Using DEA to Measure the Relative Efficiency of the Service Center and Improve Operation Efficiency Through Reorganization

Chen-Fu Chien, Feng-Yu Lo, and James T. Lin

***Abstract*—Data envelopment analysis (DEA) has become a practicable approach to evaluate the relative efficiencies of decision-making units in various contexts. This paper conducted a DEA study to measure the relative efficiencies of 17 service centers of the NAN-TOU electricity distribution district of Taiwan Power Company (TPC). In addition, this paper also investigated the alternatives for reorganizing the service centers via efficiency measurement. The results showed that the proposed reorganization alternatives have better efficiency scores. Based on DEA evaluations, we provided specific directions for the inefficient service centers to improve their operation efficiencies, and thus, maintain the competitive advantage of TPC in facing power market liberalization.**

***Index Terms*—data envelopment analysis (DEA), power systems, relative efficiency, reorganization, Taiwan Power Company (TPC).**

I. Introduction

DATA envelopment analysis (DEA) [1], [2] has been established as one of the most advanced methodologies for measuring efficiency of many homogenous entities [i.e., decision-making units (DMUs), in various contexts]. This paper presents a DEA study to evaluate the relative efficiencies of service centers of the NAN-TOU electricity distribution district of Taiwan Power Company (TPC) in Taiwan. As the TPC facing the challenges from its privatization and the liberalization of power industry, it is critical to maintain the competitive advantage by increasing the operational efficiency and reducing the operational costs [3]. In particular, TPC has recognized the importance of using its manpower efficiently to stimulate the organizational potentiality while maintaining its service quality. Therefore, some changes of internal operation environment were considered necessarily in TPC. The authors have used DEA models to assess the relative efficiencies of electricity distribution district of the TPC [4]. Furthermore, this study focused on the most inefficient district, NAN-TOU, to evaluate the relative efficiencies of its service centers and investigate the alternatives for reorganizing them to increase overall efficiency of this district. This study also proposed specific directions for the inefficient service centers to improve their efficiencies.

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The DEA is a linear programming method that can consider many inputs and outputs simultaneously to measure the relative efficiencies of evaluated entities. In particular, the DEA model does not require the assignment of predetermined weights to input and output factors. In contradistinction to the parametric approach, DEA also does not require any assumptions about the production form. DEA has been applied to efficiency measurement of various entities in public and private sectors including schools [5]–[7], hospitals [8], [9], banks [10], [11], and courts [12], [13]. Extensive reviews and additional applications can be found in the reviews by Seiford [14] and Charnes *et al.* [15]. The proposed research framework is presented in Fig. 1.

The remainder of this paper is organized as follows. Section II presents the fundamentals of DEA models and reviews the related literatures. Section III details the empirical study and illustrates the results of efficiency evaluation. Section IV discusses the reorganization of service centers. Section V concludes with the findings of this study and future research directions.

II. Data Envelopment Analysis Models

The DEA approach was first introduced by Charnes *et al.* [1], called Charnes–Cooper–Rhodes (CCR) model, to produce an efficiency frontier based on the concept of Pareto optimum. The DMUs that lie on the efficiency frontier are nondominated and are thus called Pareto-optimal units or efficient DMUs. Alternatively, DMUs that do not lie on the efficiency frontier are regarded as relatively inefficient.

In particular, the efficiency of a service center is calculated by the ratio of a weighted sum of outputs to a weighted sum of inputs. The determination of such weights can be difficult and controversial. DEA is a nonparametric approach that does not require the assignment of predetermined weights to the input and output factors. Suppose there are N DMUs, with m input factors and n output factors, let k $(1 \leq k \leq N)$ denote one of N DMUs. The efficiency E_k of the kth DMU, with outputs Y_{rk} (with $r = 1, \ldots, n$) and inputs X_{ik} (with $i = 1, \ldots, m$), is calculated by the following CCR model:

$$\text{Maximize} \quad E_k = \frac{\sum_{r=1}^{n} U_r Y_{rk}}{\sum_{i=1}^{m} V_i X_{ik}} \tag{1}$$

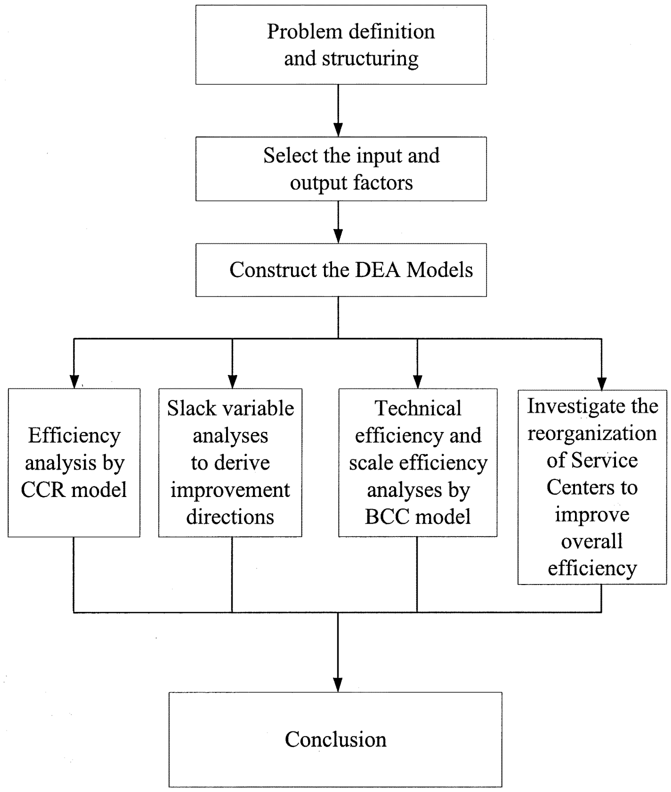

Fig. 1. Research framework.

under the following N constraints:

$$\frac{\sum_{r=1}^{n} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij}} \leq 1, \qquad j = 1, \ldots, N$$
$$U_r,\, V_i \geq \varepsilon > 0 \tag{2}$$

where ε is a non-Archimedean quantity (i.e., a very small positive number); generally, let $\varepsilon = 10^{-9}$). The above constraints restrict the efficiencies of all of the DMUs ($j = 1, \ldots, N$) to have an upper bound of 1. The kth DMU is efficient when E_k equal 1 and inefficient if E_k less than 1. The variables U_r ($r = 1, \ldots, n$) and V_i ($i = 1, \ldots, m$) are the weights to be derived for the corresponding output and input factors while maximizing the efficiency of the kth DMU. That is, DEA allows that individual DMUs may have their own preference structures and value systems, and thus, can determine their own weights. The above CCR model is a fractional programming problem, yet can be transformed into a linear programming model as follows:

$$\text{Maximize} \quad E_k = \sum_{r=1}^{n} U_r Y_{rk} \tag{3}$$

under the following constraints:

$$\sum_{r=1}^{n} V_i X_{ik} = 1 \tag{4}$$
$$\sum_{r=1}^{n} U_r Y_{rj} - \sum_{r=1}^{n} V_i X_{ij} \leq 0, \qquad j = 1, \ldots, N$$
$$U_r,\, V_i \geq \varepsilon > 0. \tag{5}$$

In general, the dual problem of the above model is solved for computational convenience and examining the slack variables. In addition, Banker *et al.* [2] developed the Banker–Charnes–Cooper (BCC) model that produces variable returns to scale (VRS) efficiency frontier to measure the technical efficiency. In particular, the BCC model for measuring the input technical efficiency of the kth DMU is as follows:

$$\text{Maximize} \quad E_k = \frac{\sum_{r=1}^{s} U_r Y_{rk}}{\sum_{i=1}^{m} V_i X_{ik} + v_k} \tag{6}$$

under the following N constraints:

$$\frac{\sum_{r=1}^{s} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij} + v_k} \leq 1, \qquad j = 1, \ldots, N \tag{7}$$
$$U_r,\, V_i \geq \varepsilon > 0. \tag{8}$$

Note that v_k indicates the returns to scale at specific points on the efficient frontier. The value of v_k can be positive, zero, or negative denoting that the corresponding DMU presents decreasing, constant, or increasing returns to scale, respectively. A DMU that is not overall efficient could be either technical inefficient or scale inefficient or technical and scale inefficient. It is shown that the overall efficiency, calculated from the CCR model, can be decomposed into the technical efficiency measured by BCC model and the scale efficiency [2]. Indeed, the scale efficiency score of a DMU is the ratio of the overall efficiency to the technical efficiency. Therefore, a DMU is overall efficient if and only if it is technical efficient and scale efficient. The overall efficiency of a DMU is less than or equal to its technical efficiency. The overall efficiency of a DMU equals to its technical efficiency if and only if this DMU is operating at the most productive scale size, and thus, its scale efficiency is 1. Alternatively, if the scale efficiency is less than 1, the DMU will be operating either at decreasing returns to scale if a proportional increase of all input levels produces a less-than-proportional increase in output levels or increasing return to scale at the converse case. This implies that resources may be transferred from DMUs operating at decreasing returns to scale to those operating at increasing returns to scale to increase average productivity at both sets of DMUs [16]. That is, using the BCC model can specify the major sources causing overall inefficiency.

A number of studies have been applied DEA in the power industry. Fare *et al.* [17] applied the DEA model to evaluate the relative efficiency of electric utilities in which an output (net generation) and three inputs (fuel, labor, and capital) were considered. Charnes *et al.* [18] evaluated the management efficiency of regulated electric cooperatives in which three outputs (net margin, total KWH sales, and total revenue received from sales of electricity) and 11 inputs (operations expense, maintenance expense, consumer accounts expense, administrative, and general expense, miles per consumer, line loss, average hours outage per customer, percent system unload, total plant, salaries, and inventory) were considered. Miliotis [19] evaluated the efficiency of 45 electricity distribution districts of Greek Public Power Corporation. He considered eight factors including the number of served customers, network length, capacity of installed transformation points, general expenses, administrative labor hours, technical labor hours, supplied energy, and served area. Four different cases with different sets of input and output factors were compared. Golany *et al.* [20] evaluated the operating efficiency of power plants in the Israel Electric Corporation in which four outputs (generated power, operational availability, deviation from operational parameters, and SO_2 pollutant emissions) and three inputs (installed capacity, fuel consumption, and manpower) were considered. Athanassopoulos *et al.* [21] developed the data envelopment scenario analysis for setting targets to electricity generating plants in the U.K. They considered four outputs (electricity produced, plant availability, accidents incurred, and generated pollution) and three inputs (fuel, controllable costs, and capital expenditure). Sueyoshi [22] explored a marginal cost (MC)-based pricing measurement using cost-based DEA (CDEA) approach to examine the tariff structure of nine electric power companies in Japan. His study considered the output of 11 electricity sales (e.g., residential services, commercial services, other services) and three input prices (labor price, capital price, and materials price). Park [23] evaluated the operating efficiency of the 64 conventional fuel power plants in South Korea in which he considered an output (net electrical energy output) and three inputs (fuel consumption, installed power, and labor). The authors [4] applied DEA models to measure the operating efficiency of 22 electricity distribution districts of Taiwan Power Company in Taiwan in which we considered two outputs (total of customer and energy supplied) and five inputs (employment expenditure, general expenditure, total asset, distribution network, and transformer capacity). Moreover, we also investigated the reorganization of the electricity distribution districts. As shown in many DEA case studies, the selection of the input and output factors will affect the evaluated efficiencies of the DMUs.

III. Empirical Study

This section details an empirical study of applying DEA of the CCR and BCC models to evaluate operating efficiencies of service centers of the NAN-TOU electricity distribution district of the TPC. In the previous study [4], we found that the NAN-TOU electricity distribution district of the TPC has the lowest efficiency score among the districts. Thus, in this study, we evaluated the relative efficiencies of the 17 service centers of NAN-TOU district and also investigated the alternatives of reorganizing its service centers to increase its efficiency. Following Golany and Roll [24], this empirical study includes the following tasks: 1) problem structuring, 2) selection of the input and output factors for evaluating operating efficiency of the selected DMUs, and 3) discussions of the results.

A. Problem Structuring

TPC is a state-owned enterprise and it is the sole electric utility in charge of the power development, generation, transmission, distribution, and sales in Taiwan. The business department of TPC is divided into 24 electricity distribution districts. The major tasks of the districts include increasing energy supplied not only to increase operating revenues but also to provide a good service to their customers. Each electricity distribution district has several service centers as the front desks to serve the customers. In particular, the NAN-TOU district has 17 service centers. Each service center is considered as a DMU to compare their relative efficiencies and identify directions for possible improvements. These 17 service centers indeed belong to a homogeneous group in which they can be evaluated on the basis of the same input and output factors. However, the scales of the various service centers are different in terms of, for example, total number of customers, total number of staff, distribution network, and transformer capacity. Thus, individual service centers may have their own specific value systems, and DEA without predetermined weights, is adequate to evaluate their relative efficiencies.

B. Inputs and Outputs

The service centers use various limited resources to accomplish their tasks of maintaining and repairing power-supply equipment as well as providing services to accommodate the customer needs of electricity use. Referring to the responsibility center system of TPC guidelines [25], we compared the efficiencies of service centers by three outputs (i.e., total number of customers, distribution network, and transformer capacity) and two inputs (i.e., total number of staff and general equipment). The total number of customers is a typical output since the service center aims to serve the customers. In addition, distribution network and transformer capacity are effective channels to deliver the electricity to specific locations to fulfill the customer needs. The service centers are responsible for maintaining their distribution networks and transformer capacities to ensure the quality of electricity supply. The total number of staff is an important input factor for service centers since all of the tasks are conducted by them. Indeed, the average number of consumers serviced by each employee at the service center and the average length of distribution network maintained by each employee are cost-effective indexes specified in the TPC guidelines. In addition, the general equipment (i.e., computers, machines, tools, and materials) are used to accomplish the tasks. The selection of inputs was determined on the basis that the efficiency measurement was focused on internal control and productivity of the service centers. In practice, the service centers use the various levels of the different input resources to serve their customers. The 2000 data were used for this study as given in Table I. The use of annual data can reduce the influence of seasonal effects.

To increase the validity of the proposed model, we examined the assumptions of the "isotonicity" relationships [26] (i.e., an increase in any input should not result in a decrease in any output) between the input and output factors by the correlation among the selected input and output factors. The resulting correlation matrix as shown in Table II does not violate the isotonicity assumptions. In addition, a desirable property of evaluation method is its discriminating power as a summary measure. As recommended by Golany and Roll [24], the number of DMUs should be at least twice the total number of input and output factors. The number of DMUs is 17—that is more than

TABLE I
INPUT AND OUTPUT DATA OF THE 17 SERVICE CENTERS

DMUs	Service Centers	Outputs			Inputs	
		number of customers (customer)*	distribution network (Km)	transformer capacity (KVA)	number of staff (person)	general equipment (NT$ 10,000)
1	Shih Chu	45,927	1,121	176,860	12	3,774
2	Wu Feng	60,414	1,514	278,473	16	14,712
3	Nan Tou	41,183	1,306	152,796	16	12,483
4	Pu Li	37,966	1,755	146,771	16	10,721
5	Ju Shan	25,877	814	87,372	12	11,717
6	Shuei Li	9,860	365	29,671	7	5,859
7	Kuo Shing	11,198	670	36,699	8	6,255
8	Lu Gu	10,744	305	33,196	6	4,555
9	Ming Juan	9,287	296	30,136	5	2,347
10	Ji Ji	4,727	213	14,006	4	2,345
11	Yu Chi	8,451	387	24,521	5	3,657
12	Shin Yi	6,504	516	23,500	5	3,559
13	Ren Ai	4,381	306	12,972	6	3,827
14	Ruei Ju	2,117	166	6,360	3	1,287
15	Jung Lian	4,676	329	14,308	4	3,547
16	Tsau Tuen	18,950	354	71,898	4	1,935
17	Chi Shuei	7,996	276	35,011	4	2,498

TABLE II
CORRELATION AMONG THE INPUT AND OUTPUT FACTORS

Factors	number of customers	distribution network	transformer capacity	number of staff
distribution network	0.907			
transformer capacity	0.991	0.884		
number of staff	0.907	0.960	0.873	
general equipment	0.776	0.832	0.763	0.911

twice the number (i.e., five) of input and output factors in this study. Therefore, in this study, the proposed DEA model has high construct validity.

C. Efficiency Analysis and Slack Analysis

We applied the CCR model, with constant returns to scale, to evaluate the overall efficiency of each service center of the NAN-TOU district. In particular, a computer program called DEAP [27] is executed on a PC running with a Pentium II processor with 350-MHz clock speed and 256-MB random-access memory (RAM). The output is a text file and the elapsed time is less than 1 s.

The overall efficiencies of 17 service centers are presented in Table III. The average efficiency score is 0.732 and only four service centers (i.e., Shih Chu, Wu Feng, Pu Li, and Tsau Tuen) are overall efficient among the others. We analyzed the slack variables of the corresponding models to identify improvement directions for the inefficient service centers as shown in Table III. Slack analysis shows the amount of the outputs should be increased for an inefficient service center to become overall efficient. According to the output slack values, eight inefficient service centers should increase their outputs of number of customers and 12 inefficient service centers should increase the outputs of transformer capacity. However, the differences between efficient and inefficient service centers in terms of the distribution network are not significant. Alternatively, an inefficient service center can decrease a specific amount of inputs to become efficient. According to the input slacks, most of the inefficient service centers should decrease the two input resources to increase the productivity for improving their overall efficiencies.

Furthermore, we also found that most of the medium and small sized service centers (i.e., Shuei Li, Lu Gu, Ming Juan, Ji Ji, Ren Ai, Ruei Ju, and Chi Shuei) are relatively inefficient. In particular, the Ren Ai service center has the lowest efficiency score (i.e., 0.471). In addition to identify the improvement directions by analyzing the slack variables, further analysis can be done by examining the reasons resulting in the inefficient service centers (i.e., technical inefficiency and/or scale inefficiency).

D. Technical and Scale Efficiency Analysis

We applied the BCC model, with variable returns to scale, to evaluate the technical efficiency of each service center of the NAN-TOU district. Also, the scale efficiency can be derived by the ratio of overall efficiency to technical efficiency. Table IV summarizes the results. The four overall efficient service centers have the technical efficiency and scale efficiency (thus presenting constant returns to scale). In particular, two DMUs (i.e., Shin Yi and Ruei Ju) have the technical efficiency scores equal to 1 while their scale efficiency scores are less than 1. They should adjust their scales of operation to improve their scale efficiencies as well as overall efficiencies. A DMU may be scale

TABLE III
OVERALL EFFICIENCY AND SLACK VALUES BASED ON THE CCR MODEL

DMUs	Service Centers	over efficiency	Slack values				
			Outputs			Inputs	
			number of customers	distribution network	transformer capacity	number of staff	General equipment
1	Shih Chu	1.000	0.000	0.000	0.000	0.000	0.000
2	Wu Feng	1.000	0.000	0.000	0.000	0.000	0.000
3	Nan Tou	0.799	0.000	0.000	4,854.213	-3.209	-4,765.404
4	Pu Li	1.000	0.000	0.000	0.000	0.000	0.000
5	Ju Shan	0.666	0.000	0.000	11,668.985	-4.013	-6,911.001
6	Shuei Li	0.495	0.000	0.000	8,209.793	-3.538	-3,668.849
7	Kuo Shing	0.764	3,296.142	0.000	19,333.234	-1.892	-2,162.083
8	Lu Gu	0.511	0.000	0.000	7,839.423	-2.936	-2,775.345
9	Ming Juan	0.589	118.718	0.000	6,129.965	-2.055	-964.558
10	Ji Ji	0.503	737.636	0.000	7,092.325	-1.988	-1,165.324
11	Yu Chi	0.707	0.000	0.000	8,139.814	-1.466	-1,294.474
12	Shin Yi	0.941	4,658.653	0.000	19,653.183	-0.296	-406.843
13	Ren Ai	0.471	2,701.713	0.000	14,394.058	-3.172	-2,023.357
14	Ruei Ju	0.561	3,534.726	0.000	15,423.429	-1.317	-565.161
15	Jung Lian	0.750	2,441.336	0.000	13,206.336	-1.001	-1,537.194
16	Tsau Tuen	1.000	0.000	0.000	0.000	0.000	0.000
17	Chi Shuei	0.682	993.572	0.000	0.000	-1.273	-795.157

TABLE IV
RESULTS OF THE BCC MODEL

DMUs	Service Centers	Over efficiency	Technical Efficiency	Scale Efficiency	Returns To Scale
1	Shih Chu	1.000	1.000	1.000	CRTS
2	Wu Feng	1.000	1.000	1.000	CRTS
3	Nan Tou	0.799	0.806	0.991	DRTS
4	Pu Li	1.000	1.000	1.000	CRTS
5	Ju Shan	0.666	0.666	0.999	DRTS
6	Shuei Li	0.495	0.581	0.851	IRTS
7	Kuo Shing	0.764	0.798	0.956	IRTS
8	Lu Gu	0.511	0.623	0.819	IRTS
9	Ming Juan	0.589	0.739	0.797	IRTS
10	Ji Ji	0.503	0.813	0.619	IRTS
11	Yu Chi	0.707	0.841	0.841	IRTS
12	Shin Yi	0.941	1.000	0.941	IRTS
13	Ren Ai	0.471	0.624	0.755	IRTS
14	Ruei Ju	0.561	1.000	0.561	IRTS
15	Jung Lian	0.750	0.967	0.776	IRTS
16	Tsau Tuen	1.000	1.000	1.000	CRTS
17	Chi Shuei	0.682	0.896	0.761	IRTS

inefficient if it exceeds the most productive scale size (thus experiencing decreasing returns to scale), or if it is smaller than the most productive scale size (thus having not taken the full advantage of increasing returns to scale). Indeed, most of the inefficient service centers (including Shin Yi and Ruei Ju) present increasing returns to scale that can increase the scales to effectively improve their efficiencies. In particular, five scale inefficient service centers (i.e., Ji Ji, Shin Yi, Ruei Ju, Jung Lian, and Chi Shuei) had their technical efficiency scores higher than the scale efficiency scores, respectively. This implies that the overall inefficiency is primarily due to the scale inefficiency. Only two inefficient service centers (i.e., Nan Tou and Ju Shan) present the decreasing returns to scale that can decrease their scales to possibly improve their efficiencies. On the other hand, seven overall inefficient service centers (i.e., Nan Tou, Ju Shan, Shuei Li, Kuo Shing, Lu Gu, Ming Juan, and Ren Ai) are mainly due to the technical inefficiency because their technical inefficiency scores are lower than scale efficiency scores. The technical inefficient service centers should improve their productivity and make better use of their resources.

Furthermore, the decision makers should examine the scale sizes of the scale inefficient service centers. On one hand, five urban service centers (i.e., Shih Chu, Wu Feng, Nan Tou, Pu Li, and Ju Shan) have similar levels of the inputs and outputs. However, Shih Chu, Wu Feng, and Pu Li present the constant returns to scale. The other two urban service centers (i.e., Nan Tou and Ju Shan) present the decreasing returns to scale. On the other hand, the service centers that are located in rural areas are small

TABLE V
CREATED DMUS OF MERGED SERVICE CENTERS OF THREE REORGANIZATION ALTERNATIVES AND THE INPUT AND OUTPUT DATA

Reorganization Alternatives	No. of DMUs*	Service Centers		Outputs			Inputs	
		Chief	Subordinates	number of customers (customers)	distribution network (Km)	transformer capacity (KVA)	number of staff (person)	general equipment (NT$10,000)
I	18	Shih Chu	Tsau Tuen	64,877	1,475	248,758	14	5,709
	19	Ju Shan	Ruei Ju	27,994	980	93,732	14	13,004
	20	Ming Juan	Chi Shuei	17,283	572	65,147	7	4,845
II	21	Shih Chu	Tsau Tuen	64,877	1,475	248,758	14	5,709
	22	Pu Li	Ren Ai	42,347	2,061	159,743	19	14,548
	23	Shuei Li	Shin Yi	16,364	881	53,171	10	9,418
	24	Lu Gu	Ruei Ju	12,861	471	39,556	8	5,842
	25	Ming Juan	Chi Shuei	17,283	572	65,147	7	4,845
	26	Ji Ji	Jung Lian	9,403	542	28,314	6	5,892
III	27	Shih Chu	Kuo Shing Tsau Tuen	76,075	2,145	285,457	20	11,964
	28	Nan Tou	Ming Juan Jung Lian Chi Shuei	63,142	2,207	232,251	23	20,875
	29	Pu Li	Yu Chi Ren Ai	50,798	2,448	184,264	22	18,205
	30	Ju Shan	Lu Gu Ruei Ju	38,738	1,285	126,928	17	17,559
	31	Shuei Li	Ji Ji Shin Yi	21,091	1,094	67,177	12	11,763

* *It denotes the number of the new service centers in this study.*

or medium sized and they all present increasing returns to scale. One way for increasing their efficiency is to adjust their scales by transferring resources from service centers operating at decreasing returns to scale to those operating at increasing returns to scale returns to scales. Alternatively, TPC is investigating the feasibility of reorganizing the service centers (e.g., merge some small service centers) of 17 service centers of the NAN-TOU distribution district.

IV. REORGANIZATION OF THE SERVICE CENTERS

Thus, we continued this study with the discussions on the alternatives of reorganizing the service centers of the NAN-TOU district. In Taiwan, the competitive environment for operating power industry has undergone drastic changes owing to the liberalization of electricity market and the privatization of TPC. The revised version of the Electricity Act, now under review by the Legislative Yuan, sets forth new operation guidelines for the electricity market that will certainly have a great impact on TPC [28]. Reorganizations and operation mergers are feasible methods to increase organizational competitiveness and efficiency.

Indeed, the NAN-TOU district had attempted to develop a "consolidated operating system" [29] that combines some small service centers to a larger one given the pressure of improving its efficiency. The proposed consolidated operating system intends to reorganize the 17 service centers for balancing their overall scales and improving the operation efficiency. Furthermore, each of the merged subordinate service centers can save approximately 50% of staffs owing to operation mergers. For example, if the Tsau Tuen service center was merged into the Shih Chu service center, then it would maintain only two staffs to serve local customers and the other two employees would be transferred to other departments. Since TPC is a state-owned company, the surplus human resource after reorganization will be transferred to other departments in the NAN-TOU district rather than be laid off. Thus, the objective of service center reorganization was not focused on personnel cuts. However, the NAN-TOU district has not applied any analysis method to examine the existing alternatives of the consolidated operating system.

Thus, based on the results of DEA, we also investigated the reorganization alternatives of service centers by comparing the efficiency evaluation results before and after the reorganizations. Furthermore, a traceable decision analysis method such as DEA was essential to avoid the potential political and social pressures and would also facilitate effective communication between the decision makers and the employees. For example, [30] applied the DEA models to measure the relative efficiency of 13 forest districts and investigate their reorganization. The authors also applied the DEA models to measure the relative efficiencies of 22 electricity distribution districts in Taiwan and compare the various reorganization alternatives [4].

In particular, this study compared three different reorganization alternatives by the efficiency evaluations. Due to geographical limitations, only the adjacent service centers can be possibly combined into a new large one. The office of the new service center will be located at the chief service center while the merged subordinate service centers will be downsized. In addition, the decision makers of NAN-TOU district had planned to aggregate human resources at the chief service centers for centralized allocation and to balance the scales of the new service centers after the reorganization. Table V summaries the new DMUs generated in the three different reorganization alternatives with the adjusted input and output data. In particular, the first alternative refers to the initial idea of the NAN-TOU district in which they planned to combine the service centers belonging to the same administrative unit. For example, the Shih Chu and Tsau Tuen service centers belong to the Tsau Tuen Town and are thus combined into a new service center (i.e., DMU 18). Similarly, Ju Shan and Ruei Ju can be combined into a new service center DMU 19 and Ming Juan and Chi Shuei can be combined into DMU 20. The second reorganization alternative based on the results of efficiency analysis in Section III was proposed to increase their scales since most of the inefficient DMUs presented increasing returns to scale. For example, the adjacent inefficient service centers that presented increasing returns to scale (i.e., Shuei Li and Shin Yi, Lu Gu and Ruei Ju, Ming Juan and Chi Shuei, Ji Ji and Jung Lian) can be combined into new service centers to increase their scales (i.e., DMU 23, 24, 25, and 26, respectively). Also, Ren Ai, which is an inefficient service center presenting increasing returns to scale, is combined with an adjacent efficient one (i.e., Pu Li) to be DMU 22. Furthermore, for benchmark, we also combine Shih Chu and Tsau Tuen that are both efficient service centers presenting constant returns to scale into a new one (i.e., DMU 21). Moreover, the third reorganization alternative was designed to combine more than two service centers to further increase the scales of the reorganized service centers. Based on the results of efficiency analysis, the inefficient service centers are merged with adjacent service centers as given in Table V. Thus, only six large service centers remained in the third alternative. In particular, the Wu Feng service center was not considered to merge with others in all the three alternatives since it was relatively efficient and its service area is also large.

To examine the different reorganization alternatives, we applied the CCR model to compare the efficiency of the service centers among all of the three alternatives. Since DEA measures the relative efficiencies among the DMUs, we evaluated all of the service centers among the different reorganization alternatives together. Thus, for validation, the efficiency scores of the DMUs among the different reorganization alternatives can be compared at the same basis. In particular, there were 31 DMUs to be evaluated and their input and output data are given in Tables I and V. Also, for validation, we found that the total number of the DMUs is more than twice the total number of input and output factors. The results of efficiency evaluation were summarized in Table VI. For each reorganization alternative, only the considered service centers were evaluated, respectively. We also calculated the average values and standard deviations of the efficiency scores among the different reorganization alternatives. As shown in Table VI, the first alternative of combining the service centers belonging to the same town has the lower average efficiency score (i.e., 0.7258) and higher standard deviation (i.e., 0.1990) than the existing status (i.e., 0.7317 and 0.1968, respectively). Both the proposed second and third alternatives have higher average efficiency score (i.e., 0.7894 and 0.8942, respectively) and lower standard deviation (i.e., 0.1474 and 0.1216, respectively) than the average efficiency score (i.e., 0.7317) and lower standard deviation (i.e., 0.1968) of the existing status. Thus, the proposed two alternatives based on the efficiency analysis results in Section III are better than the original reorganization idea of NAN-TOU district office and the existing status. They can increase the overall operating efficiency of the whole set of service centers. DEA provides a feasible direction for generating a reorganization alternative and an effective mechanism for evaluating the various alternatives for better decisions.

TABLE VI
RESULTS OF OVERALL EFFICIENCY OF THREE REORGANIZATION ALTERNATIVES

No. of DMUs	Overall Efficiency	Reorganization Alternatives		
		I	II	III
1	1.000	--------	--------	--------
2	1.000	0.974	0.974	0.974
3	0.799	0.753	0.753	--------
4	1.000	1.000	--------	--------
5	0.666	--------	0.626	--------
6	0.495	0.476	--------	--------
7	0.764	0.756	0.756	--------
8	0.511	0.473	--------	--------
9	0.589	--------	--------	--------
10	0.503	0.492	--------	--------
11	0.707	0.702	0.702	--------
12	0.941	0.937	--------	--------
13	0.471	0.467	--------	--------
14	0.561	--------	--------	--------
15	0.750	0.739	--------	--------
16	1.000	--------	--------	--------
17	0.682	--------	--------	--------
18	NA	1.000	NA	NA
19	NA	0.641	NA	NA
20	NA	0.751	NA	NA
21	NA	NA	1.000	NA
22	NA	NA	0.980	NA
23	NA	NA	0.792	NA
24	NA	NA	0.537	NA
25	NA	NA	0.751	NA
26	NA	NA	0.812	NA
27	NA	NA	NA	0.998
28	NA	NA	NA	0.879
29	NA	NA	NA	1.000
30	NA	NA	NA	0.695
31	NA	NA	NA	0.819
Total number of service centers	17	14	11	6
Average	0.7317	0.7258	0.7894	0.8942
Standard deviation	0.1968	0.1990	0.1474	0.1216

The "-------" mark denotes the DMU is merged into the new DMU and its efficiency is not calculated.
NA denotes not applicable.

V. CONCLUSION

In this paper DEA models were applied to evaluate the efficiency of the service centers of the NAN-TOU district of the TPC in Taiwan since the NAN-TOU district was the least efficient among the others. Two DEA models (CCR model and BCC model) were used to evaluate the overall efficiency, technical efficiency, and scale efficiency of each of the 17 service centers. Based on the results, we discussed the specific directions for the inefficient service centers to possibly improve their operation efficiencies. In addition, we also found that most of the inefficient service centers present increasing returns to scale.

Moreover, we also investigated the mergers of service centers to increase their operation scales, and thus, increase the overall efficiency of the whole set of service centers. The proposed reorganization alternatives based on DEA had higher averages and smaller standard deviation of the efficiency scores than the current service centers and the plan of the NAN-TOU district office. Therefore, this empirical study may provide useful information to the policy makers of TPC that have been gradually directed toward partial privatization.

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