{aligned}$$

$$\begin{aligned}W2 (2) &= W2 + \Delta W2 \\ &= 0 + -5 \\ &= -5\end{aligned}$$

$$\begin{aligned}\Delta W3 &= \alpha * \text{Error} * X3 \\ &= 0.1 * -1 * 30 \\ &= -3\end{aligned}$$

$$\begin{aligned}W3 (2) &= W3 + \Delta W3 \\ &= 0 + -3 \\ &= -3\end{aligned}$$

$$\begin{aligned}\Delta W4 &= \alpha * \text{Error} * X4 \\ &= 0.1 * -1 * 200 \\ &= -20\end{aligned}$$

$$\begin{aligned}W4 (2) &= W4 + \Delta W4 \\ &= 0 + -20 \\ &= -20\end{aligned}$$

Ket:

X1 = Income from Planting

X2 = Revenue from Renting a Tractor

X3 = Variable Costs

X4 = Machine Cost

3. Experimental process

For the training process will be done by using Nntool on Matlab.

The results of training can be seen in Figures 2, 3, and 4.

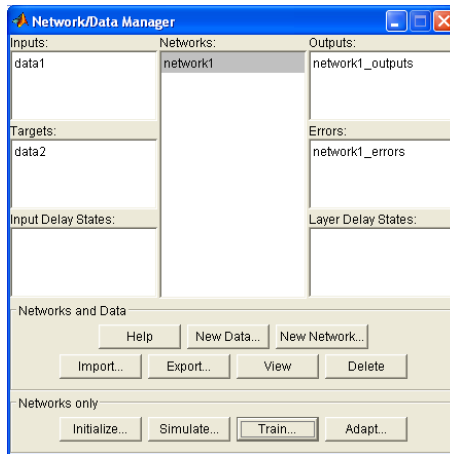


Figure 2. User Interface of Network Data Manager

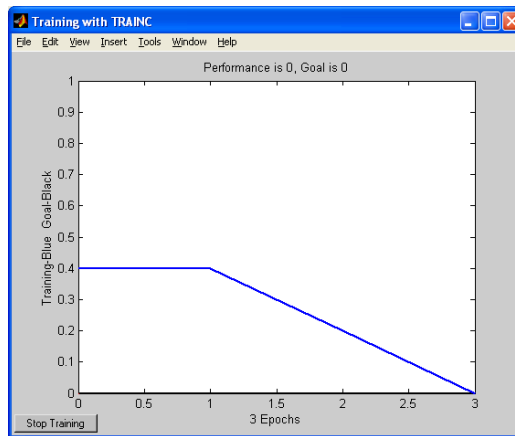


Figure 3. Performance 0 means Training Results Have Been Successfully Recognizing DMU Patterns

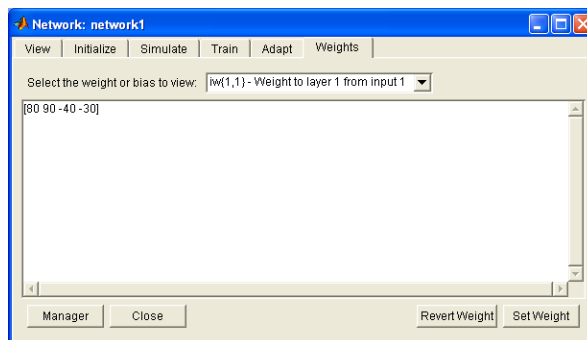


Figure 4. Final Weight Result Used to Recognize DMU

Based on training results for each DMU, we get weighted data for each DMU.

Table 4. Training Results for Each DMU

Farmer	Income from Planting	Revenue from Renting a Tractor	Variable Costs	Machine Cost
1	60	50	60	220
2	55	20	27	205
3	45	20	40	210
4	45	40	60	220
5	65	50	30	190

Testing by Using Artificial Neural Networks:

$$\begin{aligned} \text{Efficiency of Farmer 1} &= (60 \times \text{Income from Planting} + 50 \times \text{Revenue from Renting a Tractor}) / (60 \times \\ &\quad \text{Variable Costs}) + (220 \times \text{Machine Cost}) \\ &= (60 \times 80 + 50 \times 90) / (60 \times 40) + (220 \times 30) \\ &= (4800 + 4500) / (2400 + 6600) \\ &= 9300 / 9000 = 1.033, \text{ Because } \geq 1 \text{ so Efficient} \end{aligned}$$

$$\begin{aligned} \text{Efficiency of Farmer 2} &= (55 \times \text{Income from Planting} + 20 \times \text{Revenue from Renting a Tractor}) / (27 \times \\ &\quad \text{Variable Costs}) + (205 \times \text{Machine Cost}) \\ &= (55 \times 80 + 20 \times 90) / (27 \times 40) + (205 \times 30) \\ &= (4400 + 1800) / (1080 + 6150) \\ &= 6200 / 7230 = 0.86, \text{ Because } < 1 \text{ So Inefficient} \end{aligned}$$

$$\begin{aligned} \text{Efficiency of Farmer 3} &= (45 \times \text{Income from Planting} + 20 \times \text{Revenue from Renting a Tractor}) / (40 \times \\ &\quad \text{Variable Costs}) + (210 \times \text{Machine Cost}) \\ &= (45 \times 80 + 20 \times 90) / (40 \times 40) + (210 \times 30) \\ &= (3600 + 1800) / (1600 + 6300) \\ &= 5400 / 7900 = 0.68, \text{ Because } < 1 \text{ So Inefficient} \end{aligned}$$

$$\begin{aligned} \text{Efficiency of Farmer 4} &= (45 \times \text{Income from Planting} + 40 \times \text{Revenue from Renting a Tractor}) / (60 \times \\ &\quad \text{Variable Costs}) + (220 \times \text{Machine Cost}) \\ &= (45 \times 80 + 40 \times 90) / (60 \times 40) + (220 \times 30) \\ &= (3600 + 3600) / (2400 + 6600) \\ &= 7200 / 9000 = 0.8, \text{ Because } < 1 \text{ So Inefficient} \end{aligned}$$

$$\begin{aligned} \text{Efficiency of Farmer 5} &= (65 \times \text{Income from Planting} + 50 \times \text{Revenue from Renting a Tractor}) / (30 \times \\ &\quad \text{Variable Costs}) + (190 \times \text{Machine Cost}) \\ &= (65 \times 80 + 50 \times 90) / (30 \times 40) + (190 \times 30) \\ &= (5200 + 4500) / (1200 + 5700) \\ &= 9700 / 6900 = 1.4, \text{ Because } \geq 1 \text{ So Efficient} \end{aligned}$$

Testing by using DEA:

$$\text{Efficiency of Farmer 1} = (0.5 * 60 + 0.5 * 50) / (0.5 * 60 + 0.5 * 220) = 0.39 \text{ (Efficient)}$$

$$\text{Efficiency of Farmer 2} = (0.5 * 55 + 0.5 * 20) / (0.5 * 27 + 0.5 * 205) = 0.32 \text{ (Inefficient)}$$

$$\text{Efficiency of Farmer 3} = (0.5 * 45 + 0.5 * 20) / (0.5 * 40 + 0.5 * 210) = 0.26 \text{ (Inefficient)}$$

$$\text{Efficiency of Farmer 4} = (0.5 * 45 + 0.5 * 40) / (0.5 * 60 + 0.5 * 220) = 0.3 \text{ (Inefficient)}$$

$$\text{Efficiency of Farmer 5} = (0.5 * 65 + 0.5 * 50) / (0.5 * 30 + 0.5 * 190) = 0.52 \text{ (Efficient)}$$

4. Results and discussion

From the result of Optimizing DEA using Artificial Neural Network and DEA Classic for the Data in Table 4, it can be summarized in Table 5.

Table 5. Comparison result of Optimizing DEA using Artificial Neural Network and Calculating the efficiency of each DMU using DEA Classic

Famer	The Result of DEA Classic	The Result of Optimizing DEA using Artificial Neural Network
1	Efficient	Efficient
2	Inefficient	Inefficient
3	Inefficient	Inefficient
4	Inefficient	Inefficient
5	Efficient	Efficient

From the Table 5, it can be seen that the result of calculation by Optimizing DEA using Artificial Neural Network give same result if done benchmarking process by using DEA Classic, so Artificial Neural Network has succeeded in doing benchmarking process. The results showed that Artificial Neural Network Perceptron Model has succeeded in Optimizing DEA method in conducting benchmarking process

5. Conclusion

The conclusion of this research are as follows. First, DEA method is very suitable in doing benchmarking process. Second, it is confirmed that DEA method optimization using Neural Network can perform the benchmarking process since the discovery of new data. Future research should be performed on stochastic.

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