

**PERFORMANCE EVALUATION OF POWER  
DISTRIBUTION SECTOR OF SRI LANKA BASED ON  
DATA ENVELOPMENT ANALYSIS**

K.V.R.Perera

109241R



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

Degree of Master of Science

Department of Electrical Engineering

University of Moratuwa  
Sri Lanka

February 2015

**PERFORMANCE EVALUATION OF POWER  
DISTRIBUTION SECTOR OF SRI LANKA BASED ON  
DATA ENVELOPMENT ANALYSIS**

Kankanamalage Varuni Randima Perera

109241R



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

Dissertation submitted in partial fulfillment of the requirements for the  
Degree Master of Science

Supervised by: Dr.K.T.M.Udayanga Hemapala

Department of Electrical Engineering

University of Moratuwa  
Sri Lanka

February 2015

## DECLARATION

“I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books)”.

.....

Signature of the candidate

(K.V.R.Perera)



Date:  
University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

The above candidate has carried out research for the Masters Dissertation under my supervision.

.....

Signature of the supervisor

(Dr. K.T.M. Udayanga Hemapala)

Date:

## ACKNOWLEDGEMENT

First, I pay my sincere gratitude to Dr. K.T.M. Udayanga Hemapala who encouraged and guided me to conduct this investigation and on perpetration of final dissertation.

I extend my sincere gratitude to Prof. M. P. Dias, Head of the Department of Electrical Engineering, Prof.J.Rohan Lucas and all the lectures and visiting lectures of the Department of Electrical Engineering for the support extended during the study period.

I would like to take this opportunity to extend my sincere thanks to Mr. K.K.A.C.Samarasinghe, Deputy General Manager (WPN), Mr. R.R. Jayarathna, Chief Engineer (Gampaha), Mr. K.A.D. Subasinghe, Chief Engineer (Planning & Development-WPN), Mr. A.G.D.P. Jayasekara, Planning Engineer (WPN), Miss.D.Mayadunne, Accountant, Expenditure (WPN), Mrs.S.S.Welivitage, Accountant, Revenue (WPN), Mrs.M.Dissanayake, Electrical Engineer, Planning & Development (DD2) and all the Office Staff of Western Province North of Ceylon Electricity Board who gave their co-operation to conduct my research successfully.

It is a great pleasure to remember the kind co-operation extended by the colleagues in the post-graduate programme; friends and specially my husband Asanka Amarasinghe who helped me to continue the studies from start to end.



University of Moratuwa, Sri Lanka.

Electronic Theses & Dissertations

www.lib.mrt.ac.lk

## ABSTRACT

### **Performance Evaluation of Power Distribution Sector of Sri Lanka Based on Data Envelopment Analysis**

Performance benchmarking is very important for any type of organization. Results of such benchmarking studies allow the organization or the unit to compare themselves with the best organization or unit and to develop strategic plans for improvements in their performance. There are several methods and techniques for the measurement of the relative efficiency of organizations or units in relation to an efficient frontier or best practice. Each technique is either based on linear programming or econometrics. Data Envelopment Analysis (DEA), Parametric Programming Analysis (PPA), Partial Factor Productivity (PFP), Corrected Ordinary Least Squares (COLS) and Stochastic Frontier Analysis (SFA)

The algorithm which can be followed by top managers of any organization to evaluate and improve relative performance is discussed. Relative performance of 20 areas within Distribution Division 02 (DD2) of Ceylon Electricity Board is evaluated using Data Envelopment Analysis (DEA). Relative efficiency scores and methods to improve efficiencies can be identified for each area.

This paper studies how to carry out DEA analysis to evaluate CRS, VRS and scale efficiency scores and slack analysis in order to find efficient input targets and output targets. Then DEA analysis was carried out with different models and justified the selected base model for the analysis. This paper also discusses the classification of DMUs according to the sensitivity analysis.



University of Moratuwa, Sri Lanka  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

Generally, the study concludes that DEA analysis can be carried out to evaluate the performance of an organization, department or branch whether it is a public sector or private sector. The evaluation can be carried out once a year or once in two years in order to identify their position and utilized resources can also be reduced according to the results of the analysis.

Key words: Data Envelopment Analysis, Performance, Electricity Distribution Sector, Efficiency Score

## Table of Contents

DECLARATION .....	i
ACKNOWLEDGEMENT .....	ii
ABSTRACT.....	iii
Table of Contents .....	iv
List of Figures .....	vii
List of Tables.....	ix
List of Abbreviations.....	x
List of Appendices .....	xi
<b>1 INTRODUCTION .....</b>	<b>1</b>
1.1 Background .....	1
1.2 Motivation.....	3
1.3 Objective of the Study.....	3
1.4 Methodology .....	3
<b>2 DATA ENVELOPMENT ANALYSIS .....</b>	<b>4</b>
2.1 Introduction to DEA.....	4
2.2 The Mathematical Formulation of DEA .....	5
2.3 Orientations in DEA.....	7
2.4 Returns to Scale Versions.....	9
2.5 Basic DEA Model Classifications.....	10
<b>3 ALGORITHM FOLLOWED.....</b>	<b>11</b>
<b>4 EVALUATING DEA EFFICIENCY SCORES .....</b>	<b>14</b>
4.1 Selection of Input & Output Variables.....	14
4.1.1 Introduction.....	14

4.1.2	Correlation analysis.....	15
4.1.3	Input and output variables used in literature .....	20
4.1.4	Selection of input and output variables for the analysis .....	21
4.1.5	Selection of DMUs.....	22
4.2	DEA Analysis.....	24
4.2.1	Input oriented CRS efficiency score .....	24
4.2.2	Efficiency reference set.....	27
4.2.3	VRS efficiency score.....	28
4.2.4	Slack analysis .....	30
4.2.5	Efficiency targets for inputs & outputs .....	32
4.2.6	Scale efficiency .....	33
4.2.7	Summary of results and recommendations .....	34
5	DEA ANALYSIS WITH DIFFERENT MODELS .....	39
5.1	Preparation of Different Models.....	39
5.2	Efficiency Scores for Different Models .....	39
5.2.1	CRS efficiency score.....	39
5.2.2	VRS Efficiency Score .....	40
5.3	Analysis With Base Model & Different Models .....	42
5.3.1	Efficiency scores of base model and model 2.....	42
5.3.2	Efficiency scores for base model and model 3.....	44
5.3.3	Efficiency scores of model 4 and model 5 .....	46
5.3.4	Efficiency scores for base model, model 6 & 12 .....	49
5.3.5	Analysis with different models upon exclusion of variables from base model	53
5.4	Conclusion of DEA Analysis With Different Models.....	56
5.5	Justification of The Selected Base Model .....	57



6	SENSITIVITY BASED CLASSIFICATION OF DMUS .....	58
6.1	Introduction .....	58
6.2	Classification of DMUs Based On Sensitivity Analysis .....	58
6.3	Results and Discussion .....	59
7	CONCLUSION & RECOMMENDATIONS .....	66
7.1	Conclusion .....	66
7.2	Recommendations .....	69
	Reference List: .....	72
	Appendix A : Data Utilized for the Study.....	74



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)



## List of Figures

Figure 2.1 Projection of an inefficient unit on the frontier .....	8
Figure 2.2 Effect of scale assumption .....	9
Figure 2.3 Basic models based on returns to scale and model orientation .....	10
Figure 3.1 Algorithm followed .....	12
Figure 4.1 Correlated input output variables.....	19
Figure 4.2 Distribution Division 02 .....	23
Figure 4.3 CRS efficiency score plot .....	26
Figure 4.4 VRS and Scale efficiency score plot .....	35
Figure 5.1 CRS efficiency scores of base model and model 2.....	42
Figure 5.2 Percentage difference of model 2 with base model -CRS .....	42
Figure 5.3 VRS efficiency scores of base model and model 2 .....	43
Figure 5.4 Percentage difference of model 2 with base model -VRS .....	43
Figure 5.5 CRS efficiency scores of base model and model 3.....	44
Figure 5.6 Percentage difference of model 3 with base model -CRS .....	45
Figure 5.7 VRS efficiency scores of base model and model 3 .....	45
Figure 5.8 Percentage difference of model 3 with base model -VRS .....	45
Figure 5.9 CRS efficiency scores of model 4 and model 5.....	47
Figure 5.10 Percentage difference of model 4 with model 5 -CRS .....	47
Figure 5.11 VRS efficiency scores of model 4 and model 5 .....	48
Figure 5.12 Percentage difference of model 4 with model 5 -VRS.....	48
Figure 5.13 CRS efficiency scores of base model, model 06 & 12 .....	49
Figure 5.14 Percentage difference of model 6 &12 with base model –CRS .....	50
Figure 5.15 VRS efficiency scores of base model, model 6 & 12.....	50
Figure 5.16 Percentage difference of model 6 & 12 with base model –VRS .....	51
Figure 5.17 CRS efficiency scores of different models upon exclusion of variables from the base model .....	53
Figure 5.18 Percentage differences of models upon exclusion of variables from base model - CRS.....	53
Figure 5.19 VRS efficiency scores of different models upon exclusion of variables from the base model .....	54

Figure 5.20 Percentage differences of models upon exclusion of variables from base model - VRS.....	54
Figure 6.1 Sensitivity profile of robustly efficient DMUs.....	60
Figure 6.2 Sensitivity profile of marginally efficient DMUs.....	61
Figure 6.3 Sensitivity profile of marginally inefficient DMUs.....	62
Figure 6.4 Sensitivity profile of significantly inefficient DMUs.....	62
Figure 6.5 Sensitivity profile of distinctly inefficient DMUs.....	63
Figure 6.6 Plot of amount of DMUs for each category.....	64



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## List of Tables

Table 1.1 Overview of benchmarking methods .....	2
Table 4.1 Input output variables .....	15
Table 4.2 Guideline to correlation analysis.....	16
Table 4.3 Results of correlation analysis .....	16
Table 4.4 Input output variables used in literature.....	21
Table 4.5 Selected input output variables for the analysis.....	21
Table 4.6 Selected DMUs for the analysis.....	24
Table 4.7 Efficiency scores for input oriented CRS model .....	25
Table 4.8 Ranks of DMUs .....	27
Table 4.9 ERS values of DMUs.....	28
Table 4.10 VRS efficiency scores.....	29
Table 4.11 Input and output slack values.....	31
Table 4.12 Efficient input and output targets.....	32
Table 4.13 Summary of efficiency scores.....	34
Table 4.14 Summary of recommendation.....	36
Table 5.1 Different DEA models .....	39
Table 5.2 CRS efficiency scores for different models .....	40
Table 5.3 VRS efficiency scores for different models.....	41
Table 5.4 Justification of the selected base model.....	57
Table 6.1 Results of sensitivity analysis .....	60
Table 6.2 Classification of DMUs .....	64



## List of Abbreviations

Abbreviation	Description
CEB	Ceylon Electricity Board
CP	Central Province
CRS	Constant Returns to Scale
DD2	Distribution Division 02
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
DRS	Decreasing Return to Scale
EP	Eastern Province
ERS	Efficiency Reference Set
IRS	Increasing Return to Scale
LV	Low Voltage
MV	Medium Voltage
NIRS	Non-Increasing Return to Scale
O&M	Operation and Maintenance
RTS	Return To Scale
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
VRS	Variable Returns to Scale
WPN	Western Province North



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## List of Appendices

Appendix	Description	Page
Appendix A	Data utilized for the study	74



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)