PERFORMANCE EVALUATION OF THE ELEVEN STATIONS OF VOLTA RIVER AUTHORITY/NORTHERN ELECTRICITY DISTRIBUTION COMPANY (VRA/NEDCo) SUNYANI OPERATIONAL AREA: A DATA ENVELOPMENT ANALYSIS APPROACH

BY

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DECLARATION

I hereby declare that this submission is my own work towards the M.Sc. Degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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CERTIFICATION

The undersigned certify that I have read and recommended for the acceptance of this thesis.

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……………………… ……………………

Supervisor Signature Date

CERTIFICATION OF HEAD OF DEPARTMENT

I hereby certify that a copy of this work had been presented to me to keep as a record for the institution.

Prof. S. K. Amponsah ……………………… ……………………

(Head of Department) Signature Date

Certified by …………………….. ………………..

Prof. I. K. Dontwi Signature Date
(Dean, IDL)

ABSTRACT

The purpose of this study was to utilize data envelopment analysis (DEA) to measure performance assessment of the one main station and the ten outstations of Volta River Authority/Northern Electricity Distribution Company (VRA/NEDCo) in Sunyani operational area.

The DEA approach has been recognized as a robust tool that is used for evaluating the performance of profit and non-profit institutions. The proposed approach is deployed based on empirical data collected from the stations. On an efficiency scale of 0.0 to 1.0, DEA assesses the efficiency of every station relative to the rest of the stations in terms of performance assessment. For inefficient stations, DEA provides quantitative guidance on how to make them efficient.

The September 2012 data from the stations of NEDCo Sunyani operational area were used. Three (3) input variables and One (1) output variable were identified. The input variables were staff population (only technical staff including drivers), active customer population and number of vehicles. The output variable was revenue collection. The results show that one station (Mim/Goaso) was found to be efficient, the rest of the stations (Sunyani, Berekum, Kenyasi, Dormaa Ahenkro, Duayaw Nkwanta, Tepa, Bechem, Drobo, Sampa, Wamfie) were found to be inefficient for the month of September, 2012.

There was an indication that addressing some of the following problems will improve efficiencies of the ten inefficient stations; lack of logistics, too much work at hand, lack of personal, poor attitude towards work and poor planning etc.

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DEDICATION

To my beloved late mother Obaatanpa Sabina Yaa Ataa Dansowaa Sarpong, my dearly loved wife Mrs. Leah A. Appiah-Kubi, my two lovely daughters Tracy Nana Dansowaa Appiah-Kubi, Keren Owusuwaa Appiah-Kubi, my sister Rosemary Dansowaa Appiah, my brothers Kwame Owusu Appiah, Sylvester Leo Okwan and Felix Loe Okwan.

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KEYWORDS

Data Envelopment Analysis, efficiency frontier, quantitative guidance, relative efficiency, empirical data, inefficient, profit and non-profit institutions.

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LIST OF ABBREVIATIONS

NOTATION	MEANING
LP	Linear Programming
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
CHE	Centre for Higher Education
CCR	Charnes, Cooper and Rhodes
GLM	General Linear Model
SFA	Stochastic Frontier Analysis
NSW	New South Wales
ECU	European Currency Unit
OLS	Ordinary Least Squares
FTE	Full Time Equivalent
IPA	Independence Practice Association
HMO	Health Maintenance Organisation
MTF	Military Treatment Facility
DoD	Department of Defense
VRA	Volta River Authority
NED	Northern Electricity Department
PSR	Power Sector Reform
ECG	Electricity Company of Ghana
IMF	International Monetary Fund

PURC	Public Utility Regulatory Commission
JICA	Japanese International Cooperation Agency
DANIDA	Danish international Development Agency
PNDCL	Provisional National Defense Council Law
GRIDCo	Ghana Grid Company
NEDCo	Northern Electricity Distribution Company
USNWR	US News and World Report
DCCR	Dual Charnes, Cooper and Rhodes
LSAT	Law School Admission

CHAPTER 1

1.0 INTRODUCTION

Decision making involves a variety of courses of action among several alternatives to improve the performance of an organization. The Performance Assessment or Evaluations of Performance concerned is more or less especially, evaluating the activities of organizations such as business firms, government agencies, hospitals, and educational institutions. Such evaluations take a variety of forms in customary analyses. Some of the examples include; cost per unit, profit per unit, satisfaction per unit, efficiency per unit and so on. "Decision Making Units" (DMUs) refer to units of an organization or organizations that utilize similar inputs to produce similar outputs. The evaluation results in a performance score that ranges between zero and one and represents the "degree of efficiency obtained by evaluated entity.

1.1 BACKGROUND TO THE STUDY

In Sunyani, operational area of Volta River Authority (VRA)/Northern Electricity Distribution Company (NEDCo) have one (1) main station that is, Sunyani and (10) out stations. They all do the same work (that is Power Distribution) to both residential and non-residential customers and also revenue collection.

At the end of every month, each station (DMU) performance is base on the revenue collected. The revenue collected is used to determine the station (DMU) which has done well. This means that the raw data (revenue collected) is used without considering other factors like the Number of staffs at the stations, the Active customer base, Limitation of the stations, Total area coverage of the stations and the Number of cars and other logistics of the stations.

1.2 ORGANIZATION PROFILE

The mother organization of Northern Electricity Distribution Company (NEDCo) is Volta River Authority (VRA) which was established on April 26, 1961 under the Volta River Development Act, Act 46 of the Republic of Ghana, with the core business to generate and supply electrical energy for industrial, commercial and domestic use in Ghana. VRA started with the development of the hydroelectric potentials of the Volta River and the construction and maintenance of a nation-wide grid transmission system. Today, it has expanded into distribution of electricity in the northern sector of Ghana, and thermal generation to complement inadequate capacity for hydro generation.

In 2005 following the promulgation of a major amendment to the VRA Act in the context of the Ghana Government Power Sector Reforms, the VRA's mandate has now been largely restricted to generation of electricity. The transmission function has been hived off into a separate entity, designated Ghana Grid Company (GRIDCo) to perform the transmission activities. The VRA is planning to operate its distribution agency, the

Northern Electricity Department (NED) which is now NEDCo as a subsidiary company. The amendment is expected to attract independent power producers onto the Ghana energy market.

1.3 BRIEF HISTORY OF NEDCo

NEDCo was formed out of the Northern Electricity Department (NED) of the Volta River Authority (VRA). NED itself was established in April, 1987 when the northern electricity distribution operations of the then Electricity Corporation of Ghana were ceded to the VRA. The Authority, at the time, was in the process of extending the national grid beyond Kumasi to the northern parts of Ghana. The Volta River Development (Amendment) Law, 1987 (PNDCL 171) was passed to enable VRA to enter the distribution market at the level of the consumer.

At the time of the inception of NED, some major towns were served by diesel generators. Some of these towns included Sunyani, Techiman, Berekum, Wenchi, Dormaa Ahenkro, Tamale, Yendi, Salaga, Bolgatanga, Navrongo, Bawku and Wa. New diesel plant was also installed in Wa through the support of the Danish International Development Agency (DANIDA) in 1989. The electricity distribution network in Wa was also completely rehabilitated through DANIDA support in 1992.

NED was originally started as three operational areas namely Upper Area, Northern Area, and Brong-Ahafo Area. In 1995, however, the Upper Area was divided into

Upper East and Upper West Area. In 2003, the Brong-Ahafo Area was also further divided into two areas, Sunyani and Techiman.

In June 1994, the Government of Ghana initiated the Power Sector Reform (PSR) programmed aimed at bringing efficiency and managerial effectiveness in the Energy Sector to improve general service delivery to all consumers. In pursuance of the Power Sector Reforms, VRA Management registered NEDCo as a wholly-owned VRA subsidiary with a Board of Directors since 1997 to take over the operations of NED.

NEDCo's current operations extend into the northern parts of Volta, Ashanti, and Western regions. Although NEDCo's operations cover about 64% of the geographical area of Ghana, the customer density of the operating area is low with access to electricity in the NEDCo operating area put at about 36%as at the end of 2011. The Ghana Government, in line with its vision of making electricity available to all by year 2020, has undertaken power extensions over the years to new towns and communities that were hitherto not served by NEDCo. Customer population has thus grown from less than 20,000 in 1987 to over 380,000 in 2011.

VRA Management has now taken the decision to fully operationalise NEDCo. On May 8, 2012, NEDCo was, therefore, officially inaugurated and a new Board of Directors was sworn into office on the same day.

The full operationalisation of NEDCo as a VRA subsidiary seeks to achieve the following objectives:

1. Make NEDCo economically viable and sustainable by attracting additional resources from both external and internal sources to supplement VRA's on-

going support of the current NEDCo operations. In this arrangement, NEDCo will also be able to deal directly with multilateral agencies such as the World Bank, Japanese International Cooperation Agency (JICA), IMF, etc for financial support to prosecute its business agenda. It is important to note that the present support from VRA is inadequate because of equally competing demands from other departments.

2. Empower NEDCo to manage its own affairs more effectively by providing it with the right organizational structure and corresponding authority. Thus, NEDCo management will have the authority to take timely and appropriate decisions on customer issues and challenges to improve service delivery without recourse or reference to VRA.
3. Empower NEDCo to streamline key procedures and decision making processes in respect of procurement of its strategic equipment and spares, construction of needed office buildings and staff training and development, all of which are critical to efficient service delivery to our cherished customers.
4. Empower NEDCo to deal directly with Government and regulators such as the PURC, EC on key issues pertaining to its viability and sustainability. For instance, NEDCo will be illegible to file a tariff proposal to PURC separate from what is filed by VRA.

1.4 VISION STATEMENT OF NEDCo

The vision of VRA/NEDCo is to be the leading electricity distribution in Ghana and the West African Sub-Region.

1.5 MISSION STATEMENT OF NEDCo

The mission of VAR/NEDCo is to safely and reliably supply electricity to homes and businesses in Ghana and neighboring countries.

1.6 THE CORE VALUES OF NEDCo

The core values of VRA/NEDCo are Commitment, Integrity, Teamwork, Trust and Accountability.

1.7 SCOPE OF ACTIVITIES

The main or the major activity of VRA/NEDCo is to supply or distribute safe, reliable and un-interacted electricity throughout the northern sector of the country Ghana and beyond its borders to residential, non-residential and industrial customers.

In the country like ours (Ghana), the constitution gives right to only ECG and VRA/NEDCo to distribute safe and reliable electricity power supply to all over the country residential, non-residential and industrial customers.

In this case revenue collection can be high if there is safe, reliable and un-interacted power supply. The diagramed below shows the electricity supply chain,

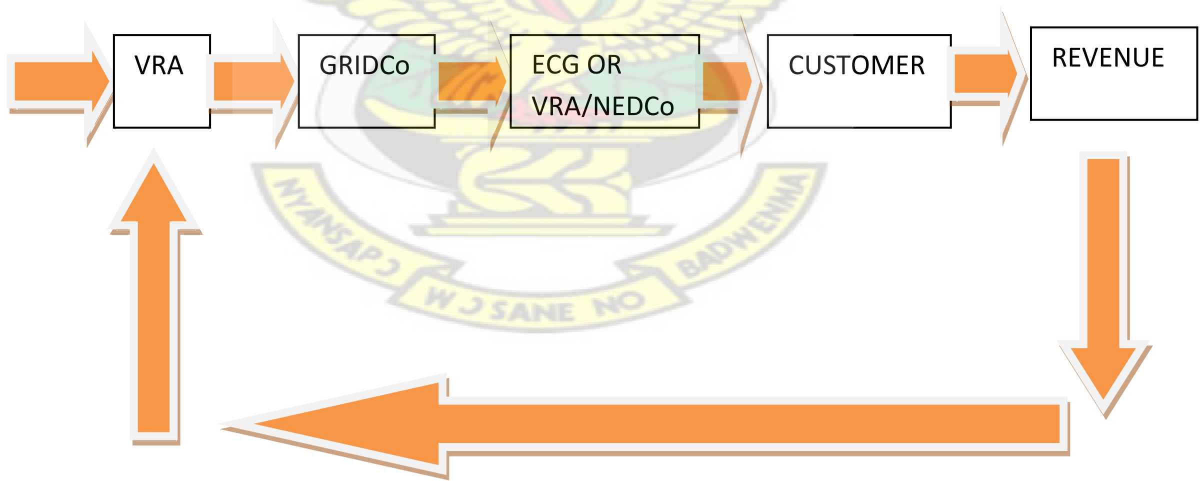

Figure 1.1 Electricity supply chain

In electricity supply chain, a break in any part of the chain will affect the whole operation system including revenue. The current situation in the country of load schedule has affected the revenue collection of both VRA/NEDCo and ECG.

1.8 STATEMENT OF THE PROBLEM

The use of raw data on revenue collection alone to rank the stations according to performance does not represent a robust approach to assessing the true performance of the stations since it totally ignores the inputs used by each station; each station's true performance can be measured by comparing its inputs to its outputs for a given period. An existing generally accepted approach like the DEA provides a good way of assessing the true performance of the stations. Consequently, this study uses the DEA approach to assess the true performance of NEDCo (Sunyani operational area) stations

1.9 OBJECTIVES OF THE STUDY

General objective:

The general objective of this study was to assess the performance of revenue collection rate of the NEDCo Sunyani operational area.

Specific objectives:

The specific objectives include;

i. To develop a Linear Programming (LP) model which can determine the performance of DMU's in a company.

ii. The Linear Programming (LP) model which can effectively and efficiently in order to optimize profit margin of a company.

iii. To make recommendations that can improve the performance of revenue collection in VRA/NEDCo Sunyani operational area.

1.10 JUSTIFICATION

The outcome of this study may inform the management of VRA/NEDCo to make plans to improve the efficiency on various DMUs through its inputs and outputs policies. DMUs which are inefficient will evaluate and measure their activities to match up with the most efficient one and that will become the target for the other DMUs.

1.11 METHODOLOGY

The data for this study will consists of Secondary data collected from VRA/NEDCo Sunyani Operational area from monthly or annual report. In other for the best performance assessment, the company's actual revenue collection data will be used. The model will be solved using Simplex Algorithm.

The Linear Programming model has three basic components, these are;

(i) The objective function which is to optimize (minimize or maximize).

(ii) The constraints or limitation and

(iii) The non-negative constraint.

The computerized software application program called Lips (Linear Programming Solver) for windows based on the Simplex algorithm was used to facilitate the solution of the Linear Programming Model developed. The Lips was considered the best option for the project because the spreadsheet offers a very convenient data entry and editing features which allows for a greater understanding of how to construct linear programs.

1.12 SIGNIFICANCE OF THE STUDY

This project seeks to assess the performance of the company. It is hope that the model designed in the course of this study based on empirical evidence, would go a long way in providing useful planning tool for the company.

Suggestions and recommendations would be given to strengthen any weakness of the company which would be exposed in the course of the study.

1.13 LIMITATION OF THE STUDY

The study considered only inputs and outputs elements that are paramount to the efficiency of the VRA/NEDCo Sunyani operational area. The study was restricted to the one main station and ten outstations of the company. The analysis was based on the data obtained from the Commercial Section, Finance Section, Technical Section and Station Supervisors of the company.

1.14 ORGANISATION OF THE STUDY

The thesis is divided into five (5) main chapters

1. Chapter 1, Overview of the thesis topic under consideration.
2. Chapter 2, Review literature relating to the scope of study, which covers application of linear programming to performance assessment.
3. Chapter 3, Methodology used for the study with an in depth analysis of some of the underlying principles of DEA used in the study. It considers the method of data collection and analysis of the main and outstation of the Sunyani Operational Area of NEDCo Company for the research.
4. Chapter 4, Describes the results an analysis of the data collected using the necessary tools for implementation of the model. This will also include the findings.
5. Chapter 5 summarizes the various findings, conclusions and recommendations.

1.15 SUMMARY

In the introductory chapter, we considered Background of performance assessment, Organizational profile, Brief history of VRA/NEDCo, the Vision and Mission statements, Core values, Scope of activities, Objective of the study, Methodology, Significance of the study, Limitation and Organization of the study. In the next chapter, we shall review some literature in the area of linear programming and some theories.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter deals with general literature on DEA, applied to a wide field of diversity in the assessment of efficiency.

2.1 Data Envelopment Analysis

Data Envelopment Analysis (DEA) was accorded this name because of the way it "envelops" observations in order to identify a "frontier" that is used to evaluate observations representing the performances of all of the entities that are to be evaluated. Uses of DEA have involved a wide range of different kinds of entities that include not only business firms but also government and non-profit agencies including schools, hospitals, military units, police forces and court and criminal justice systems as well as countries, regions, etc. The term "Decision Making Unit" (DMU) was therefore introduced to cover, in a flexible manner, any such entity, with each such entity to be evaluated as part of a collection that utilizes similar inputs to produce similar outputs. These evaluations result in a performance score that ranges between zero and unity and represents the "degree of efficiency" obtained by the thus evaluated entity. In arriving at these scores, DEA also identifies the sources and amounts of inefficiency in each input and output for every DMU. It also identifies the DMUs (located on the "efficiency frontier") that entered actively in arriving at these results. These evaluating entities are all efficient DMUs and hence can serve as benchmarks and route to effecting improvements in future performances of the evaluated DMUs. The different types of efficiency covered in this text range from "allocative," or "price," efficiency, and extend through "scale" and "technical" efficiency, as well as "mix" and other kinds of efficiencies. Technical inefficiency, which represents "waste," is the one we focus on in this Preface because it requires the least information, makes the fewest assumptions, and is the one most likely to be agreed upon as to what is meant by the term "inefficiency." Uses of DEA to effect these evaluations are almost entirely "data dependent" and do not require explicit characterizations of relations like "linearity," "nonlinearity," etc., which are customarily used in statistical regressions and related approaches where they are assumed to connect inputs to outputs, etc.

2.2 Empirical review

Barros, (2007), analyzed the efficiency of the Lisbon Police Force precincts with a two stage DEA. In the first stage, the study estimated the DEA efficiency scores and compares the precincts with each other. The aim of this procedure was to seek out those best practices that will lead to improved performance of all of the precincts. The author ranks the precincts according to their efficiency for the period 2000-2002. In the second stage, he estimated a bit model in which the efficiency scores are regressed on socioeconomic issues, identifying social causes which vary across the city and affect deterrence policy. The study considers economic implications of the work. Usher and Savino (2006) compared nineteen (19) ranking systems from Australia, Canada, China, USA, Hong-Kong, Italy, Poland, Germany, Spain and the United Kingdom. They pointed out the fact that the difference in the content of the systems can be ascribed to the geographical location and culture, and refer to the standardization issue of results. However, there is agreement on the best institutions and category based rankings. International ranking systems can be complemented with indicators that would allow inter-institutional performance comparison.

Garcia-Sanchez (2006) established a procedure for evaluating the efficiency of providing the water supply. This procedure has allowed the author realized that the proposed indicators have a discriminating capability in the analysis of the service, and to reject criticisms traditionally assigned to the sensitivity of the DEA technique in relation to degrees of freedom. The article studies efficiency and also illustrate of the use of the technique of DEA.

According to Bretschneider (2005), the purpose of their article is twofold.

First, it critically examines the underlying assumptions associated with "best practices research" in Public Administration in order to distill an appropriate set of rules to frame research designs for best practice studies. Second, it reviews several statistical approaches that provide a rigorous empirical basis for identification of "best practices" in public organizations - methods for modeling extreme behavior (i.e., iteratively weighted least squares and quartile regression) and measuring relative technical efficiency.

Ouellette, and Vierstraete (2005), studied the efficiency of Quebec's school boards during a period of severe cutbacks in their finance using DEA. The average efficiency is found to be relatively high. In spite of this, potential savings could be achieved if school boards were fully efficient. Results depended heavily on school boards' socio-economic conditions. They were subjected to bit analysis and the boards' corrected efficiencies recalculated. The inefficiencies cost $800 million of which$200 million came from unfavorable socio-economic conditions.

Moore, (2005), applied DEA as a response to their view that the literature describing the performance of municipal services often uses imperfect or partial measures of efficiency. DEA has emerged as an effective tool for measuring the relative efficiency of public service provision. This article uses DEA to measure the relative efficiency of 11 municipal services in 46 of the largest cities in the United States over a period of 6 years. In addition, this information is used to explore efficiency differences between cities and services and provide input into a statistical analysis to explore factors that may explain differences inefficiency between cities. Finally, the writers discuss municipal governments' use of performance measures and problems with collecting municipal data for benchmarking.

Van Dyke (2005) does a detailed presentation and comparison of ranking systems(Asia week, The Center, CHE, Good Guides, The Guardian, Macleans, Melbourne Institute, Perspektywy, The times and USNWR) regarding indicators and attributes the difference in the systems to the variety of objectives, systems, culture and availability of data.

Casu, (2004), for the period 1994-2000, in an efficiency analysis of the European banking institutions found that Italian banks had an 8.9% productivity increase, Spanish banks had a 9.5% increase, while German, French and English banks had

1.8%, 0.6%and 0.1% productivity increase, respectively. The main reason for such improvement inefficiency for the Italian and Spanish banks was the cost reduction that these institutions managed to achieve.

Dill and So (2004), criticized rankings systems regarding statistical validity, the selection of indicators that reflected quality and the negative impact on university performance. They concentrated on USNWR, Australian Good University Guide, Ma-cleans, Times Good University Guide and Guardian University Guide. They examine validity, comprehensiveness, comprehensibility and functionality of the systems and reach the conclusion that the system can be supplemented with other indicators and reflect the quality of an institution in a better way.

Schure, (2004), estimated the productivity of the European banking sector for the period 1993-1997. They found out that, the larger commercial banks were more productive on the average than the smaller banks. However, the Italian and the Spanish banks were found to be the least efficient.

Brockett, (2003), in a study on Health Maintenance Organizations (HMO), which employ Independent Practice Associations (IPA) versus those that employ group/staff arrangements in a 'game-theoretic' DEA model was evaluated. In this model, they combine the two-person zero sum game approach with DEA, evaluating the results from both society's and the consumers' perspectives. Individual DMUs from one group are compared to the collective second group (or the efficient frontier from the second group). This technique is relevant when there are components of a system that may be in competition with each other. Specifically, the civilian network component of the military health care system versus the MTF components might be evaluated using this unique DEA approach.

Similarly, Brockett et al (2003), employed the same combination of DEA and Ordinary Least Squares (OLS) methodology in evaluating advertising programs for military recruitment. They evaluated a "service specific" program for advertising in comparison with a "joint program." Using data from a previously conducted "designed experiment" advertising study, the writers showed that joint recruitment efforts are less efficient then service specific recruiting.

Casu and Molyneux (2003) employed DEA to investigate whether the productivity efficiency of European banking systems had improved and converged towards a common European frontier between 1993 and 1997. The geographical coverage of the study was France, Germany, Italy, Spain and the United Kingdom. All the data generated were reported in ECU as the reference currency. Their results indicated relatively low average efficiency levels. Nevertheless, it was possible to detect an average efficiency levels. Nevertheless, it was possible to detect a slight improvement in the average efficiency scores over the period of analysis for almost all banking systems in the sample, with the exception of Italy.

Woodbury, (2003), reviews municipal efficiency measurement in Australia to advance the argument that the present reliance on partial measures of performance is inadequate and should be heavily augmented by DEA. The authors summarize progress made in efficiency measurement on a state-by-state basis and then examine performance measurement in water and waste water as a more detailed case study. On the basis of this evidence, the authors argue that DEA provides the best means of providing public policy makers with the necessary information on municipal performance.

Drake and Simper (2002), this study uses both parametric and nonparametric techniques to analyze scale economies and relative efficiency levels in policing in England and Wales. Both techniques suggest the presence of significant scale effects in policing and considerable divergence in relative efficiency levels across police forces.

Fernandez, (2002), studied the economic efficiency of 142 financial intermediaries from eighteen countries over the period 1989-1998 and the relationship between efficiency, productivity change and shareholders' wealth maximization. The authors applied DEA to estimate the relative efficiency of commercial banks of different geographical areas (North America, Japan and Europe). The European banks were from Austria, Belgium, Denmark, Finland, Germany, Ireland, Italy, Luxemburg, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. The three preferred outputs were total investments, total loans, and non-interest income plus other operating income. In parallel, the four input variables were property, salaries, other operating expenses and total deposits. All these values were expressed in billions of US dollars.

Their results showed that commercial bank productivity across the world had grown significantly (19.6%) from 1989 to 1998.

This effect had been principally due to relative efficiency improvement, with technological progress having a very moderate effect.

Maudos (2002) analyzed the cost and profit efficiency of European banks in ten countries, including Italy, for the period 1993-1996. They used multiple regression analysis along with DEA and they split their sample in large, medium and small banks. Their results indicated that only medium sized banks were profit efficient.

Lozano-Vivas (2002), examined banking efficiency in ten European countries among which was Italy, for 1993. The authors adopted the value added approach and analyzed also the macroeconomic environment where the banks operated. Their results showed that banking efficiency was low in Europe during that time period. Furthermore, the banks in Italy and Netherlands were the only ones which were not able to operate in a unified European banking system compared to the most efficient banks of the other sample countries.

Worthington and Dollery (2002), used the planning and regulatory function of 173 New South Wales (NSW) local governments, several approaches for incorporating contextual or nondiscretionary inputs in DEA are compared. Non-discretionary inputs (or factors beyond managerial control) in this context include the population growth rate and distribution, the level of development and non-residential building activity, and the proportion of the population from a non-English speaking background. The approaches selected to incorporate these variables include discretionary inputs only, nondiscretionary and discretionary inputs treated alike and differently, categorical inputs, 'adjusted' DEA, and 'endogenous' DEA. The results indicate that the efficiency scores of the five approaches that incorporated non-discretionary factors were significantly positively correlated. However, it was also established that the distributions of the efficiency scores and the number of councils assessed as perfectly technically efficient in the six approaches also varied significantly across the sample.

Sun, in (2002) employed DEA to measure the relative efficiency of the 14 police precincts in Taipei city, Taiwan. The results indicate how DEA may be used to evaluate these police precincts from commonly available police statistical data for the years 1994–1996. To sharpen the efficiency estimates, the study uses window analysis, slack variable analysis, and output-oriented DEA models with both constant and variable returns to scale. The problem of the presence of nondiscretionary input variables is explicitly treated in the models used. Potential improvements in technical efficiency of police precincts are examined by readjusting the particular output/input indicators. The analysis indicates that differences in operating environments, such as resident population and location factors, do not have a significant influence upon the efficiency of police precincts.

Mante and O'Brien (2002), this paper provide a review and an illustration of the DEA methodology for measuring the relative efficiency of public sector organizations performing similar tasks. The study focuses on measuring the relative technical efficiency of State secondary schools in a geographical region in the Australian State of Victoria. It recognizes that state secondary schools, like other non-profit making organizations, produce multiple outcomes by combining alternative discretionary and non-discretionary inputs.

Bikker (2001), examined the banking productivity of a sample of European banks in various countries, along with was Italy also, for the period 1989-1997. His results indicated that the most inefficient banks were first the Spanish ones, followed by the French and the Italian banks. The most productive banks were the one in Luxemburg, in Belgium and in Switzerland.

Hasan (2000) analyzed the banking industries of Belgium, Denmark, France, Germany, Italy, Luxemburg, Netherlands, Portugal, Spain and the United Kingdom. First, the authors attempted to evaluate the efficiency scores of banking industries operating in their own respective countries. Later, they used a common frontier to control the environmental conditions of each country. The results based on cross-country efficiency scores suggested that the banks in Denmark, Spain and Portugal were relatively the most technically efficient and successful. Especially, when the banks of these countries tried to enter into any other European country of the sample were most efficient. On the other hand, the banks in France and Italy were found to be the least efficient institutions among the ones.

Drake and Simper (2000), utilized DEA to estimate the productivity of the English and Welsh police forces and to determine whether there are categorical scale effects in policing using multiple discriminate analysis (MDA). The article demonstrated that by using DEA efficiency results, it is possible to make inferences about the optimal size and structure of the English and Welsh police forces.

Worthington (1999), sampled one hundred and sixty-eight New South Wales local government libraries to analyze the efficiency measures derived from the non-parametric technique of data envelopment analysis. Depending upon the assumptions employed, 9.5 percent of local governments were judged to be over all technically efficient in the provision of library services, 47.6 percent as pure technically efficient, and 10.1 percent as scale efficient. The study also analyses the posited linkages between comparative performance indicators, productive performance and non-discretionary environmental factors under these different model formulations.

Pastor, (1997), analyzed the productivity, efficiency and differences in technology in the banking systems of United States, Spain, Germany, Italy, Austria, United Kingdom, France and Belgium for the year 1992. Using the non-parametric approach DEA together with the Malmquist index, they compared the efficiency and differences in technology of several banking systems. Their study used the value added approach.

Deposits, productivity assets and loans nominal values were selected as measurements of banking output, under the assumption that these are proportional to the number of transactions and the flow of services to customers on both sides of the balance sheet.

Similarly, personnel expenses, no-interest expenses, other than personnel expenses were employed as a measurement of banking input. According to the results France had the banking system with the highest efficiency level followed by Spain, while UK presented the lowest level of efficiency.

Allen and Rai (1996) estimated a global cost function using an international database of financial institutions for fifteen countries. Their sample was divided into two groups according to the country's regulatory environment. Universal banking countries (Australia, Austria, Canada, Switzerland, Germany, Denmark, Spain, Finland, France, Italy, United Kingdom and Sweden) permitted the functional integration of commercial and investment banking, while separated banking countries (Belgium, Japan and US) did not. Large banks in separated banking countries exhibited the largest measure of input in efficiency and had anti-economies of scale. All other banks had significantly lower inefficiency measures. Moreover, small banks in all countries showed significant levels of economies of scale. Italian banks, along with French, UK and US ones were found less efficient from Japanese, Austrian, German, Danish, Swedish and Canadians ones.

Arnold, (1996), illustrated how DEA may be coupled with traditional Ordinary Least Squares analysis of log linear models to produce satisfactory efficiency estimations. In this study, the authors show that the OLS regression and Stochastic Frontier Analysis (SFA) do not provide results consistent with economic theory or expectations, because they deal with "central tendency" estimates without allowing for differences in efficient and inefficient performers. DEA is then employed to determine efficient public secondary schools in Texas. Subsequently, a dummy variable reflecting efficient versus inefficient schools is incorporated into OLS regression models. The results illustrate that the combined methodology approach produces results consistent with economic theory and successfully combines estimation for efficient and inefficient behavior as identifiable components in one model.

Altunbas and Molyneux (1996) examined the banking systems of France, Germany, Italy and Spain for economies of scale and scope. They found differences among the four markets regarding economies of scale. However, the latter were significant only for the Italian banks, which gained as they succeeded in lowering costs.

Pedraja-Chaparro and Salinas-Jiminez (1996), the objective of the article is to provide a measure of technical efficiency of the Administrative Litigation Division of the Spanish High Courts. The concept of efficiency to be measured and the most adequate technique for carrying out the efficiency analysis are selected by considering the specific characteristics of public production. The analysis is undertaken by using (DEA) and various homogeneity tests (returns to scale and restrictions on weights) are applied in order to ensure a correct comparison between Courts.

In 1995, John W. Young contributed a report to the "Educational and Psychological Measurement" bimonthly journal entitled, "A Comparison of Two Adjustment Methods for Improving the Prediction of Law School Grades." Young (1995), wrote, "Criticisms about the effectiveness of preadmission measures generally focus only on limitations of the predictors". As the title suggests, Young (1995), sought to detect any changes in the predictive validity of the law school admissions test (LSAT) on law school performance when the criterion was changed from first-year grade point average (GPA) to the cumulative GPA (1995). He suggested that many predictive validity studies were inherently limited due their reliance on first year GPA as the criterion. Institutional studies favored first year GPAs because they are easy to obtain and are a well-defined criterion (1995). Further, cumulative GPAs contain "noise" generated by unique grade distributions of the varying combinations of courses taken by students (1995).

Young (1995), viewed the first-year GPA criterion as "neither a sufficient nor an adequate measure of a student's overall achievement" and suggested that a cumulative

GPA would offer more advantage. Thus, he proposed using a previously validated grade adjustment method to correct for the interruptive nature of the cumulative GPA. Young (1995), was the first to use his method in a study on post-graduate performance. Young (1995), obtained data from four accredited U.S. law schools, choosing one school from the West (School A), one from the South (School B), and two from the Northeast (C and D, respectively). Three of the schools were public and one private. Using item response theory (IRT) and the (statistical) general linear model (GLM), Young (1995), generated figures that equated grades from different course (using a rating scale) and displayed optimizing characteristics of the least squares approach.

The results of Young's grade adjustment methods were minor, indicating that the correlation of predictive validity of the law school admissions test (LSAT) was only slightly improved (1995).Young (1995), attributed the low improvement to the similarity of the law courses taken by the students. In other words, previous efforts using the same adjustment methods yielded greater results because of the greater variation in chosen courses among undergraduate students. In law school, everyone essentially takes the same courses. Thus, correlation improvements based on course differences "would likely have little impact in changing the relative rankings of students" (Young, 1995).

School D (from the Northeast) displayed an 83 percent greater correlation between LSAT and future performance than the other three schools. Young (1995) explained this disparity emphasizing that School D had a significantly higher variation of LSAT scores than the other three schools.

Favero and Papi (1995) used the non-parametric Data Envelopment Analysis on a cross section of 174 Italian banks in 1991 to measure the technical and the scale efficiencies of the Italian banking industry. In implementing both the intermediation and the asset approach the traditional specification of inputs was modified to allow for an explicit role of financial capital. In addition, regression analysis was used on a bank specific measure of inefficiency to investigate determinants of banks' efficiency. According to the empirical results, efficiency was best explained by productivity specialization by bank size and to a lesser extent by location (north-Italian banks were more efficient than south-Italian banks).

Ozcan and Bannick (1994) used DEA to study trends in Department of Defense hospital efficiency from 1998-1999 using 124 military hospitals and data from the American Hospital Association Annual Survey. In a 1995 study, these authors also compared DoD hospital efficiency with that of Veteran's Administration hospital efficiency (n=284) using 1989 data. These studies were conducted at the strategic level under a different operational paradigm, prior to the large-scale adoption of managed care.

Berg, (1992), introduced the Malmquist index as a measurement of the productivity change in the banking industry. They focused on the Norwegian banking system during the deregulation period 1980-1989. Their results indicated that deregulation lead into a more competitive environment. The increase of productivity was faster for larger banks, due to the increased antagonism they faced.

Mihara (1990), Mihara's efficiency analysis of the utilization of personnel at Navy Medical Treatment Facilities using 1987-1988 data provided implications for resource allocation. In this study, Mihara initially employed DEA to provide efficiency scores pertaining to the utilization of personnel at individual U.S. Navy hospitals. Efficient facilities were then further analyzed using least squares methods to base line physician requirements (which were deemed workload and beneficiary dependent) and professional staff requirements (which were deemed physician dependent). "In other words, the optimal composition of personnel in terms of output can be determined from the structural equations of hospitals that are efficient." This study reveals that DEA methodologies might be used in conjunction with other tools to provide implications for resource allocation. Mihara's work, while relevant, was primarily driven by raw workload statistics. While workload is an important aspect for resource allocation, it is not the only input or output to be considered. Readiness, prevention, training, and prevention measures are important as well.

Charnes, (1985), conducted arguably the first Data Envelopment Analysis in a military health care facility. These authors evaluated the efficiency of 24 Army military hospitals using criteria that are still relevant for inclusion in this analysis. The authors selected traditional workload criteria for analysis of outputs including personnel trained, relative work product, and clinic visits. These outputs are considered

Traditional elements of production in health care and are relevant for inclusion along with other less traditional factors. For inputs, the study evaluated Full Time Equivalent (FTE) employees by specific category, inpatient expenditures, outpatient expenditures, weighted procedures, occupied bed days, and operating room hours(2). Despite the fact that the research was conducted 20 years previously, most of the variables include detrain relevance for measuring the traditional workload functions, although the paradigm in military health care has shifted towards prevention and health promotion instead of treatment. Most impressively, a training output is specifically included in this study, although prevention, readiness, and other aspects are absent, as they were less relevant measures in the 1980s. Evaluation of performance is especially concerned with evaluating the activities of organizations such as business firms, government agencies, hospitals, educational institutions, etc. Such evaluations take a variety of forms in customary analyses. Examples include cost per unit, profit per unit, satisfaction per unit, and so on, which are measures stated in the form of a ratio like the following, Output/Input.

This is a commonly used measure of efficiency. The usual measure of "productivity" also assumes a ratio form when used to evaluate worker or employee performance. "Output per worker hour" or "Output per worker employed" was examples with sales, profit or other measures of output appearing in the numerator. Such measures are sometimes referred to as "partial productivity measures." This terminology is intended to distinguish them from "total factor productivity measures," because the latter attempt to obtain an output-to-input ratio value which takes account of *all* outputs and *all* inputs. Moving from partial to total factor productivity measures by combining all inputs and all outputs to obtain a single ratio helps to avoid imputing gains to one factor (or one output) that are really attributable to some other input (or output).

For instance, a gain in output resulting from an increase in capital or improved management might be mistakenly attributed to labor (when a single output to input ratio is used) even though the performance of labor *deteriorated* during the period being considered. However, an attempt to move from partial to total factor productivity measures encounters difficulties such as choosing the inputs and outputs to be considered and the weights to be used in order to obtain a single-output to single-input ratio that reduces to a form like expression Output/Input.

Other problems and limitations are also incurred in traditional attempts to evaluate productivity or efficiency when multiple outputs and multiple inputs need to be taken into account. Some of the problems that need to be addressed will be described as we proceed to deal in more detail with Data Envelopment Analysis (DEA). The relatively new approach embodied in DEA does not require the user to prescribe weights to be attached to each input and output, as in the usual index number approaches, and it also does not require prescribing the functional forms that are needed in statistical regression approaches.

DEA utilizes techniques such as mathematical programming which can handle large numbers of variables and relations (constraints) and this relaxes the requirements that are often encountered when one is limited to choosing only a few inputs and outputs because the techniques employed will otherwise encounter difficulties. Relaxing conditions on the number of candidates to be used in calculating the desired evaluation measures makes it easier to deal with complex problems and to deal with other considerations that are likely to be confronted in many managerial and social policy contexts. Moreover, the extensive body of theory and methodology available from mathematical programming can be brought to bear in guiding analyses and interpretations. It can also be brought to bear in effecting computations because much of what is needed has already been developed and adapted for use in many prior applications of DEA.

DEA provides a number of additional opportunities for use. This includes opportunities for collaboration between analysts and decision-makers, which extend from collaboration in choices of the inputs and outputs to be used and includes choosing the types of "what-if" questions to be addressed. Such collaborations extend to "benchmarking" of "what-if" behaviors of competitors and include identifying potential (new) competitors that may emerge for consideration in some of the scenarios that might be generated. Some advantages of DEA are (a) its ability to identify sources and amounts of inefficiency in each input and each output for each entity (hospital, store, furnace, etc.) and *(b)* its ability to identify the benchmark members of the efficient set used to effect these evaluations and identify these sources (and amounts) of inefficiency.

CHAPTER 3

METHODOLOGY

3.0 INTRODUCTION

This chapter deals with fundamental of DEA models, which is the model which was initially proposed by Charnes, Cooper and Rhodes (CCR) in 1978.

DEA is a flexible, mathematical programming approach for the assessment of efficiency, where efficiency in general is defined as a linear combination of the weighted outputs (virtual outputs) divided by a linear combination of the weighted inputs (virtual inputs).

In DEA modeling (CCR model), we assume that there are number (n) DMU, each of them has 'm' inputs and 'r' outputs of common types. All inputs and outputs are assumed to be nonnegative, but at least one input and one output are positive. The following notations were used throughout this study.

Indices:

$i = 1,2, \cdots, n$

$j = 1,2, \cdots, m$

$k = 1,2, \cdots, r$

Notation:

$DMU_i$is thei^{th}DMU,

$DMU_o$is the target DMU,

x_{ji} is the amount of input j consumed by DMU_i,

$x_i = \left(x_{ji}\right)_{mx1}$ is the column vector of inputs consumed by DMU_i,

$x_o = \left(x_{jo}\right)_{mx1}$ is the column vector of inputs consumed by the target DMU,

X = $\left(x_{ji}\right)_{mxn}$ is the matrix of inputs,

y_{ki} isthe amount of output k produced by DMU_i,

$y_i = (y_{ki})_{rx1}$ is the column vector of outputs produced by DMU_i,

$y_o = (x_{ko})_{rx1}$ is the column vector of outputs produced by the target DMU,

Y = $(y_{ki})_{rxn}$ is the matrix of outputs,

u_j is the weight of input j,

U = $\left(u_j\right)_{mx1}$ is the column vector of input weights,

v_k is the weight of output k,

V= $(v_k)_{rx1}$ is the column vector of output weights,

$\lambda = (\lambda_i)_{nx1}$ is the matrix of outputs, $\lambda \in R^n$ is the column vector of a linear combination of n DMU_s, θ is the objective value (efficiency) of the Charnes, Cooper and Rhodes (CCR) model.

3.1 Input-Oriented CCR Model

In the CCR model, the multiple-inputs and multiple-outputs of each DMU are aggregated into a single virtual input and a single virtual output, respectively. The input oriented CCR model for target DMU_O can be expressed by the following fractional programming model:

$$\max \theta = \frac{v_1 y_{1o} + v_2 y_{2o} + \cdots + v_r y_{ro}}{u_1 x_{1o} + u_2 x_{2o} + \cdots + u_m x_{mo}}$$

such that

$$\frac{v_1 y_{1i} + v_2 y_{2i} + \cdots + v_r y_{ri}}{u_1 x_{1i} + u_2 x_{2i} + \cdots + u_m x_{mi}} \leq 1, \qquad i = 1, 2, \cdots, n \qquad (3.1)$$

$u_{1,} u_{2,} \ldots, u_m \geq 0$

$v_{1,} v_{2,} \ldots, u_r \geq 0$

Let θ^* be the optimal objective value (efficiency value),

u^*be the optimal input weights and

v^*be the optimal output weights.

The objective of this model is to determine the input weights and output weights that maximize the ratio of a virtual output to a virtual input for DMU$_o$. The constraints restrict the ratio of the virtual outputs to the virtual inputs for every DMU to be less than or equal to one (1). This implies that the maximal efficiency,θ^*, is at most one (1). In the input-oriented CCR model, a DMU is inefficient if it is possible to reduce any input without increasing any other inputs and achieve the same level of output. Under the assumption that all outputs and inputs have non-zero worth, DMU in the above model will be efficient if $\theta^*$is equal to 1. If θ^*< 1, it is possible to produce the given output ($y_{1o.} y_{2o,\ldots,} y_{ro}$) using a smaller vector of inputs which may be obtained as a linear combination of the input vectors of otherDMU_s. The efficiencies of all $DMU_s$are obtained by solving model (3.1) n times, once for each DMU as the target DMU:

Charnes and Cooper (year) developed a transformation from a linear fractional programming problem to an equivalent linear programming problem. By using His transformation; the fractional CCR model (3.1) can be transformed into the following linear programming model:

Max $\theta = v_1 y_{1o} + v_2 y_{2o} + \ldots + v_r y_{ro}$

$s.t. u_1 x_{1o} + u_2 x_{2o} + \ldots + u_m x_{mo} = 1$

$v_1 y_{1i} + v_2 y_{2i} + \ldots + v_r y_{ri} \leq u_1 x_{1i} + u_2 x_{2i} + \ldots + u_m x_{mi}$, $i = 1,\ldots, n$

$u_1, u_2, \ldots, u_m \geq 0$

$v_1, v_2, \ldots, u_r \geq 0$ (3.2)

The above linear CCR model and its dual can be written in the following vector-matrix form:

(CCR) max $v^T y_o$

$s.t. u^T x_o = 1$

$-u^T X + v^T Y \leq 0$ (3.3)

$u \geq 0$

$v \geq 0$

(DCCR) minθ

$s.t. \theta x_o - X \lambda \geq 0$ (3.4)

$Y \lambda \geq y_o$

$\lambda \geq 0$

Note that the Dual Charnes, Cooper and Rhodes (DCCR) model has a feasible solution, $for\theta = 1$,$\lambda_{1=}0$ for I $\neq 0$, and λ_o = 1.

Therefore, the optimal value $\theta^*$of the DCCR model is not greater than the constraint $Y \lambda \geq y_o$ forces λ to be a nonzero vector. This along with $\theta x_o - X \lambda \geq 0$ implies that $\theta^* > 0$. Therefore, 0 <θ^*≤ 1 thus, the DCCR model has an optimal solution. From the strong duality theorem of linear programming, the CCR model also has an optimal solution and the optimal objective values of the CCR and DCCR models are equal.

3.2 Interpretation of the CCR Model:

The target DMU (DMU_o) is being compared with a linear combination of otherDMU_s. The objective of the CCR model is to find a vector of weights such that the efficiency of DMU, relative to other $DMU_s$is maximized, provided that no other DMU_sor linear combination of other DMUs could achieve the same output levels with smaller amount of any input.

3.3 Interpretation of the DCCR Model:

$DMU_o$is efficient if no linear combination of other DMU_scan produce the same or higher output levels using less of all inputs. θ Indicates a possible proportional reductionin inputs (x_o). Reduction in inputs $x_o$can be viewed as a radial movement from($x_{o\,,} y_o$) toward the production frontier.

θ^*= 1 implies that no linear combination of other DMUs has $X\lambda$<x_o and $Y\lambda$≥ y_o. Otherwise, we can further reduce θ^*while $X\lambda$ ≤ $\theta^* x_o$still holds. Thus, $\theta^*$is not an optimal solution because we can find θ<θ^*that satisfies all the constraints.

On the other hand, θ^*< 1 indicates that the resulting linear combination of DMU_sactsas a benchmark for DMU_O. θ^*can also be interpreted as the largest ratio of $x_o to X\lambda$which outputs are at least equalized, that is, $Y\lambda \geq y_o$.

3.4 Determination of Efficiency

To determine which $DMU_s$are efficient, we introduce the definition of Pareto-Koopmans efficiency as follows:

Definition of Pare to-Koopmans Efficiency: A DMU is fully efficient if and only if it is impossible to improve any input or output without worsening some other inputs or outputs.

From the above definition, the DMU_s with θ^*= 1 may not be are to-Koopmans Efficient if it is possible to make additional improvement (lower input or higher output) without worsening any other input or output. Therefore, we introduce a vector of input excesses (S^-) and output shortfalls (S^+) as follows:

S^-= θx_o - $X\lambda$, and S^+= $Y\lambda$ - y_o

Where S^-≥ 0, S^+≥ 0 are defined as slack vectors for any feasible solution (λ) of the DCCR model (3.4).

Based on the slack vectors, a DMU is Pareto-Koopmans efficient if it satisfies the following two conditions:

(1) θ^{*}= 1

(2) S^{-}= 0 and S^{+}= 0

The first condition is referred to as a weak efficiency, technical efficiency of "Farrell efficiency" after M.J. Farrell (1957).

For the CCR model, the Pareto-Koopmans efficiency is called the CCR efficiency.

We summarize the CCR-efficiency conditions for a DMU as follows.

1. If θ^{*}< 1, then the DMU is CCR-efficiency.

2 If θ^{*}= 1, and there is nonzero slacks, i.e., S^{-*}≠ 0, or S^{+*}≠ 0, then the DMU is CCR-inefficient. From the complementary slackness conditions of linear programming, the elements of the vectors $u^{*} and v^{*}$corresponding to the positive slacks must be zero. Thus, the DMU with θ^{*}= 1 is CCR-inefficient if there is not at least one optimal $u^{*} and v^{*}$such that u^{*}> 0 $and v^{*}$> 0.

3 If θ^{*}= 1 with zero slack, then the DMU is CCR-efficient. From the strong theorem of complementarily, there exist optimal $u^{*} and v^{*}$suchthat u^{*}> 0 $and v^{*}$> 0.

The inefficiency that occurs from the slack variables is called the "mix inefficiency". To determine the efficiency of a DMU, we have to solve the following two-phase linear programming problem:

Phase 1: Solve the DCCR model (3.4). $\theta^*$is equal to the optimal objective value $(u^{*T}y_o)$ of the CCR model (3.3).

Phase 2: Use $\theta^*$from phase 1 to solve the following LP with (λ,s^-, s^+) as variables.

max $= e^T s^- + e^T s^+$

$s.t. s^- = \theta^* x_o - X\lambda$

$s^+ = Y\lambda - y_o$(3.5)

$\lambda \geq 0$

$s^- \geq 0$, $s^+ \geq 0$

Where = $(1, \dots, 1)^T, e^T s^- = \sum_{j=1}^{m} s_j^- \; and e^T S^+ = \sum_{k=1}^{T} s_k^-$, $s_j^-$is the input excess ofthe j^{th}input, and $s_k^-$is the output shortfall of the k^{th}output.

An optimal solution ($\lambda^*, s^{-*}, s^{+*}$) of phase 2 is called the max-slack solution. If themax-slack solution satisfies s^{-*}= 0 and s^{+*} 0, then it is called zero slack.

Phase 2 finds an optimal solution that maximizes the sum of input excesses and output Shortfalls obtainable with $\theta^*$from phase 1. If a DMU has θ^*= 1, s^{-*}= 0 and s^{+*}= 0, it is CCR-efficient.

For an efficient DMU_S, a "reference set", Eo, is defined based on the max-slack solutionas follows:

$Eo = \{i| \lambda_i^* > 0, i = 1, \dots, n\}$.

The linear combination of the reference set is the projected point on the efficient frontier of the inefficient DMU_o. The relationship between the optimal solution of DMU_O and itsreferenceset can be given as:

$$\theta^* x_o = \sum_{i \in Eo} x_i \lambda_i^* + s^{-*}$$

$$y_o = \sum_{i \in Eo} y_i \lambda_i^* - s^{+*}$$

From this relationship, the efficiency of the DMU_S with $(x_{o,} y_o)$ can be improved by reducing the input values x_o radically by the ratio θ^* and then reducing the remaining input excesses by s^{-*}. From the output viewpoint, the efficiency can be improved by increasing the outputs y_o by the output shortfalls, s^{+*}.

The CCR model (3.3) is developed on the assumption of "constant return to scale" of DMU_s. For the long-run analysis, the scale of firm's operations should be considered. The amount of increased outputs associated with increased inputs is fundamental to the long-run nature of the firm's production process. From the economic theory, there are three types of "return to scale":

1. Constant returns to scale (CRS): an increase in the amount of inputs used leads to a proportional increase in the amount of outputs produced.
2. Increasing return to scale (IRS): an increase in the amount of inputs used leads to a larger than proportional increase in the amount of outputs produced.

3. Decreasing returns to scale (DRS): an increase in the amount of inputs used leads to a smaller than proportional increase in the amount of outputs produced.

CHAPTER 4

DATA ANALYSIS AND RESULTS

4.0 INTRODUCTION

This chapter describes the results of the factors which may be associated with efficiency score. It also looks at the linear programming problems formulated out of the data.

In Sunyani Operational Area of Volta River Authority (VRA)/Northern Electricity Distribution Company (NEDCo), have one (1) main station and ten (10) out stations. They all dose the same work (i.e. Power distribution) to both residential and non-residential Customers and revenue collection.

The table 4.0 consists of Stations (DMU's), Staff Population only technical staff including drivers (INPUT u_1), Active Customer Population (INPUT u_2), Number of vehicles (INPUT u_3) and Revenue Collection (OUTPUT v) for the month of September, 2012. This means three (3) inputs and one (1) output. The stations are the Decision Making Units (DMU's), the stations are as follows: SUNYANI (A), MIM/GOASO (B), BEREKUM (C), KENYASI (D), DORMAA AHENKRO (E), DUAYAW NKWANTA (F), TEPA (G), BECHEM (H), DROBO (I), SAMPA (J) AND WAMFIE (K).

TABLE 4.0 INPUT AND OUTPUT DATA FOR THE MONTH OF SEPTEMBER, 2012

DMU's	INPUT U_1 (STAFF POPULATION)	INPUT U_2 (ACTIVE CUSTOMER POPULATION)	INPUT U_3 (NO OF VEHICLES)	OUTPUT V (REVENUE COLLECTION) GH ¢
SUNYANI (A)	50	40920	12	8,789,479.00
MIM/GOASO (B)	7	15344	1	3,779,108.00
BEREKUM (C)	7	16078	1	2,185,966.00
KENYASI (D)	6	9962	1	1,793,739.00
DORMAA AHENKRO (E)	6	10938	1	1,137,352.00
DUAYAW NKWANTA (F)	5	6365	1	659,666.00
TEPA (G)	4	6319	1	606,380.00
BECHEM (H)	6	4891	1	583,911.00
DROBO (I)	6	7339	1	564,419.00
SAMPA (J)	6	7506	1	486,965.00
WAMFIE (K)	3	5250	1	415,064.00

4.1 EFFICIENCY MODELING

In solving linear programming model one needs 3 components, (i) the objective function which is to optimized (minimize or maximized), (ii) the constraints or limitation (subject to), (iii) the non -negativity constraints. With the inputs and output identified in the data, the basic DEA model for a given station can be formulated as follows:

Target DMU (Max θ) $= y_{10}v_1 + y_{20}v_2 + \cdots + y_{ro}v_r$

$s.t.\quad x_{10}u_1 + x_{20}u_2 + \cdots + x_{mo}u_m = 1$

$x_{1i}u_1 + x_{2i}u_2 + \cdots + x_{mi}u_m \,, \geq y_{1i}v_1 + y_{2i}v_2 + \cdots + y_{ri}v_r, \quad i = 1, \ldots, n$

$u_1, u_2, \ldots, u_m \geq 0$

$v_1, v_2, \ldots, v_r \geq 0$

x_i = Amount of input i

u_i= Weight assigned to the input i

y_r = Amount of output r

v_r = Weight assigned to the output r

DMU's for Sunyani (A)

Max (Z): = 8789479v

Subject to:

$50u_1 + 40920u_2 + 12u_3 \geq 8789479v$

$7u_1 + 15344u_2 + u_3 \geq 3779108v$

$7u_1 + 16078u_2 + u_3 \geq 2185966v$

$6u_1 + 9962u_2 + u_3 \geq 1793739v$

$6u_1 + 10938u_2 + u_3 \geq 1137352v$

$5u_1 + 6365u_2 + u_3 \geq 659666v$

$4u_1 + 6319u_2 + u_3 \geq 606380v$

$6u_1 + 4891u_2 + u_3 \geq 583911v$

$6u_1 + 7339u_2 + u_3 \geq 564419v$

$6u_1 + 7506u_2 + u_3 \geq 486965v$

$3u_1 + 5250u_2 + u_3 \geq 415064v$

$50u_1 + 40920u_2 + 12u_3 = 1$

$u_1, u_2, u_3, v \geq 0$

DMU's for Mim/Goaso (B)

Max (Z): = $3779108v$

Subject to:

$50u_1 + 40920u_2 + 12u_3 \geq 8789479v$

$7u_1 + 15344u_2 + u_3 \geq 3779108v$

$7u_1 + 16078u_2 + u_3 \geq 2185966v$

$6u_1 + 9962u_2 + u_3 \geq 1793739v$

$6u_1 + 10938u_2 + u_3 \geq 1137352v$

$5u_1 + 6365u_2 + u_3 \geq 659666v$

$4u_1 + 6319u_2 + u_3 \geq 606380v$

$6u_1 + 4891u_2 + u_3 \geq 583911v$

$6u_1 + 7339u_2 + u_3 \geq 564419v$

$6u_1 + 7506u_2 + u_3 \geq 486965v$

$3u_1 + 5250u_2 + u_3 \geq 415064v$

$7u_1 + 15344u_2 + u_3 = 1$

$u_1, u_2, u_3, v \geq 0$

DMU's for Berekum (C)

Max (Z): = $2185966v$

Subject to:

$50u_1 + 40920u_2 + 12u_3 \geq 8789479v$

$7u_1 + 15344u_2 + u_3 \geq 3779108v$

$7u_1 + 16078u_2 + u_3 \geq 2185966v$

$6u_1 + 9962u_2 + u_3 \geq 1793739v$

$6u_1 + 10938u_2 + u_3 \geq 1137352v$

$5u_1 + 6365u_2 + u_3 \geq 659666v$

$4u_1 + 6319u_2 + u_3 \geq 606380v$

$6u_1 + 4891u_2 + u_3 \geq 583911v$

$6u_1 + 7339u_2 + u_3 \geq 564419v$

$6u_1 + 7506u_2 + u_3 \geq 486965v$

$3u_1 + 5250u_2 + u_3 \geq 415064v$

$7u_1 + 16078u_2 + u_3 = 1$

$u_1, u_2, u_3, v \geq 0$

DMU's for Kenyasi (D)

Max (Z): = $1793739v$

Subject to:

$50u_1 + 40920u_2 + 12u_3 \geq 8789479v$

$7u_1 + 15344u_2 + u_3 \geq 3779108v$

$7u_1 + 16078u_2 + u_3 \geq 2185966v$

$6u_1 + 9962u_2 + u_3 \geq 1793739v$

$6u_1 + 10938u_2 + u_3 \geq 1137352v$

$5u_1 + 6365u_2 + u_3 \geq 659666v$

$4u_1 + 6319u_2 + u_3 \geq 606380v$

$6u_1 + 4891u_2 + u_3 \geq 583911v$

$6u_1 + 7339u_2 + u_3 \geq 564419v$

$6u_1 + 7506u_2 + u_3 \geq 486965v$

$3u_1 + 5250u_2 + u_3 \geq 415064v$

$6u_1 + 9962u_2 + u_3 = 1$

$u_1, u_2, u_3, v \geq 0$

DMU's for Dormaa Ahenkro (E)

Max (Z): = $1137352v$

Subject to:

$50u_1 + 40920u_2 + 12u_3 \geq 8789479v$

$7u_1 + 15344u_2 + u_3 \geq 3779108v$

$7u_1 + 16078u_2 + u_3 \geq 2185966v$

$6u_1 + 9962u_2 + u_3 \geq 1793739v$

$6u_1 + 10938u_2 + u_3 \geq 1137352v$

$5u_1 + 6365u_2 + u_3 \geq 659666v$

$4u_1 + 6319u_2 + u_3 \geq 606380v$

$6u_1 + 4891u_2 + u_3 \geq 583911v$

$6u_1 + 7339u_2 + u_3 \geq 564419v$

$6u_1 + 7506u_2 + u_3 \geq 486965v$

$3u_1 + 5250u_2 + u_3 \geq 415064v$

$6u_1 + 10938u_2 + u_3 = 1$

$u_1, u_2, u_3, v \geq 0$

DMU's for Duayaw Nkwanta (F)

Max (Z): = $659666v$

Subject to:

$50u_1 + 40920u_2 + 12u_3 \geq 8789479v$

$7u_1 + 15344u_2 + u_3 \geq 3779108v$

$7u_1 + 16078u_2 + u_3 \geq 2185966v$

$6u_1 + 9962u_2 + u_3 \geq 1793739v$

$6u_1 + 10938u_2 + u_3 \geq 1137352v$

$5u_1 + 6365u_2 + u_3 \geq 659666v$

$4u_1 + 6319u_2 + u_3 \geq 606380v$

$6u_1 + 4891u_2 + u_3 \geq 583911v$

$6u_1 + 7339u_2 + u_3 \geq 564419v$

$6u_1 + 7506u_2 + u_3 \geq 486965v$

$3u_1 + 5250u_2 + u_3 \geq 415064v$

$5u_1 + 6365u_2 + u_3 = 1$

$u_1, u_2, u, v \geq 0$

DMU's for Tepa (G)

Max (Z): = $606380v$

Subject to:

$50u_1 + 40920u_2 + 12u_3 \geq 8789479v$

$7u_1 + 15344u_2 + u_3 \geq 3779108v$

$7u_1 + 16078u_2 + u_3 \geq 2185966v$

$6u_1 + 9962u_2 + u_3 \geq 1793739v$

$6u_1 + 10938u_2 + u_3 \geq 1137352v$

$5u_1 + 6365u_2 + u_3 \geq 659666v$

$4u_1 + 6319u_2 + u_3 \geq 606380v$

$6u_1 + 4891u_2 + u_3 \geq 583911v$

$6u_1 + 7339u_2 + u_3 \geq 564419v$

$6u_1 + 7506u_2 + u_3 \geq 486965v$

$3u_1 + 5250u_2 + u_3 \geq 415064v$

$4u_1 + 6319u_2 + u_3 = 1$

$u_1, u_2, u_3, v \geq 0$

DMU's for Bechem (H)

Max (Z): = $583911v$

Subject to:

$50u_1 + 40920u_2 + 12u_3 \geq 8789479v$

$7u_1 + 15344u_2 + u_3 \geq 3779108v$

$7u_1 + 16078u_2 + u_3 \geq 2185966v$

$6u_1 + 9962u_2 + u_3 \geq 1793739v$

$6u_1 + 10938u_2 + u_3 \geq 1137352v$

$5u_1 + 6365u_2 + u_3 \geq 659666v$

$4u_1 + 6319u_2 + u_3 \geq 606380v$

$6u_1 + 4891u_2 + u_3 \geq 583911v$

$6u_1 + 7339u_2 + u_3 \geq 564419v$

$6u_1 + 7506u_2 + u_3 \geq 486965v$

$3u_1 + 5250u_2 + u_3 \geq 415064v$

$6u_1 + 4891u_2 + u_3 = 1$

$u_1, u_2, u_3, v \geq 0$

DMU's for Drobo (I)

Max (Z): = $564419v$

Subject to:

$50u_1 + 40920u_2 + 12u_3 \geq 8789479v$

$7u_1 + 15344u_2 + u_3 \geq 3779108v$

$7u_1 + 16078u_2 + u_3 \geq 2185966v$

$6u_1 + 9962u_2 + u_3 \geq 1793739v$

$6u_1 + 10938u_2 + u_3 \geq 1137352v$

$5u_1 + 6365u_2 + u_3 \geq 659666v$

$4u_1 + 6319u_2 + u_3 \geq 606380v$

$6u_1 + 4891u_2 + u_3 \geq 583911v$

$6u_1 + 7339u_2 + u_3 \geq 564419v$

$6u_1 + 7506u_2 + u_3 \geq 486965v$

$3u_1 + 5250u_2 + u_3 \geq 415064v$

$50u_1 + 7339u_2 + u_3 = 1$

$u_1, u_2, u_3, v \geq 0$

DMU's for Sampa (J)

Max (Z): = $486965v$

Subject to:

$50u_1 + 40920u_2 + 12u_3 \geq 8789479v$

$7u_1 + 15344u_2 + u_3 \geq 3779108v$

$7u_1 + 16078u_2 + u_3 \geq 2185966v$

$6u_1 + 9962u_2 + u_3 \geq 1793739v$

$6u_1 + 10938u_2 + u_3 \geq 1137352v$

$5u_1 + 6365u_2 + u_3 \geq 659666v$

$4u_1 + 6319u_2 + u_3 \geq 606380v$

$6u_1 + 4891u_2 + u_3 \geq 583911v$

$6u_1 + 7339u_2 + u_3 \geq 564419v$

$6u_1 + 7506u_2 + u_3 \geq 486965v$

$3u_1 + 5250u_2 + u_3 \geq 415064v$

$6u_1 + 7506u_2 + u_3 = 1$

$u_1, u_2, u_3, v \geq 0$

DMU's for Wamfie (K)

Max (Z): = $415064v$

Subject to:

$50u_1 + 40920u_2 + 12u_3 \geq 8789479v$

$7u_1 + 15344u_2 + u_3 \geq 3779108v$

$7u_1 + 16078u_2 + u_3 \geq 2185966v$

$6u_1 + 9962u_2 + u_3 \geq 1793739v$

$6u_1 + 10938u_2 + u_3 \geq 11373\ 52v$

$5u_1 + 6365u_2 + u_3 \geq 659666v$

$4u_1 + 6319u_2 + u_3 \geq 606380v$

$6u_1 + 4891u_2 + u_3 \geq 583911v$

$6u_1 + 7339u_2 + u_3 \geq 564419v$

$6u_1 + 7506u_2 + u_3 \geq 486965v$

$3u_1 + 5250u_2 + u_3 \geq 415064v$

$3u_1 + 5250u_2 + 12u_3 = 1$

$u_1, u_2, u_3, v \geq 0$

,

Linear Program Solver (Lips) software is used to run the CCR model. Table 1.1 summarizes the descriptive statistics of the result. The maximum efficiency score is 1.00, while the minimum efficiency score is 0.26 and the average efficiency score is 0.53.

TABLE 4.1 DMU's and their Efficiencies

Positions of DMU's	DMU's	Efficiencies
1	MIM/GOASO	1.00
2	SUNYANI	0.87
3	KENYASI	0.73
4	BEREKUM	0.58
5	BECHEM	0.48
6	DORMAA AHENKRO	0.42
7	DUAYAW NKWANTA	0.42
8	TEPA	0.39
9	WAMFIE	0.32
10	DROBO	0.31
11	SAMPA	0.26

Table 4.1 shows the efficiencies of the 11 stations obtained from DEA using CCR model. These efficiency scores were under the following conditions:

1. All data and all weights are positive.
2. Efficiency scores must lie between zero (0.00) and unity (1.00).
3. The same weights for the target stations are applied to all stations.

There is only one station (Mim/Goaso) which is efficient and is considered to have better collection rate performances in the month of September, 2012.

The efficient station has an efficiency score equal to one (1.00). This is on the efficient frontier. The station is more efficient in converting the input s into better collection rate performance as compared to Sampa station of (0.26) which is inefficient.

TABLE 4.2 Description of statistics for DEA results

Items	Scores
Total number of DMU's	11
Number of efficient DMU's	1
Number of inefficient DMU's	10
Maximum efficiency	1.00
Minimum efficiency	0.26
Average efficiency	0.53
Above average efficiency	4
Below average efficiency	7

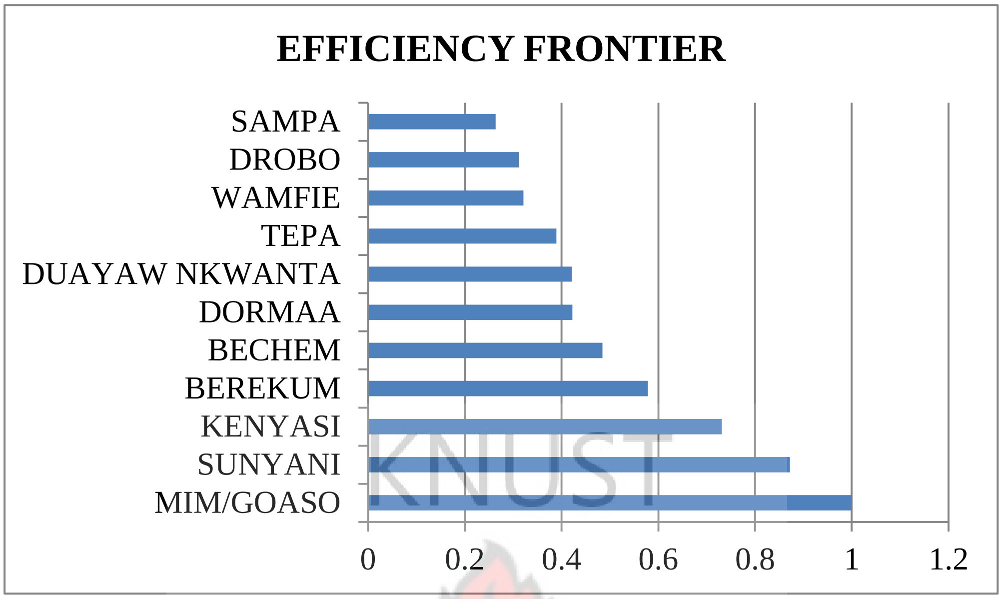

Figure 4.1Efficiency frontier for the positions of the stations

Efficiency Frontier is a set of optimal portfolios that offers the maximum expected return for a defined level of risk or the minimum risk for a given level of expected return. Portfolios that lie on the left hand side of the efficient frontier are sub-optimal, because they do not provide enough returns for the level of risk. Portfolios that cluster to the right hand side of the efficient frontier are also sub-optimal, because they have a higher level of risk for the defined rate of return.

In the above efficiency frontier, it was only Mim/Goaso which obtained maximum efficiency of 1.00. The rest of the stations that lie on the left hand side of the efficient frontier are sub-optimal, since they do not provide enough return for the level of risk. In the case of this efficiency frontier there are no portfolios that are cluster to the right hand side of the efficient frontier therefore there is no higher level of risk for the defined rate of retune.

All the answering reports for the DMU’s can be found in the appendix A to K.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 INTRODUCTION

This chapter summarizes the major findings and conclusions. It also provides recommendations for Volta River Authority (VRA)/Northern Electricity Distribution Company (NEDCo) Management and the staffs as a whole.

5.1 DISCUSSIONS AND CONCLUSIONS

When considering this analysis as a whole, one must also give consideration to the variables selected as inputs and output. When staff population, active customers, vehicles were selected as inputs and revenue collection also selected as an output, these were selected in an attempt to show the most important attributes pertinent to the problem at hand.

This paper had a DEA approach for performance assessment of all the stations. A point of departure for DEA approach compared to existing methods is the input and output framework. Compared to each other, DEA measures the efficiency of revenue collection performance of the stations. Therefore, the DEA approach relates resources expended on stations to revenue collection performance.

The analysis identifies Mim/Goaso station as most efficient among all the stations. It serves as the benchmark for the other stations and can be utilized as a role models to which the inefficient stations may adjust their resources in order to become efficient.

In Ghana, the constitution gives right to only ECG and VRA/NEDCo to distribute safe and reliable electricity power supply to all over the country residential, non-residential and industrial.

In this case revenue collection can be high if there is safe, reliable and un-interrupted power supply.

In electricity supply chain, a break in any part of the chain will affect the whole operation system including revenue. The current situation in the country of load schedule has affected both VRA/NEDCo and ECG.

5.2 RECOMMENDATIONS

1. VRA/NEDCo management should make sure of supplying their customers with safe, reliable and un-interrupted power supply for them to feel happy to pay their light bills promptly to increase their revenue.

2. It is recommended that the management of VRA/NEDCo should introduce more pre-paid meters (PPM) into the system and do away with the post-paid or credit meters. This will do away with disconnection exercise, also to avoid meter wrong

reading from the meter readers to prevent over billing, under billing and passing of bill adjustment.

Again more PPM will prevent flat rate connections for customers when there no meters, which of course be in advantage of the customer mostly or the company.

3. Also management should do will to recruit more personal to reduce staff customer ratio, provide more logistics, good policies towards revenue mobilization and more collaboration between the stake holders.
4. For the employees, they should have positive attitude towards work, effective work planning proper supervision and effective customer education.
5. For the customers they should pay their light bills promptly to enable the company to serve them better. Also stop illegal connections which affect revenue since the company cannot account for the power lose.

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APPENDIX

Introduction

This section compares of all the answering reports as the target DMUs, which gives the maximum optimal solution (efficiency) of each DMUs. Some of the problems pertaining to the DMUs were point out and address them by giving solution or recommendations to them as to achieve efficiency of 1.00. In all one DMU (Mim/Goaso) attains the efficiency of 1.00 to adjudge the best DMU of the month of September, 2012.

APPENDIX AANSWER REPORT ON SUNYANI (A) AS THE TARGET DMU

TABLE A.1 RESULTS VARIABLES

VARIABLE	VALUE	OBJECTIVE COST	REDUCED COST
u_1	0.00	0.00	27.33
u_2	0.00	0.00	0.00
u_3	0.00	0.00	8.14
v	9.9223e-008	8,78948e+006	0.00

TABLE A.2 RESULTS CONSTRAINTS

CONSTRAINT	VALUE	RIGHT HAND SIDE	DUAL PRICE
Sunyani	0.13	0.00	0.00
Mim/Goaso	0.00	0.00	0.00
Berekum	0.18	0.00	0.00
Kenyasi	0.07	0.00	0.00
Dormaa Ahenkro	0.15	0.00	0.00
Duayaw Nkwanta	0.09	0.00	0.00
Tepa	0.09	0.00	0.00
Bechem	0.06	0.00	0.00
Drobo	0.12	0.00	0.00
Sampa	0.14	0.00	0.00
Wamfie	0.09	0.00	0.00
Sunyani	1.00	1.00	0.87

Optimal Solution Found: Maximum = 0.87

From the results constraints table it indicated that, when power is supplied to DMU A station, the station was able to collect 0.87 percentage revenue instead of 1.00. That means 0.13percentage revenue will still be with the customers. From this observation one can imagine the revenue that the station will lose to the customers at a period of 12 months. For DMU A to achieve efficiency of 1.00 as in the case of DMU B, DMU A has to address some of this problems; lack of logistics, poor attitude towards word, poor planning etc. In the case of lack of personal, is no because by comparing DMU A to DMU B interns of staff to customer ratio, DMU A has a staff to 818.40 customers while DMU B has a staff to 2192 customers but they were able to achieved a efficiency of 1.00.

APPENDIX B ANSWER REPORT ON MIM/GOASO (B) AS THE TARGET DMU

TABLE B.1 RESULTS VARIABLES

VARIABLE	VALUE	OBJECTIVE COST	REDUCED COST
u_1	0.00	0.00	0.00
u_2	0.00	0.00	0.00
u_3	0.00	0.00	0.00
v	2.64613e-007	3.77911e+006	0.00

TABLE B.2   RESULTS CONSTRAINTS

CONSTRAINT	VALUE	RIGHT HAND SIDE	DUAL PRICE
Sunyani	0.34	0.00	0.00
Mim/Goaso	0.00	0.00	-1.00
Berekum	0.47	0.00	0.00
Kenyasi	0.17	0.00	0.00
Dormaa	0.41	0.00	0.00
Duayaw Nkwanta	0.24	0.00	0.00
Tepa	0.25	0.00	0.00
Bechem	0.16	0.00	0.00
Drobo	0.33	0.00	0.00
Sampa	0.36	0.00	0.00
Wamfie	0.23	0.00	0.00
Mim/Goaso	1.00	1.00	1.00

Optimal Solution Found: Maximum = 1.0

From table B.2, the optimal solution of 1.00 was achieved. Which means DMU B was the best station among the 11 DMU's in the month of September, 2012.

For the DMU B to maintain it efficiency of 1.00, it should be proved with more logistics, and more personal, since the station were able to use the little logistics, positive attitude towards work and effective planning to achieved their goal.

From the table C.2 it shows that DMU C has efficiency a little over half of that of the B. Comparing DMU C to that of the DMU B, it has to work hard to achieve efficiency of 1.00, because these 2 stations have some of their feature in common, that is number of staffs and almost equal staff to customer ratio. This station has a problem of lack of logistics, too much work at hand, poor attitude towards work and poor planning. For this DMU to be able to achieved efficiency of 1.00, it should be provided with more logistics, more personal, positive attitude towards work, effective planning and effective education for the customer to know the importance to pay light bills.

With reference to DMU B, DMU D is above the average efficiency line. But there is more room for improvement. With the staff customer ratio of 1660.3, the station should have been more up and doing than DMU B. This station need to work extra 0.30 to attained efficiency of 1.00. This DMU needs to be supported with additional logistics, have a good planning and also positive attitude towards work.

The following DMU's have below average (E, F, G, H, I, J AND K).Which means the performance of these DMU's are inefficient and need serious attention.

For these 7 DMU's to be 1.00 efficient, some of the following problems or all of the following have to be address; lack of logistics, too much work at hand, lack of personal, poor attitude towards work and poor planning etc.

In these situation, some of the possible solution to the problems will be, provision of logistics, recruitment of more personal, positive attitude towards work, effective work planning, proper supervision, effective customer education etc.

Some of the suggestions to improved revenue collection rate to 100% are more logistics will boost revenue mobilization, position attitude will greatly improve the collection rate, provision of policies towards revenue mobilization, more pre-paid meters should be employed in to the system, there should be collaboration between stake holders, especially the customer to understand the utility business.

APPENDIX C ANSWER REPORT ON BEREKUM (C) AS THE TARGET DMU

TABLE C.1 RESULTS VARIABLES

VARIABLES	VALUE	OBJECTIVE COST	REDUCED COST
u_1	0.14	0.00	0.00
u_2	0.00	0.00	424.57
u_3	0.00	0.00	0.00
v	2.64613e-007	2.18597e+006	0.00

TABLE C.2 RESULTS CONSTRAINTS

CONSTRAINT	VALUE	RIGHT HAND SIDE	DUAL PRICE
Sunyani	4.82	0.00	0.00
Mim/Goaso	0.00	0.00	-0.58
Berekum	0.42	0.00	0.00
Kenyasi	0.38	0.00	0.00
Dormaa	0.56	0.00	0.00
Duayaw Nkwanta	0.54	0.00	0.00
Tepa	0.41	0.00	0.00
Bechem	0.70	0.00	0.00
Drobo	0.71	0.00	0.00
Sampa	0.73	0.00	0.00
Wamfie	0.32	0.00	0.00
Berekum	1.00	1.00	0.58

Optimal Solution Found: Maximum = 0.58

APPENDIX D ANSWER REPORT ON KENYASI (D) AS THE TARGET DMU

TABLE D.1 RESULTS VARIABLES

VARIABLE	VALUE	OBJECTIVE COST	REDUCED COST
u_1	0.00	0.00	1.06
u_2	0.00	0.00	0.00
u_3	0.00	0.00	0.26
v	4.07571e-007	0.00	0.00

TABLE D.2   RESULYS CONSTRAINTS

CONSTRAINT	VALUE	RIGHT HAND SIDE	DUAL PRICE
Sunyani	0.53	0.00	0.00
Mim/Goaso	0.00	0.00	-0.47
Berekum	0.73	0.00	0.00
Kenyasi	0.27	0.00	0.00
Dormaa	0.63	0.00	0.00
Duayaw Nkwanta	0.37	0.00	0.00
Tepa	0.39	0.00	0.00
Bechem	0.25	0.00	0.00
Drobo	0.51	0.00	0.00
Sampa	0.55	0.00	0.00
Wamfie	0.36	0.00	0.00
Kenyasi	1.00	1.00	0.73

Optimal Solution Found: Maximum = 0.73

APPENDIX EANSWER REPORT ON DORMAA AHENEKRO (E) AS THE TARGET DMU

TABLE E.1   RESULTS VARIABLES

VARIABLE	VALUE	OBJECTIVE COST	REDUCED COST
u_1	0.00	0.00	0.43
u_2	0.00	0.00	0.00
u_3	0.00	0.00	0.12
v	3.71203e-007	1.13735e+006	0.00

TABLE E.2 RESULTS CONSTRAINTS

CONSTRAINT	VALUE	RIGHT HAND SIDE	DUAL PRICE
Sunyani	0.48	0.00	0.00
Mim/Goaso	0.00	0.00	-0.30
Berekum	0.66	0.00	0.00
Kenyasi	0.24	0.00	0.00
Dormaa	0.58	0.00	0.00
Duayaw Nkwanta	0.34	0.00	0.00
Tape	0.35	0.00	0.00
Bechem	0.23	0.00	0.00
Drobo	0.46	0.00	0.00
Sampa	0.51	0.00	0.00
Wamfie	0.33	0.00	0.00
Dormaa	1.00	1.00	0.42

Optimal Solution Found: Maximum = 0.42

APPENDIX F ANSWER REPORT ON DUAYAW NKWATA (F) AS THE TARGET DMU

TABLE F.1 RESULTS VARIABLES

VARIABLE	VALUE	OBJECTIVE COST	REDUCED COST
u_1	0.00	0.00	0.88
u_2	0.00	0.00	0.00
u_3	0.00	0.00	0.25
v	6.3787e-007	659666	0.00

TABLE F.2 RESULTS CONSTRAINTS

CONSTRAINT	VALUE	RIGHT HAND SIDE	DUAL PRICE
Sunyani	0.82	0.00	0.00
Mim/Goaso	0.00	0.00	-0.17
Berekum	1.13	0.00	0.00
Kenyasi	0.42	0.00	0.00
Dormaa	0.99	0.00	0.00
Duayaw Nkwanta	0.58	0.00	0.00
Tepa	0.61	0.00	0.00
Bechem	0.39	0.00	0.00
Drobo	0.79	0.00	0.00
Sampa	0.87	0.00	0.00
Wamfie	0.56	0.00	0.00
Duayaw Nkwanta	1.00	1.00	0.42

Optimal Solution Found: Maximum = 0.42

APPENDIX G ANSWER REPORT ON TEPA (G) AS THE TARGET DMU

TABLE G.1 RESULTS VARIABLES

VARIABLE	VALUE	OBJECTIVE COST	REDUCED COST
u_1	0.00	0.00	0.44
u_2	0.00	0.00	0.00
u_3	0.00	0.00	0.23
v	6.42541e-007	606380	0.00

TABLE G.2 RESULTS CONSTRAINTS

CONSTRAINT	VALUE	RIGHT HAND SIDE	DUAL PRICE
Sunyani	0.83	0.00	0.00
Mim/Goaso	0.00	0.00	-0.16
Berekum	1.14	0.00	0.00
Kenyasi	0.42	0.00	0.00
Dormaa	1.00	0.00	0.00
Duayaw Nkwanta	0.58	0.00	0.00
Tepa	0.61	0.00	0.00
Bechem	0.39	0.00	0.00
Drobo	0.79	0.00	0.00
Sampa	0.87	0.00	0.00
Wamfie	0.56	0.00	0.00
Tepa	1.00	1.00	0.39

Optimal Solution Found: Maximum = 0.39

APPENDIX H   ANSWER REPORT ON BECHEM (H) AS THE TARGET DMU

TABLE H.1   RESULTS VARIABLES

VARIABLE	VALUE	OBJECTIVE COST	REDUCED COST
u_1	0.00	0.00	1.83
u_2	0.00	0.00	0.00
u_3	0.00	0.00	0.00
v	8.30141e-007	583911	0.00

TABLE H.2 RESULTS CONSTRAINTS

CONSTRAINT	VALUE	RIGHT HAND SIDE	DUAL PRICE
Sunyani	1.07	0.00	0.00
Mim/Goaso	0.00	0.00	-0.15
Berekum	1.47	0.00	0.00
Kenyasi	0.55	0.00	0.00
Dormaa	1.29	0.00	0.00
Duayaw Nkwanta	0.75	0.00	0.00
Tepa	0.79	0.00	0.00
Bechem	0.52	0.00	0.00
Drobo	1.03	0.00	0.00
Sampa	1.13	0.00	0.00
Wamfie	0.73	0.00	0.00
Bechem	1.00	1.00	0.48

Optimal Solution Found: Maximum = 0.48

APPENDIX I ANSWER REPORT ON DROBO (I) AS THE TARGET DMU

TABLE I.1 RESULTS VARIABLES

VARIABLE	VALUE	OBJECTIVE COST	REDUCED COST
u_1	0.00	0.00	0.89
u_2	0.00	0.00	0.00
u_3	0.00	0.00	0.16
v	5.53239e-007	564419	0.00

TABLE I.2 RESULTS CONSTRAINTS

CONSTRAINT	VALUE	RIGHT HAND SIDE	DUAL PRICE
Sunyani	0.71	0.00	0.00
Mim/Goaso	0.00	0.00	-0.15
Berekum	0.98	0.00	0.00
Kenyasi	0.37	0.00	0.00
Dormaa	0.86	0.00	0.00
Duayaw Nkwanta	0.50	0.00	0.00
Tepa	0.53	0.00	0.00
Bechem	0.34	0.00	0.00
Drobo	0.69	0.00	0.00
Sampa	0.75	0.00	0.00
Wamfie	0.49	0.00	0.00
Drobo	1.00	1.00	0.31

Optimal Solution Found: Maximum = 0.31

APPENDIX J ANSWER REPORT ON SAMPA (J) AS THE TARGET DMU

TABLE J.1 RESULTS VARIABLES

VARIABLE	VALUE	OBJECTIVE COST	REDUCED COST
u_1	0.00	0.00	0.68
u_2	0.00	0.00	0.00
u_3	0.00	0.00	0.13
v	5.4093e-007	486965	0.00

TABLE J.2 RESULTS CONSTRAINTS

CONSTRAINT	VALUE	RIGHT HAND SIDE	DUAL PRICE
Sunyani	0.69	0.00	0.00
Mim/Goaso	0.00	0.00	-0.13
Berekum	0.96	0.00	0.00
Kenyasi	0.36	0.00	0.00
Dormaa	0.84	0.00	0.00
Duayaw Nkwanta	0.49	0.00	0.00
Tepa	0.51	0.00	0.00
Bechem	0.34	0.00	0.00
Drobo	0.67	0.00	0.00
Sampa	0.74	0.00	0.00
Wamfie	0.47	0.00	0.00
Sampa	1.00	1.00	0.26

Optimal Solution Found: Maximum = 0.26

APPENDIX K ANSWER REPORT ON WAMFIE (K) AS THE TARGET DMU

TABLE K.1 RESULTS VARIABLES

VARIABLE	VALUE	OBJECTIVE COST	REDUCED COST
u_1	0.00	0.00	0.19
u_2	0.00	0.00	0.00
u_3	0.00	0.00	0.21
v	7.7335e-007	415064	0.00

TABLE K.2 RESULTS CONSTRAINTS

CONSTRAINT	VALUE	RIGHT HAND SIDE	DUAL PRICE
Sunyani	0.99	0.00	0.00
Mim/Goaso	0.00	0.00	-0.11
Berekum	1.37	0.00	0.00
Kenyasi	0.51	0.00	0.00
Dormaa	1.20	0.00	0.00
Duayaw Nkwanta	0.70	0.00	0.00
Tepa	0.73	0.00	0.00
Bechem	0.48	0.00	0.00
Drobo	0.96	0.00	0.00
Sampa	1.05	0.00	0.00
Wamfie	0.68	0.00	0.00
Wamfie	1.00	1.00	0.32

Optimal Solution Found: Maximum = 0.32