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Evaluating Performance of Electricity Distribution Centers and Improving Relative Operational Efficiencies through Reorganization: A Case of Nepal

Deependra K. Jha, Naoto Yorino, and Nava Raj Karki

Abstract

This paper analyzes the performance of the electricity distribution system in Nepal. Weight restriction data envelopment analysis (DEA) technique has been used to quantify the relative operational efficiencies of the distribution centers (DCs) owned by Nepal Electricity Authority (NEA). The proposed model incorporates a wide range of variables that capture the essence of electricity distribution process. Decision maker's opinion on the relevance and relative importance of the decision variables have been incorporated judiciously in the analysis in order to identify the possible improvement strategies for the DCs. This study also investigates the possibility of reorganization of the existing DCs inside the NEA's distribution framework on the basis of geographical convenience. Sensitivity analysis is carried out in order to check the robustness of the results and to suggest the direction for improvements. Strengths and weaknesses of individual DCs are identified based on the results of the sensitivity analysis.

KEYWORDS: data envelopment analysis, weight restriction, efficiency, electricity distribution centers, reorganization, sensitivity analysis, ranking

1. Introduction

Huge investment and growing competition in the electricity sector has forced the utilities to introduce productivity efficiency measurements and ensure improved operation of the constituent units. In Nepal, where the electricity utility continues to enjoy some sort of monopoly in all the sectors i.e. generation as well as transmission & distribution (T&D), the T&D loss constitutes a major portion of the produced electricity (NEA, 2009). Nepal Electricity Authority (NEA) is a state-owned electric utility that owns and operates the national-grid called Integrated Nepal Power System (INPS). NEA is the major distributor of electricity in the country having its network in all of the 75-districts (Pokharel, 2005). In a bid to improve the operational efficiency of its constituent units, NEA has established separate business groups dedicated to generation, transmission and distribution activities (NEA, 2005).

NEA evaluates the performance of its business groups and their associated units towards the end of every fiscal year (FY). It takes into account some specific single factor efficiency indices while doing so. In case of the distribution business group, current practice of evaluating performance of the distribution centers (DCs) on the basis of single factor efficiency indices like loss reduction, average collection period, stock turnover ratio, capital work progress, average connection period etc., does not give a clear view of the overall relative efficiencies of the DCs. The approach to evaluate performance of the DCs does not appear to be good enough as it fails to incorporate various parameters affecting the efficiency in a single analysis.

Jha and Shrestha (2006) and Jha et al. (2006) applied data envelopment analysis (DEA) technique in order to measure the relative efficiencies of the NEA owned hydropower plants. DEA is one of the most popular techniques that have been used in evaluating the performance of the organizational units involving multiple inputs and outputs (Pahwa et al., 2003). It is a linear programming based approach that utilizes an optimization technique to automatically calculate the weights assigned to the inputs and outputs of the units. The actual inputs and outputs are then multiplied with those weights to determine efficiency of the decision making units (DMUs). However, in conventional DEA models, weight flexibility allows different units to assign vastly different weights to the same factor. To address this issue, researchers have suggested weight restriction DEA models (Kabnurkar, 2001). Since its introduction, DEA has undergone several modifications and developments. DEA has been used to assess the performances of several electrical systems (Jha et al., 2007, 2008; Chien et al., 2003; Pahwa et al., 2003; Golany et al., 1994; London Economics, 1999; Meibodi, 1998; Pollitt, 1994 and 1996; Chitkara, 1998; Diewert and Nakamura, 1999; Miliotis, 1992; Hattori et al., 2003; Jha, 2004 and Pokharel, 2005 etc).

Jha et al. (2007, 2008), proposed weight restriction DEA models in order to evaluate performance of the generation and distribution units in Nepal. The results show that most of the DCs of NEA are inefficient and hence, it is imperative to improve their performance by introduring various possible measures on both administrative and technical levels. It is suggested that NEA should recognize the importance of productivity efficiency measures. Besides, the human resource utilization should also be effective and judicious. However, the service quality in the respective distribution territories should not be affected. This study investigates the possibility of reorganizing the DCs in a bid to improve their relative operational efficiencies. The DCs located geographically closer have been investigated for a possible merger. A modified DEA model is proposed in order to evaluate the performance of the existing DCs and, some changes in the present operating practices are recommended.

This paper evaluates the performance of the distribution system in Nepal by determining the relative operational efficiencies of the DCs owned by NEA and, investigates the possibility of reorganization of the DCs in a bid to improve the overall efficiency of the same. The relative efficiencies of the existing DCs as well as the reorganized ones are compared. It is found that the relative efficiencies increase after the merger of the proposed DCs.

The rest of the paper is organized as follows. The next section presents the analytical framework that is used in the study and the rationale of using weight restriction in DEA. Section 3 presents with a case study in order to show the effectiveness of the proposed methodology. Section 4 investigates the possibility of reorganization of the DCs and, Section 5 concludes the paper with some improvement directions recommended for the inefficient DCs.

2. Analytical Framework Used in the Study

2.1 Data Envelopment Analysis

Data Envelopment Analysis (DEA) is one of the most widely used methods used in benchmarking of the organizational units or decision making units (DMUs). It was first proposed by Charnes et al. (1978, 1994) to evaluate the relative efficiencies of the organizational units and often described as an extension of simple input to output ratio analysis, rigorously generalized to handle multiple inputs and outputs.

In DEA, the efficiency frontier is formed by the observed performances of the units, determined by relationships between the inputs and the outputs. The efficiency frontier is based on the concept of Pareto-optimum. Units that lie on the efficiency frontier are considered to be pareto-optimal units or efficient units whereas; those that do not lie on the efficiency frontier are regarded as relatively

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inefficient (Chien et al., 2003). Hence, the efficiency frontier provides a yardstick against which the comparative performances of all the units that do not lie on the frontier are judged.

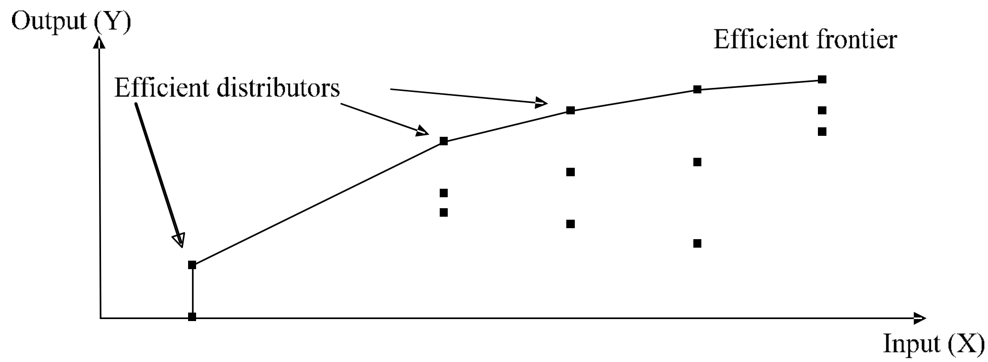

Fig.1. The efficiency frontier in DEA

Fig.1. shows the efficiency frontier for an utility that produces single output, Y, from a single input, X. The units that make up the efficiency frontier are those with the highest ratios of the output to the input. These units "envelope" the others in the sample and define the best practice frontier. The relative efficiency of any unit is calculated by forming the ratio of a weighted sum of outputs to weighted sum of inputs. Charnes et al. (1994) demonstrated that the weights for both outputs and inputs are to be selected in a manner that calculates the efficiency measure of each unit subject to the constraint that no unit can have relative efficiency score more than unity.

The DEA model developed originally by Charnes, Cooper and Rhodes (known as CCR model) in linearized form is given by (Charnes et al. 1978, 1994):

$$\left.\begin{aligned} & Maximize\ \theta_0 = \sum_r u_r y_{rj0} \\ & Subject\ to \\ & \sum_i v_i x_{ij0} = 1 \qquad ;\ for\ j = 1\ to\ n \\ & \sum_r u_r y_{rj} - \sum_i v_i x_{ij} \le 0 \\ & u_r, v_i \ge \varepsilon \qquad ;\ for\ r = 1\ to\ t\ and\ i = 1\ to\ m \end{aligned}\right\} \qquad (1)$$

Here, y_{rj0} and x_{ij0} denote the output and input of current unit j_0 of which efficiency is being maximized whereas; n is the total number of units under consideration. In each optimization run the efficiency of a specific unit is maximized and it is then repeated for all the units.

DEA maximizes the relative efficiency score of each unit, subject to the condition that the set of weights obtained in this manner for each unit must also be feasible for all the other units included in the calculation. As shown in the Fig.1, DEA produces piece-wise empirical external production surface, which represents the best practice production frontier – the maximum output obtainable from any unit in the observed sample, given its level of inputs.

2.2 Weight Restriction in DEA

The classical DEA model allows almost total flexibility in the selection of weights for individual units, particularly if fewer units are included in the analysis. This ensures the units to achieve the maximum feasible efficiency scores for current levels of inputs and outputs. An argument in favor of total weight flexibility is that if a unit is identified as inefficient in spite of using a favorable set of weights, it is a strong indication of the fact that the unit is really inefficient. Another argument in favor of total flexibility is that the relative efficiencies of different units are evaluated using different sets of weights allowing the units to express their different circumstances and objectives. Total weight flexibility, however, also has several drawbacks. Some of the major drawbacks are listed below (Kabnurkar, 2001):

1. DEA is meant for measuring relative efficiency of an organizational unit rather than its absolute efficiency. That is, efficiency scores in DEA are derived relative to the performance of other units and not to any ideal production frontier. As a result, a unit that is superior to all the other units in only a single output - input ratio will receive an efficiency score of 1 by placing very high weights on that particular output - input ratio. Thus, factors of secondary importance may dominate in the efficiency assessment and some significant factors may be ignored. This may be unacceptable given the fact all factors are meticulously selected. There might also be an unfounded emphasis on efficient use of relatively unimportant inputs or on a higher production of relatively unimportant outputs, thus concealing inefficiencies in the most important activities undertaken by the unit (Chaparro et al., 1997).
2. Weight flexibility allows different units to assign vastly different weights to the same factor. The argument in favor of this is that different units have different circumstances and therefore one factor may be more important to one unit compared to another unit. Thus, some degree of weight flexibility may be desirable to allow the units to reflect their particular circumstances. However, complete flexibility becomes unacceptable as most of the units employ similar

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technologies, pay similar prices for inputs, produce the same kind of outputs and have the same overall objectives.

3. Unbounded weight restriction models do not allow incorporating into the analysis any information that might be available regarding the importance of inputs and outputs.

The original DEA model has undergone several modifications and developments. Most of the developments occurred when inadequacies of the classical model got exposed while applying it to solve the real life problems. The first significant development occurred in this regard when the complete flexibility allotted by the classical model to the input/output weights found to be unacceptable was when Thompson et al. (1986) tried to use DEA to choose one best site from amongst six probable sites for locating a high energy physics lab. The classical DEA model with complete weight flexibility identified five out of the six sites to be efficient. In order to precisely identify the one best site, they had to modify the existing model by imposing suitable Assurance Region (AR) constraints on the input/output weights. This led to the evolution of a whole new series of models called weight restriction DEA models. In such models, the constraints imposing bounds on the input/output weights are added to the classical DEA model. In general, the following two types of weight restriction DEA models are implemented in most of the real-life applications (Kabnurkar, 2001).

2.2.1 Absolute Weight Restriction DEA Model

This model involves adding additional constraints to the classical DEA model generally in the form of upper and lower limits on the weights of the inputs and outputs. The absolute weight restriction ensures that the model does not assign excessively high weights to certain factors while completely ignoring other factors. The first step in the procedure for determining the values of absolute bounds is to run the unbounded model. This is followed by a close scrutiny of the results of the model to identify anomalies in the weight values calculated. Finally, appropriate bounds are assigned to deal with the identified anomalies.

Several methods are available to the decision-maker to calculate the weight bound values. However, the choice of the method, which governs the bound values and the subsequent efficiency scores calculated, rests entirely with the decision-maker. This introduces an element of subjectivity in the DEA analysis.

2.2.2 Assurance Region DEA Model

The model involves setting bounds on the ratios of weights. There are two ways in which the Assorance Region (AR) bound values are determined (Zhu, 1996):

1. The first approach is based on expert opinion. It involves setting AR bounds on the basis of the magnitude of relative importance of the different inputs/outputs as perceived by the experts.
2. Another method for setting AR bounds involves utilizing the fact that the input/output weight (or multiplier) values in the dual of the DEA model are the prices/costs of the inputs/outputs. Therefore, economic information about the price/cost ranges of the inputs/outputs can be used to set AR bounds. Setting AR bounds of this type represents a move from pure technical efficiency measurement to the overall efficiency measurement.

In the light of the above discussion, the weight restriction DEA models serve the following main purposes:

1. Ensures incorporation of all inputs and outputs in the assessment of performance: The upper and lower bounds on the weights in a weight restriction model ensure that almost all factors are considered in the analysis.
2. Incorporates prior views on the values of individual inputs and outputs: By assigning specific values to the weight bounds, opinions of decision-makers regarding the relative importance of the factors can be judiciously incorporated in the analysis.
3. Relates values of certain inputs with values of certain outputs
4. Enables discrimination among the efficient units: Whenever the classical DEA model fails to single out one best unit from amongst the available viable alternatives, weight restriction models can better address this problem.

The imposition of restrictions on the weights implies the formulation of value judgments on the relative importance of different outputs and relative opportunity costs of the inputs that produce these outputs. Weight restrictions reduce the region of search for the weights thus possibly reducing the efficiency of the units. As the restrictions become increasingly severe, the measure of efficiency derived moves from one of relative technical efficiency to one of relative overall efficiency (Kabnurkar, 2001).

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3. Evaluating Performance of Distribution Centers: A Case of Nepal

3.1 Status of Distribution System in Nepal

Before elaborating the methodology proposed for evaluating the relative performance of the DCs, it would be appropriate to present a brief description of the status of electricity distribution system in Nepal. At present, two utilities named NEA and Butwal Power Company (BPC), cover the distribution network in the country. NEA is currently distributing electricity in all the 75-districts of Nepal whereas; BPC distributes electricity in few villages of the two districts called Syangja and Pyuthan. Within NEA, 64 distribution centers are operating in the grid connected mode, while a few rural DCs are operating in isolated mode. In an effort to improve the efficiency of the distribution centers, NEA has declared its 34 distribution centers as profit centers (PCs). Remaining of the NEA's grid-connected DCs are called Distribution branch offices (DBOs) which act under the control of central management (Pokharel, 2005; NEA, 2005).

11kV lines are used as the main distribution feeders except in few rural distributions, where 33kV lines are also used for the distribution purpose. 11kV and 33kV distribution lines are known as primary feeders where as 400V three-phase lines and 220V single-phase lines exist as secondary feeders. Majority of the customers, by volume, are low voltage customers who are supplied through secondary distribution lines. In case of BPC distribution system, distributors at 1kV is also used along with the other voltage levels i.e. 33kV and 11kV as primary distributions (Pokharel, 2005).

The number of customers of NEA continued to increase as it did in the recent past. In FY 2009/10, total number of customers increased by 10.59%. Of the total customers, 95.18% domestic customers accounted for 41.41% sales and 41.1% revenue, 1.65% industrial customers accounted for 37.66% sales and contributed 35.23% revenue, 0.43% commercial customers accounted for 7.27% sales and contributed 9.95% revenue, 0.70% non commercial customers accounted for 4.14% sales and 5.73% revenue whereas other 2.04% customers accounted for 9.52% sales and 7.99% revenue (NEA, 2010).

BPC has its two DCs: Galyang-BPC and Pyuthan - BPC serving over 23000 customers. They are supplied by two BPC owned power stations named Andhi Khola (5.1MW) and Jhimruk (12MW). The surplus power generated from these power stations is sold to NEA via national grid through power purchase agreement (PPA) (Pokharel, 2005).

3.2 Research Outline

Weight restriction DEA model is formulated in order to evaluate the relative operational efficiency of the NEA owned DCs. Decision maker's preference as well as economic aspect of various parameters have been taken into consideration in the analysis. The schematic diagram in Fig. 2 outlines the research framework of the study.

After obtaining the relative efficiency scores of the respective DCs, an analysis for identifying the possibility of re-organization of the DCs is carried out. The results confirm an increase in overall efficiency of the DCs after the re-organization.

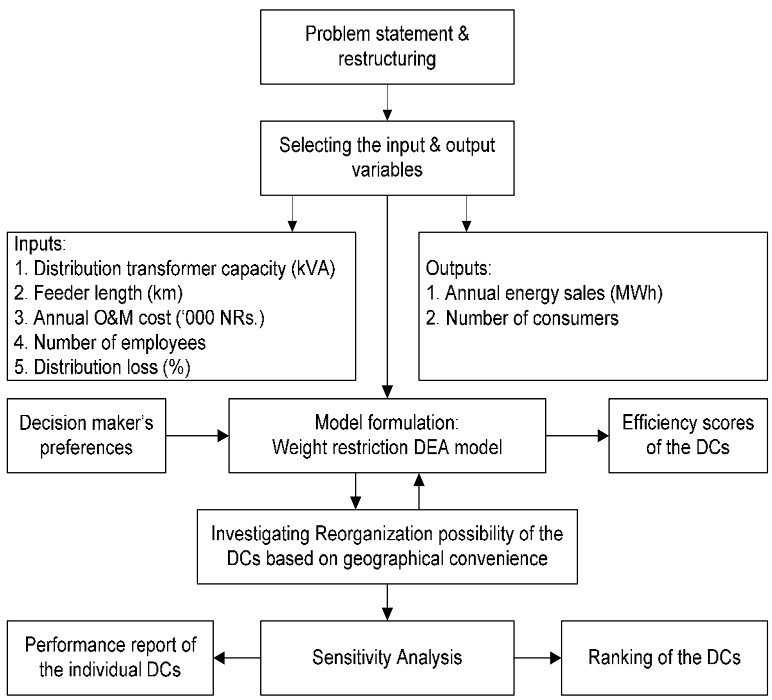

Fig.2. Research framework of the study

Sensitivity analysis is performed in order to check the robustness of the DEA results and finally, performance reports for individual DCs are prepared highlighting the strengths and weaknesses of the respective DCs.

3.3 Selection of Inputs and Outputs

Selection of the inputs and outputs is based on our judgment along with the standard practices that is followed in the DEA based performance analysis of various distribution systems world-wide (Pahwa, 2003). The constraints related to reliability (like transformer tripping) have been omitted from the analysis due to the fact that NEA is facing both capacity and energy shortages in recent years (NEA, 2010); as such the supply outages are, most of the times, dictated by the administrative preferences. The inputs and outputs selected in the study are outlined as under:

Inputs:

1. **Distribution transformer capacity**: It is the total capacity of transformers connected to the distribution system for the distribution purpose. It is measured in KVA.
2. **Feeder length**: It is the total length expressed in kilometers of primary distribution system including 11kV and 33kV feeders.
3. **Annual O&M cost**: It is the annual expenditure for both labor and non-labor inputs expressed in ‘000 of Nepalese Rupees.
4. **Number of employees**: The number of personnel working at respective DCs irrespective of their status.
5. **Distribution loss**: It is total loss within the area served by the DC expressed in percentage.

Outputs:

1. **Annual energy sales**: This represents the energy sold annually by a DC in MWh.
2. **Number of customers**: It is the total number of connection points to supply the customers.

3.4 Model Formulation

Weight restriction DEA model has been proposed in order to evaluate the performance of the DCs owned by NEA. The model incorporates a simple ordering of weights on the input and output variables and is given by:

$$\left.\begin{aligned}
&Maximize\ \theta_0 = \sum_r u_r y_{rj0} \\
&Subject\ to \\
&\sum_i v_i x_{ij0} = 1 \qquad ;\ for\ j = 1\ to\ n \\
&\sum_r u_r y_{rj} - \sum_i v_i x_{ij} \le 0 \\
&v_{O\&M\ \mathrm{cost}} \ge v_{feeder-length} \\
&v_{O\&M\ \mathrm{cost}} \ge v_{transformer-cap} \\
&v_{O\&M\ \mathrm{cost}} \ge v_{employee} \\
&v_{distribution-loss} \ge v_{O\&M\ \mathrm{cost}} \\
&u_{annual-sales} \ge u_{customer} \\
&u_r, v_i \ge \varepsilon \qquad ;\ for\ r = 1\ to\ t\ and\ i = 1\ to\ m
\end{aligned}\right\} \quad (2)$$

Although transformer capacity and feeder length of distributors are dependent on the service territory and the customer base, they are considered in the analysis to include asset utilization in the efficiency evaluation (Pahwa, 2003).

3.5 Execution of DEA Model using GAMS

The General Algebraic Modeling System (GAMS) is a high-level modeling system for mathematical programming and optimization. It consists of a language compiler and a stable of integrated high-performance solvers. GAMS is tailored for complex, large scale modeling applications and it allows to build large maintainable models that can be adapted quickly to new situations. The proposed DEA models are executed using GAMS software. GAMS system enables us to solve linear and mixed integer Data Envelopment Analysis (DEA) programs along with other linear, mixed integer and simple quadratic models efficiently (Kalvelagen, 2001).

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3.6 Results and Discussion

The performance evaluation of DCs is carried out in two groups. The first group (group-A) considers the largest 23 DCs having annual sales of energy more than 20000MWh. These DCs represent either urban or semi-urban areas so service territory variation is not a significant factor. A separate analysis is done for the second group (group-B) of 34 DCs totaling a complete analysis of 57 DCs within the NEA. The annual operational data of the NEA owned DCs for the FY 2004/05 has been used as a case study. Table 1 presents the statistics of the group-A DCs (please refer to section 4.3 for the units of the variables).

Table 1: Statistics of the Major DCs for FY 2004/05

Description	**Max**	**Min**	**Median**	**Mean**	**Standard deviation**
O&M Cost	84357	5592	24409	28524.9	19939.1
No. of employee	267	19	77	89.1	55.1
Feeder length	726.8	56.4	218.9	256.5	150.4
Distribution loss	61.2	7.2	22.7	25.1	13.1
Transformer capacity	117864	1970	16050	25379	25841.8
Annual energy sales	178401	992	14152.5	31719.0	40056.4
No. of customers	48389	2025	17061	18707.2	11499.5

Fig.3 shows the graphic representation of the results obtained after executing model (2) with operational data of FY 2004/05 for the group-A DCs. A careful analysis of the results reveal that 11 out of the 23 DCs are efficient (i.e. with overall efficiency score of 100%) with the CCR model whereas; only 3 DCs (Kathmandu Central, Birgunj, Kathmandu East) are found to be efficient with the proposed model. The average efficiency score of the group-A DCs, with CCR model, is calculated to be around 95% but that with the modified model is found to be about 80%. A better discrimination in the efficiency scores of the DCs is achieved due to rational modification in the classical DEA model through incorporation of judicious ordering of weights.

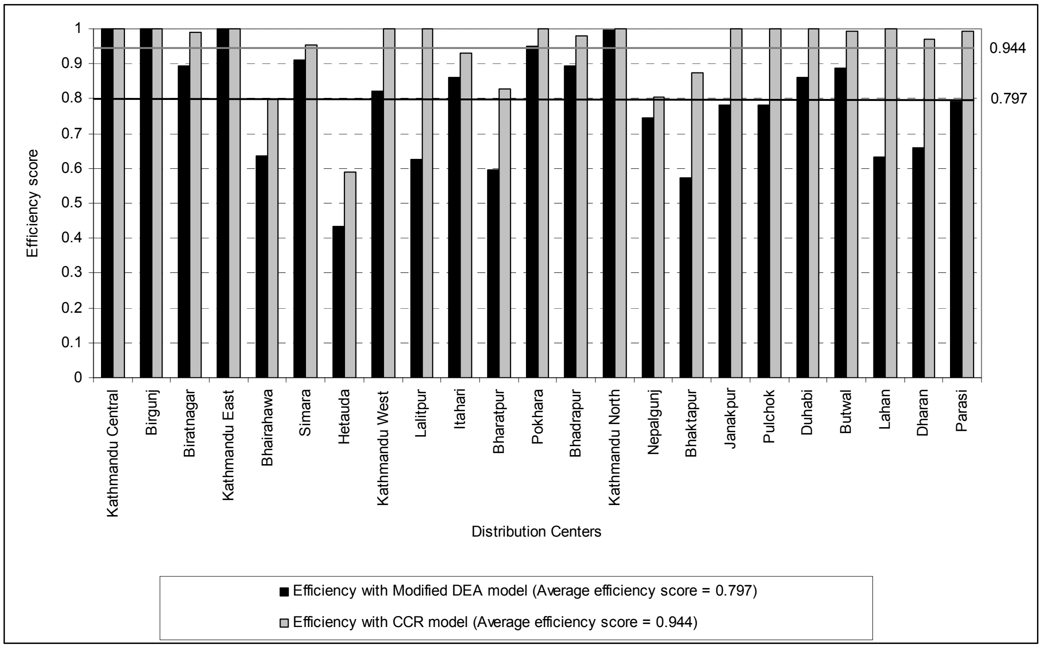

Fig.3. Overall efficiency of the major distribution centers (Group-A)

The DCs like Hetauda, Bhaktapur, Bharatpur, Lalitpur, Lahan and Dharan have displayed relatively poor efficiency scores. The analysis with proposed model shows that almost 50% of the DCs in the group-A actually have an overall efficiency score below their group average score of 80%. This finding exposes the shortcomings that exist in the operation of the DCs.

Table 2: Change in Weights for a typical DC

DCs →	**Name of the DC: Lalitpur**	
Weights assigned to↓	**CCR Model**	**Proposed Model**
Transformer capacity	0	0.0000082
Feeder length	0.00225367	0.0000082
O&M cost	0	0.0000082
No. of employees	0.00364365	0
Distribution loss	0	0.0000082
Annual energy sales	0	0.00000639
No of customers	0.00002752	0.00000639
Efficiency	**1**	**0.625**

Table 2 presents the change in the weights assigned to various factors (inputs and outputs) with both classical as well as proposed DEA models. A

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careful analysis of the assigned weights to different factors shown in Table 2 reveals that Lalitpur DC has the CCR efficiency score of 1 largely due to the higher weights assigned to relatively less important factors. In actual operating scenario, inputs like O&M cost and distribution loss and output like annual energy sales is considered to be dominant.

If we analyse the above results, we observe that the weights on various factors have changed due to the restrictions imposed on the weights. The fundamental approach to assign weights by DEA model is kept intact; however, the relative importances of the weights is changed based on the decision makers preferences.

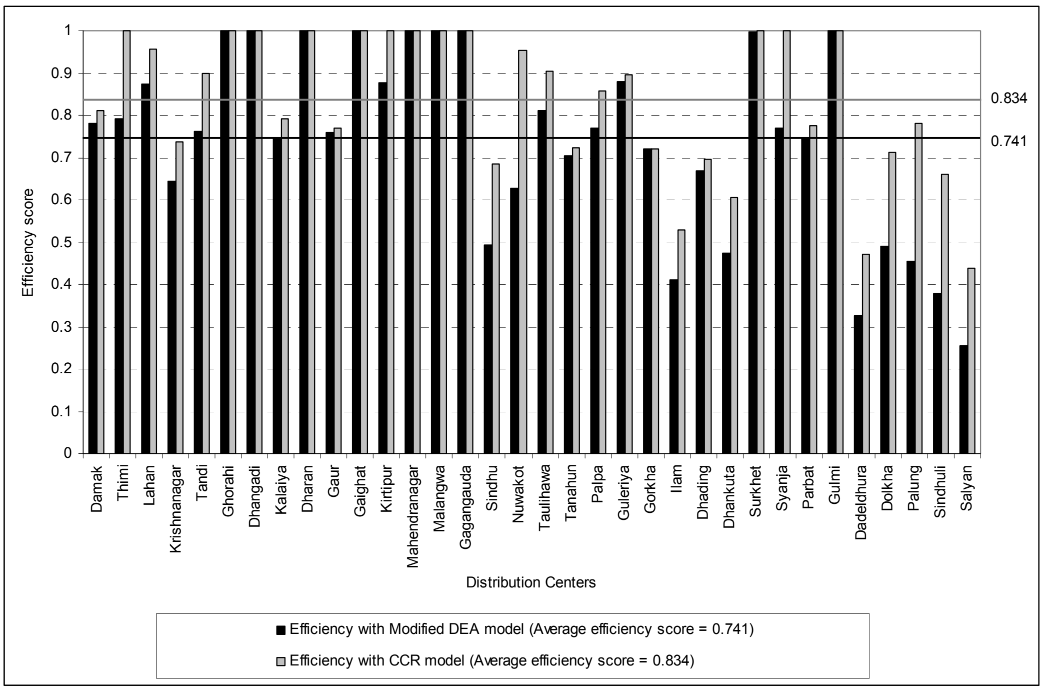

Fig.4. Overall efficiency of the distribution centers (Group-B)

Likewise, Fig.4 depicts the graphic representation of the results obtained for second group (group-B) of the DCs (i.e. DCs with annual sale of energy less than 20000 MWh in FY 2004/05). The average efficiency score of the group-B DCs, with the CCR model, is found to be a little over 83% whereas, that with the modified model is found to be around 74%. It is apparent that the group-B DCs are operating less efficiently than the DCs of group-A. Results also reveal that DCs like Ghorahi, Dhangadi, Dharan, Mahendranagar, Malangwa, Gagangauda and Gulmi have shown better performance in this group (group-B) whereas, DCs like Salyan, Sindhu, Sindhuli, Dadeldhura etc. have failed to impress with their performance. A careful analysis of the results based on the proposed model finds that about 40% of the DCs in the group-B possess an overall efficiency score less than their group average score of 74.1%.

The results suggest that some sort of reform is necessary in order to get rid of the operational inefficiencies existing in the DCs. Therefore, an analysis to investigate the strengths and weaknesses of the DCs has been carried out through sensitivity analysis.

3.7 Sensitivity Analysis

Sensitivity analysis is an important aspect of the DEA based analysis. It is carried out in order to check the robustness of the obtained results. As DEA is a data based analysis, any error in the data set can change the results significantly. However, in this study we assume that the data set is correct and precise, as it is taken from various sources of NEA. The sensitivity analysis is carried out based on removal of the variables one by one from the data set, and finding out the relative efficiency scores (Pahwa, 2003).

Performance report for each DC is prepared based on the results of the sensitivity analysis. Table 3 presents an example of such a performance report where, strengths and weaknesses of the DCs are outlined. The efficiency scores of Kathmandu East, Kathmandu Central and Birgunj DCs were found to be comparatively robust for the study period (FY 2004/05).

Table 3: Performance reports of typical DCs

Distribution Center	**Kathmandu East**	**Kathmandu West**	**Bhaktapur**
Variation in DEA efficiency score	0.893 to 1	0.480 to 1	0.334 to 0.691
Strengths	Distribution loss, number of customers	Annual sale of energy, transformer capacity	Transformer capacity, number of customers
Weaknesses		Annual O&M cost	Distribution loss, annual sale of energy, annual O&M cost

Results reveals that there is large variation in the efficiency scores of almost all other DCs, which indicates the dependency of efficiency scores on some specific set of variables. It is found that most of the DCs have spent excessively on their annual O&M works. Performance of the DCs like Bhaktapur, Nepalgunj and Parasi etc. suffered due to high distribution loss. Many of the DCs have shown excellent performance in terms of the annual sale of energy however, at the cost of increased O&M expenditure.

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Fig.5 displays the average efficiency scores of the DCs (group-A) along with their rankings in the graphical form. The average overall efficiency scores of the DCs have been calculated based on the results of the sensitivity analysis.

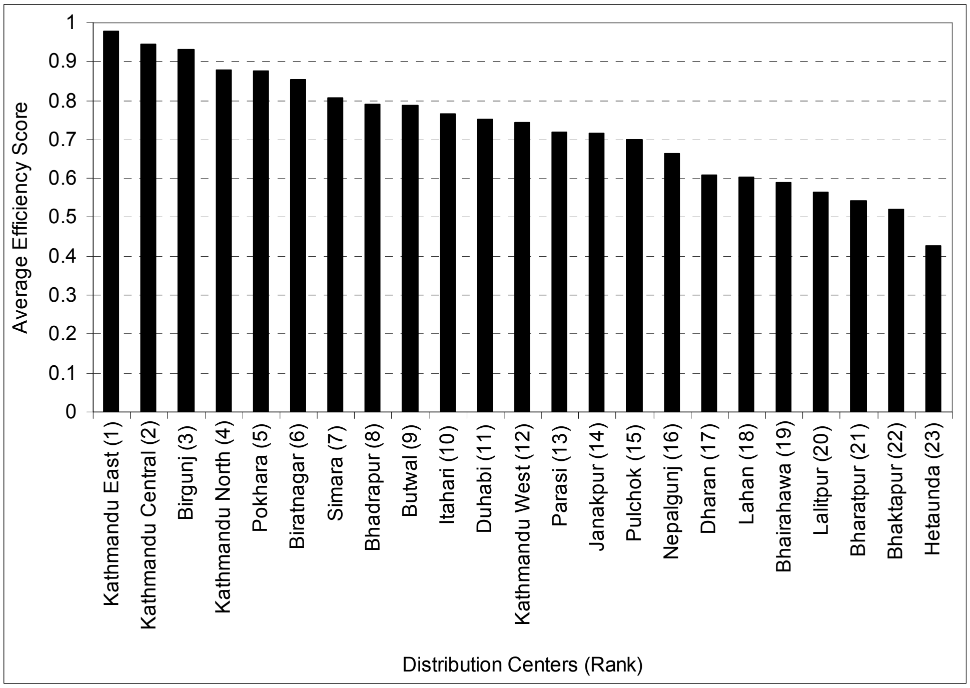

Fig.5. Plot of average efficiency scores of the major DCs along with their respective ranks in FY 2004/05

For FY 2004/05, Kathmandu East DC excelled with the its overall performance followed by Kathmandu Central and Birgunj DCs; all displaying overall efficiency score of 100% for most of the cases during sensitivity analysis. Likewise, Hetauda, Bhaktapur and Bharatpur DCs showed poor performances in group-A DCs. Results for the second group of NEA owned DCs (group-B) are not included in the paper.

4. Efficiency Improvement through Reorganization of Distribution Centers

Based on geographical convenience, a possibility of reorganization of the existing DCs within NEA distribution framework has been investigated. DCs like Birganj and Simara, Biratnagar and Duhabi, Bhaktapur and Thimi, Lalitpur and Pulchowk, Dharan and Itahari could be reorganized as the pairs of DCs are close enough to be operated as single DCs. The main assumptions for reorganization of the DCs are outlined as follows:

- Number of employees working in the existing pair of DCs is to be reduced by half (NEA being a big organization is expected to assign other relevant duties to the staff displaced from the DCs).
- Annual O&M expenditure is reduced by 25% (as the annual O&M expenditure includes both labor and non-labor costs).

Based on the above assumptions, the proposed DEA model (given by equation 2) is executed through a computer program written in GAMS. Table 3 presents the overall efficiency scores of DCs with the proposed model before and after reorganization of the closely located DCs.

Table 3: Overall efficiency of the major DCs after reorganization

S. N.	Distribution Centers	Efficiency with proposed DEA model	Efficiency with proposed DEA model after re-organization
1	Kathmandu Central	1	1
2	Birgunj	1	-
3	Biratnagar	0.893	-
4	Kathmandu East	1	1
5	Bhairahawa	0.636	0.642
6	Simara	0.910	-
7	Hetauda	0.435	0.442
8	Kathmandu West	0.821	0.823
9	Lalitpur	0.625	-
10	Itahari	0.860	-
11	Bharatpur	0.596	0.598
12	Pokhara	0.949	0.957
13	Bhadrapur	0.893	0.895
14	Kathmandu North	0.997	1
15	Nepalgunj	0.745	0.748
16	Bhaktapur	0.572	-
17	Janakpur	0.781	0.783
18	Pulchok	0.781	-
19	Duhabi	0.860	-
20	Butwal	0.887	0.889
21	Lahan	0.631	0.633
22	Dharan	0.658	-
23	Parasi	0.792	0.795
24	Thimi	0.791	-
25	Birgunj-Simara	-	1
26	Biratnagar-Duhabi	-	0.972
27	Dharan-Itahari	-	0.921
28	Bhaktapur-Thimi	-	0.657
29	Lalitpur-Pulchowk	-	0.788

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The results show that the average overall efficiency of the reorganized DCs is increased from 79.5% to 86.7%. Likewise, the average overall efficiency score of the group-A DCs increases (2.2%) during FY 2004/05 after the reorganization. Here, DEA provides a strong background for reorganization of the smaller and inefficient DCs that are nearby located. The analysis indicates a clear feasibility of reorganization of the DCs.

5. Conclusion

Weight restriction DEA model incorporating decision makers preferences has been formulated to evaluate the relative operational efficiencies of the NEA owned DCs. The results show that Kathmandu East and Hetauda DCs occupy top and bottom positions respectively in the rankings of the major DCs during FY 2004/05. Improvement directions are identified for an efficient operation of the DCs based on results of the sensitivity analysis. The results reveal that most of the DCs have spent excess money on their O&M works. Distribution loss is also found to be high for some of the DCs. The utility should emphasize on the strengths and weaknesses of the respective DCs, and take actions to improve their performance accordingly. Ideally, the resources used by a DC should be decreased proportionally to the lowest possible level, as suggested by its relative efficiency score, in order to make it efficient. However, it may not always be possible to reduce the input level to the lowest due to several technical as well as administrative constraints.

The paper also presents an analysis to identify a possibility of reorganization of the closely located DCs within the NEA distribution network. The results suggest a marginal increase in the overall efficiency score of the DCs after reorganization. It is recommended that a comprehensive analysis for identifying the various reorganization alternatives of the existing DCs be carried out for a considerable length of period in order to decide the most appropriate service territory for the respective DCs.

6. Nomenclature

θ_0	Efficiency score of the current DMU j0
y_{rj}	Amount of output r from DMU j
x_{ij}	Amount of input i to DMU j
n	Number of units (DMUs)
t	Number of outputs
m	Number of inputs
ε	A small positive number

Following are the weights assigned to:

u_r	output r
v_i	input i
$v_{O\&Mcost}$	annual O & M cost
$v_{feeder-length}$	total length of distributors
$v_{transformer-cap}$	total capacity of distribution transformers
$v_{employee}$	number of employees working for a DC
$v_{distribution-loss}$	distribution loss
$u_{annual-sales}$	annual sales of energy by a DC
$u_{customer}$	number of customers supplied by a DC

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