KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

MEASUREMENT OF RELATIVE EFFICIENCY OF FOUR S.D.A. SENIOR HIGH SCHOOLS IN GHANA USING DATA ENVOLOPEMENT ANALYSIS

By

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DECLARATION

I hereby declare that this submission is my own work towards the MSc 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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DEDICATION

To my dearly loved wife, Mrs Hannah Buasilenu

ABSTRACT

The purpose of this research is to utilize data envelopment analysis (DEA) to measure academic efficiency of four S.D.A Senior High Schools . DEA has been recognized as a 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 four schools. On an efficiency scale of 0-1.0, DEA analysis assesses the relative efficiency of each of the four S.D.A Senior High Schools relative to the rest of the schools in terms of academic performance. For inefficient schools, DEA analysis provides quantitative guidance on how to make them efficient. The 2012/13 academic year data from four S.D.A Senior High schools were used. Four input variables and five output variables were identified. The input variables were teacher to student ratio, trained to non trained teachers ratio, library facilities and contact hours per day. Output variables were estimated as: grades obtained.(8 passes, 7 passes, 6 passes, 5 passes and below) Three schools (Bekwai S.D.A Senior High School, Bantama S.D.A Senior High. School, Kenyase S.D.A Senior High School) formed the efficiency frontier and the fourth school (Tamale S.D.A Senior High School) was found inefficient for the academic year. There was an indication that reduction in contact hours per day as input has a larger effect on efficiency of Tamale S.D.A S.H.S campus than does library facilities and trained to non trained teachers ratio . For Tamale S.H.S to be efficient the Adventist Education unit should implore the Tamale S.D.A Senior High School to utilize effectively their contact hours.

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Contents

LIST OF ABBREVIATIONS

Notation	Meaning
BK	Bekwai S.D A .Senior High School
BT	Bantama S.D.A Senior High School
CCR	Charnes, Cooper and Rhodes
DCCR	Dual Charnes, Cooper and Rhodes
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
KY	Kenyase S.D.A Senior High School
SDA	Seventh Day Adventist
SHS	Senior High School
TL	Tamale S.D.A Senior High School

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CHAPTER 1

INTRODUCTION

This chapter outlines the background of the study. The measurement of the relative efficiency of academic institutions to ensure their continued existence is important. Governments over the years have taken giant strides to ensure accountability of state owned enterprises in order to facilitate the judicious use of resources. The establishment of the public accounts committee of parliament, the Alliance For Accountable governance (AFAG) and other groups can attest to this assertion. This has necessitated the use of management techniques that evaluate the performance of these units so as to avail tools that can improve management and policy decisions in the public and private sector as a whole.

In order to evaluate the activities embedded in some organizations that do not place emphasis on profit making, the traditional use of measuring the effectiveness and efficiency of a product in terms of profitability cannot be employed since the emphasis here is on the efficiency of an institution not a product. Here performance and efficiency measurement considers inputs or resources used by the institution and the outputs that are the result of input utilization. This thesis describes the use of DEA methodology to assess academic efficiency of four Seventh Day Adventist Senior High Schools namely Seventh Day Adventist Senior High School (Tamale), Seventh Day Adventist Senior High School (BANTAMA) Seventh Day Adventist Senior High School (KENYASE), Seventh Day Adventist Senior High School (Bekwai) according to data of the year 2012/2013 West African Senior Secondary School Certificate Examination(WASSCE).

1.1 ADVENTIST EDUCATION GHANA

Adventist education dates back no further than the advent of the Adventist faith in Ghana. In 1953, the premier Adventist educational institution The Bekwai S.D.A college was established. On October 8, 1974, the Adventist Girls' Vocational Institute was opened in Techiman, Brong Ahafo region, as a day school by action of the Ghana Conference and the West African Union Mission, with Mrs. Emelia Kusi as headmistress.

In 1979: The Adventist Missionary College was established at Adenta in Accra. In the late 1980s, it took on the name - Valley View College and now Valley View University. It is the first accredited and chartered private tertiary University in Ghana. The first Director was W. S. Whaley and the current Vice Chancellor is Prof Dr. Dr. Buoh.The church also established some additional institutions including second cycle institutions. Four of which is captured for this study.

1.1.1 BRIEF HISTORY OF S.D.A SENIOR HIGH, TAMALE

The Adventist Senior High School, Tamale was established in the year 2000 with an initial intake of 80 students. The School runs the usual secondary curriculum with programmes in home economics, general arts, business etc.The school is located in Tamale. There have been five headmasters since its establishment, the first being elder Frempah and the current being Mr Issifu Fajin.The school currently has a student population of 700 students and a staff strength of 35 teachers.

1.1.2 BRIEF HISTOY OF BEKWAI S.DA.SENIOR HIGH SCHOOL

S.D.A. Senior High School, as the name depicts is a mission one established by the Seventh - day Adventist Missionaries and Church in 1953 at Bekwai Ashanti. It is the first higher Educational Institution established in the country. It is also the first in the Bekwai and Amansie East District. Hence, the popular names "PIESIE" and "AMANSIE UNIVERSITY" all are referring to this Great school.Almost every facility in the school until 2004 was given by the church. SDASS indeed depended on the church for her survival. SDASS used to co-exist with a Teacher Training College which was also established by the church in 1944 till the year 1974 when this Training College was faced out.

This facing out of the Training College saw the addition and establishment of a sixth form in the same year, later in the year 1990, the school saw the new birth of Senior Secondary School students and the current new Senior High School in the year 2007/2008 Academic year. The school has actually gone through a lot of transformation since its establishment in 1953 to date.The school has seen thirteen (13) heads or administrators since its establishment in 1953 with the current one, the only female head, Madam Mercy Adu-Tiwaah, being the longest serving one for the school, serving from January 2000 academic year to date.

Status

The school, S.D.A. Senior High is both Boarding and Day with the Boarders outnumbering the day-students with a ratio of ten is to two (10:2).

It is also a co-educational school with the boys outnumbering the girls with a ratio of ten is to eight (10:8). Administratively, the school which used to be in the Amansie East District is now in the Bekwai Municipality. Geographically, it is at the Northern part of Bekwai town, about one kilometer (0.6 miles) from the Central Business District of Bekwai town.The school is on a hill-top and this location makes it a “Mountain View” school.There are many beautiful flowers and trees in the school and this plant community in the school gives it a perfect look like a garden and also provides a cool and refreshing atmosphere, congenial to academic studies.

The school has five houses for students’ accommodation. Namely; Amoah, Clifford, Paulsen (for Girls only), all named after Pastors of the church White House, Jubilee the most recent one built by Old Students of the school (BAOSANS) in 2006.

1.1.3 BRIEF HISTORY OF S.D.A SENIOR HIGH SCHOOL, BANTAM

Bantama S.D.A Senior High School the known as Adventist Day Secondary was founded by the S.D.A church in Kumasi in 1983 with 80 students grouped into two classes.It operated as a private mission school until when it was absorbed into the public school system.In 2003 the boys dormitory was put up to meet the need of those boys who wanted to leave in the school. This called for the deletion of the word ‘day’ from the name of the school to reflect its status.The first headmaster of the school was Mr Festus Boadi and the present is Ernest Kofi Gyimah.

1.1.4 BRIEF HISTORY OF S.D.A SENIOR HIGH KENYASE

The school was founded in October 2004 as a private institution to train all round students who can stand test of time. Geographically, it is at the Northern part of

Kumasi town, about one kilometer (0.6 miles) from the Central Business town. of Kumasi .There are many beautiful flowers and trees in the school and this plant community in the school gives it a perfect look like a garden and also provides a cool and refreshing atmosphere, congenial to academic studies.The school has a population of 880 students and 75 teachers.The school runs the normal S.H.S curriculum with courses in Business, General Science and General Arts.

1.2 VARIABLES

The results of DEA model are sensitive to the inputs and outputs factors. Indeed, an accurate selection of the input and output indicators, which are best adapted to the objective of the analysis, is critical to the success of the study. Next; the variables that would be considered to be included in the analysis would be discussed.

1.2.1 Input variables

The inputs variables are units of measurement, which represent the factors used to carry out the delivery of services. The identification and measurement of these factors is crucial in a fair evaluation of the economy and efficiency in the programs and services management. Previous studies on other performance models (Johnes, 1996) have shown that inputs of educational institutions can be categorized in various ways. In our case, we classify the inputs used by. the four Senior high Schools as follows. The input variables used in the study are as follows:

1. Trained to non trained teachers ratio
2. Teacher to student ratio
3. Contact hours per day

4. Library Facilities

1.2.2 Output variables

Output variables measure the yield or the level of activity of programmes and services. A broad range of outputs of educational institution can be found in Segers (1990).The output indicator used in the study is the passes obtained (i.e. 8 passes,7 passes, 6 passes, 5 passes and below.

1.3 PROBLEM STATEMENT

Christian organizations (churches) have established educational institutions to augment government efforts in the provision of quality education to the Ghanaian populace, but the problem is that, the assessment of the performance of these institutions in order to ensure their continued existence has been minored upon. The collapse of some of these institutions is eminent if no work is done to evaluate their efficiency. No work has been done in measuring the efficiency of these four schools.

1.4 OBJECTIVES OF STUDY

The study seeks to address the following objectives

- ⇏ Assess the academic efficiency of students performance in four S. D.A Senior High Schools using DEA.
- ⇏ Provide results to the Adventist Education Department to improve efficiency of these four schools

1.5 JUSTIFICATION

The study when completed will provide information for the Adventist education department in making plans to improve efficiency in the four S.D.A Schools through its inputs and outputs indicators Schools which are less efficient will evaluate and measure their activities to match upwith the most efficient one. The most efficient school becomes a target for the other schools

1.6 SCOPE AND LIMITATIONS

The study considered only inputs and outputs elements that are paramount to the efficiency of the the four schools. The study was restricted to four S.D.A Senior High Schools. The analysis was based on data obtained from Administration of the four schools.

1.7 METHODOLOGY

Secondary data on staff, students, and library facilities were collected from the four schools. The researcher wanted to consider only S.D.A Senior High Schools in the Northern Region but had to select three schools from the Ashanti Region since there is only one S.D.A S.H.S in the Northern Region The data on 2012/2013 academic year was used. The data comprised of number of teachers, students, library facilities, and results of students. DEA was performed on the data obtained. Software used in analyzing and drawing conclusions about the data obtained included Solver (Linear Programming-simplex), and other relevant mathematical formula.

1.8 ORGANIZATION

The study was organized in five chapters. The first chapter deals with the overview of the thesis topic under consideration whiles the second chapter deals with the review of literature relating to the scope of the study. The third chapter outlines a detailed analysis of some of the underlying principles of DEA used in the study whiles the fourth and fifth chapters deal with the analysis and (results, conclusion and recommendation) respectively.

CHAPTER 2

LITERATURE REVIEW

This chapter outlines the works of earlier authors on the assessment of efficiency in a variety of fields using DEA which are relevant to this study. The whole idea of efficiency measurement relies on production theory, which sees a firm as a production system where inputs are the resources that are utilized by the firm or the organization and are transformed into desirable outputs.

Jana (2009) estimated cost efficiency of 99 general hospitals in the Czech Republic during 2001-2008 using Data Envelopment Analysis and Stochastic Frontier Analysis. It tests comparability of their results finding out a certain qualitative similarity. Next, determinants were added into SFA and efficiency of Czech hospitals examined. The presence of inefficiency is group specific even having accounted for various determinants. The effects of determinants were tested. Inefficiency increases with teaching status, more than 20,000 treated patients a year, not-for-profit status, larger share of the elderly in the municipality and average salary in the district. Inefficiency decreases with less than 10,000 patients treated a year, larger population.

Hamaad (2007) measured the technical efficiency of the banks working in Palestine through the period from 2002 to 2005 .Two basic models of the DEA were used under the assumptions of constant returns to scale and the variable returns to scale; the study found that, there were differences among banks in relation to their technical efficiency scores, and the average pure technical efficiency score was 96.3%. The main source of overall technical inefficiency was caused by the scale problem. The study compared the efficiency scores between local and foreign banks and found that local banks had a higher averaged score of technical efficiency than foreign banks, but the difference was statistically insignificant. The study also compared the efficiency scores between the Islamic and commercial banks. Islamic banks had a higher average technical efficiency than commercial banks, although the difference was statistically insignificant. With regards to size, (represented by total assets) it was found that the efficient banks had an average size which was higher than inefficient banks. It was also found that the difference was statistically insignificant. Finally, regarding relationship between technical efficiency score and the returns on assets, the study found that the average returns on assets of efficient banks was higher than the average of inefficient banks, even though, there was no significant statistical relationship between technical efficiency and return on assets.

Nunamaker (2006) used DEA to measure the efficiency of nonprofit making organization .His study examined the potential effects of variable set expansion and data variations upon the efficiency scores generated using the Data Envelopment Analysis (DEA) model. It was found that variable set expansion (either through disaggregation of existing variables or addition of new factors) should produce an upward trend in efficiency scores. In addition, ample opportunity exists for 'decision-making units' to increase their efficiency scores through manipulation of reported data. In real-world applications of DEA, these problems must be resolved as much as possible (e.g. increased audit of data) in order to improve DEA's practical usefulness and reliability.

Bobyking (2010) conducted a study on bank failure predictions in Ukranian banks by measuring efficiency using DEA. . This paper develops several models predicting banking failures based on multi period logit and survival estimation procedures using elements of CAMELS system as determinants of failures. As management quality is the only characteristics which cannot be quantified I concentrated on testing whether efficiency measures can be proxy for management quality and help in predicting failures. The efficiency measures are evaluated using Data Envelopment Analysis and the bias of estimates is corrected using bootstrap procedure. The results show quite good predictive power (about 90%) of both models based on CAMELS system estimated using data for 2006-2009. The banks with low capital and liquidity and bad asset quality tend to fail. Also this paper contributes to aggregation of hyperbolic efficiency measure which is used to calculate group efficiency of foreign banks versus domestic. Thus banks with foreign capital appeared to be more efficient on average and had lower probability to fail.

Chenfu et'al(2003) measured the relative efficiency of the service centers of Nan - Tau electricity distribution centers of a a Taiwn Power Company(TPC). They conducted a DEA study to measure the relative efficiencies of 17 service centers of the NAN-TOU electricity distribution district of Taiwan Power Company (TPC). In addition, this paper also investigated the alternatives for reorganizing the service centers via efficiency measurement. The results showed that the proposed reorganization alternatives have better efficiency scores. Based on DEA evaluations, the authors provided specific directions for the inefficient service centers to improve their operation efficiencies, and thus, maintain the competitive advantage of TPC in facing power market liberalization.

Sanjuan et'al(2011) conducted a study on measuring and improving eco–effeciency using DEA.The concept of eco-efficiency can be defined with the "product value/environmental influence" ratio. Different models have been proposed to measure eco-efficiency. The main difference among them is the weighting system used to aggregate the environmental results. Data envelopment analysis (DEA) permits this aggregation without requiring a subjective judgement about the weights. In this study, we applied a DEA model to Spanish Mahón-Menorca cheese production to determine the most eco-efficient production techniques.

To this end, 16 scenarios of Mahón-Menorca cheese production were built regarding technical (degree of automation) and cleaner production criteria. The environmental impacts were assessed by means of life cycle assessment. We carried out an economic assessment by determining the economic value added and the net income for each scenario. The results are referred to as 1 kilogram (kg) cheese ripened over 105 days. Through DEA, an eco-efficiency ratio between 0 and 1 was obtained. Three scenarios were found to be eco-efficient, with a high degree of automation (enclosed vat and molding and demolding machines) and accelerated cheese ripening. Monte Carlo simulation was used to carry out a sensitivity analysis to compare the influence of price changes on the eco-efficiency ratio. The results emphasize the consistency and stability of the eco-efficient scenario.

Jose (1998) measured the efficiency of selected Austrailian and other international ports using DEA. The study appliesd data envelopment analysis (DEA) to provide an efficiency measurement for four Australian and twelve other international container ports. While DEA has been applied to a wide number of different situations where efficiency comparisons are required, this technique has not previously been applied to ports. The DEA technique is useful in resolving the measurement of port efficiency because the calculations are non-parametric, can handle more than one output and do not require an explicit a priori determination of relationships between output and inputs, as is required for conventional estimation of efficiency using production functions. The ports of Melbourne, Rotterdam, Yokohama and Osaka are found to be the most inefficient ports in the sample, based on constant and variable returns to scale assumptions, mainly due to the enormous slack in their container berths, terminal area and labor inputs. The study also drew some policy implications for ports and recommends certain areas for future research.

Ouellette, and Vierstraete (2005), studied the efficiency of Quebec's school boards during a period of severe cutbacks in their finance is examined 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 Tobit analysis and the boards' corrected efficiencies recalculated. The inefficiencies cost $800 million of which $200 million came from unfavorable socio-economic conditions.

Moore et al., (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 authors 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 (Asiaweek, 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.

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 is to seek out those best practices that will lead to improve 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 Tobit 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 and his associates (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.

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Casu et al., (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 in efficiency for the Italian and Spanish banks was the cost reduction that these institutions managed to achieve.

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

Brockett et al., (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, the authors 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 and his associates (2003), employed the same combined DEA and Ordinary Least Squares (OLS) methodology in evaluating advertising programs for military recruitment. The authors evaluated a "service specific" program for advertising in comparison with a "joint program." Using data from a previously conducted "designed experiment" advertising study, the authors 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 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 et al., (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 policymakers 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 et al., (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 et al. (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 et al., (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 (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 1994-96. 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 provides 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 et al.,(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 discriminant 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 nonparametric technique of data envelopment analysis. Depending upon the assumptions employed, 9.5 percent of local governments were judged to be overall 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 et al., (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 inefficiency 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 et al., (1996), illustrated how DEA may be coupled with traditional Ordinary Least Squares analysis of loglinear 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 favoured 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 sectionof 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 HospitalFavero and Papi (1995), used the non-parametric Data Envelopment Analysis on a cross sectionof 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 et al., (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 baseline 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.

Yongjun Shen et al. (2009) evaluated Road Safety Performance using Data Envelopment Analysis. A data set consisting of 21 indicators for 26 European countries is analyzed, and data envelopment analysis (DEA) as a performance measurement technique is applied to combine these 21 indicators into a composite index. In particular, the concept of hierarchical structure is embodied in the model thereby giving a more detailed insight into the layered hierarchy of the indicators. In addition, the presence of both quantitative and qualitative indicators is taken into account. In the end, a separate, best possible model is constructed for each country, the most optimal road safety index score is computed, and the weights assigned to each layer of the hierarchy are analyzed.

Chin Huan Huan et al. (2008) applied Data Envelopment Analysis to evaluate the Municipal Solid Waste Management Projects in Metro Manila, Taiwan. In this paper the authors in consultations with a Municipal Solid Waste Management (MSW) expert group, this study elucidates how governmental officials can solve the problems surrounding municipal solid waste management in Metropolitan-Manila. A crucial related issue is how the expert group can better evaluate MSW solutions and select favorable ones better evaluate and select a favorable MSW solution using a series of criteria.The study applies cost-benefit analysis (CBA) and data envelopment analysis (DEA) to determine the benefits and cost / input and output technical efficiency of alternative projects, which affords financial data information that evaluators can use for economic decision-making regarding MSW projects. Results of this study suggest that the thermal process technology is less efficient than resource recovery using DEA.

Womer et al. (2006) evaluated Benefit-cost analysis using data envelopment analysis The paper develops an - cost approach analysis derived from for data envelopment analysis (DEA). The models and methodology proposed give decision makers a tool for evaluating alternative policies and projects where there are multiple constituencies who may have conflicting perspectives.

Chun-Yu Lin et al. (2007) used Data Envelopment Analysis for Product Line Selection They define product line selection problem as selecting a subset of potential product variants that can simultaneously minimize product proliferation and maintain market coverage. This paper proposes a method based on Data Envelopment Analysis (DEA) for product line selection. In this study, they construct a five steps method that systematically adopts DEA to solve a product line selection problem. They then apply the proposed method to an existing line of staplers to provide quantitative evidence for managers to generate desirable decisions to maximize the company profits while also fulfilling market demands.

Mishra and Gokulananda (2009) applied Data Envelopment analysis to Suppliers Development Strategies. This study developed an application guideline for the assessment, improvement, and control of quality in Supply Chain Management using Data Envelopment Analysis. Improvement in the quality of all supply chain processes lead to cost reductions as well as service enhancement. The data is collected from 25 suppliers of food and agro based industry for the analysis.

Joost Schalken et al. used Data Envelopment Analysis in measuring IT Infrastructure Project Size: Infrastructure Effort Points. The objective of the research was to design a metric that can be used to measure the size of projects that install and configure commercial-of-the-shelf components COTS stand-alone software, firmware and hardware components.

Xiangyu Wang (2010) used Data Envelopment Analysis to measure the performance of 25 insurance companies. This Project focused on a linear programming model used in performance evaluation of 25 property and casualty insurance companies as of the year of 2007. The goal was to determine the efficiency of each company compared to the peer competitors within property and casualty insurance industry. The technique is called data envelopment analysis (DEA). The emphasis was on data selection and cleanup, mathematical approach behind the data envelopment analysis model, and the application of this model to the efficiency comparison.

Mohammad S. etal. (2009) Utilized data envelopment analysis to benchmark safety performance of construction contractors. The purpose of this paper was to utilize data envelopment analysis (DEA) to benchmark safety performance of construction contractors. DEA has been recognized as a robust tool that is used for evaluating the performance of business organizations. The proposed approach is deployed based on empirical data collected from 45 construction contractors. On a scale of 0–1.0, DEA analysis assesses the relative efficiency of every contractor relative to the rest of the contractors in terms of safety performance. For inefficient contractors, DEA analysis provides quantitative guidance on how to become efficient.

Brenda McCabe et al. (2004) measured Construction Prequalification using data envelopment analysis. Data envelopment analysis (DEA) had been recognized as a useful technique to prequalify contractors by assigning relative efficiency scores. Data envelopment analysis, however, usually requires a large amount of data and has not been fully developed to achieve reliable results. The established practical frontier can be used as a regional performance standard for the owner in prequalification and as improvement guidelines for contractors.

M. Francesca Cracolici et al. (2006) made an assessment of Tourist Competitiveness by analysing destination efficiency. Recently the notion and the measurement of destination competitiveness have received increasing attention in the economics literature on tourism. The reason for this interest emerges from both the increasing economic importance of the tourist sector and the increasing competition on the tourist market as a consequence of the transition from mass tourism to a new age of tourism that calls for a tailor-made approach to the specific attitudes and needs of tourists. The central subject of this paper concerned the efficiency of tourist site destinations. Using a dataset of 103 Italian regions for the year 2001, an economic efficiency analysis based on a production frontier approach was made in the study. The study deploys a measure of tourist site competitiveness in terms of its technical efficiency using parametric and non-parametric methods, a stochastic production function and data envelopment analysis, respectively.

Paul Lau Ngee Kiong et al. (Universiti Teknologi MARA Sarawak) measured school performance using Data Envelopment Analysis. This paper reports the findings of a project that examined the determinants contributing to school efficiency gh Standardised on Quality the Hi Education compiled by the Malaysian School Inspectorate and evaluated the relative efficiencies of all the secondary schools in the Sri Aman/Betong Division for the year 2002. The research reveals that the performances of all the participating schools were average. The frontier analysis shows that 9 schools were efficient and 7 schools were inefficient. There were obvious differences in evaluating performances of schools by DEA and the methodology. However, there was no significant difference in the efficiencies between schools in the urban and rural area of the Sri Aman/Betong Division. Based on slack analysis, the output maximization BCC model shows that all the three principal inputs, student quality, managerial quality and school facilities were of equal importance. For the output variables, school uniqueness topped performance, and change of academic performance and achievement in co-curriculum.

Manuel SALAS-VELASCO (University of Granada, Spain,2006) evaluated the performance private and public schools. Data envelopment analysis (DEA) was used to investigate the technical efficiency of the public-sector funded schools in Spain. Particular attention is paid to the role of uncontrollable factors such as the socioeconomic status of the schools as inputs into the production process. The dataset used came from the OECD Programme for International Student Assessment (PISA). He concluded that publicly funded private schools in Spain, operating with similar amounts of money, are more efficient than public schools.

These private schools are free of bureaucratic constraints that encumber public schools, and are able to control many more decisions at the school level.

Preeti Tyagiet al. (Department of Mathematics, IIT, Roorkee, India) measured the efficiency of schools in India. This paper assessed the technical efficiency and efficiency differences among 348 elementary schools of Uttar Pradesh state in India by a linear programming based technique, Data Envelopment Analysis (DEA). They assessed the schools with eight inputs and three outputs.

Inputs include school resources (teaching, p and home environment of schools' students (parents' edu comprise school wise average marks in environment studies, mathematics, language. In preparing these inputs and outputs, Principal Component Analysis is used.

Moffat and Abbas (2009) measured the efficiency of financial institutions in Botswana. This paper examined technical and pure technical efficiencies of ten major financial institutions in Botswana for each year during the period 2001-2006 using data envelopment analysis. In order to obtain more robust and reliable results, the sensitivity of their efficiency indices were put into test by choosing three alternative approaches in specifying the mix of inputs and outputs. The empirical results indicate that: (a) no matter which approach and year are taken into consideration, Bank of Baroda and First National Bank (which are both foreign banks) and Botswana Savings Bank (which is a publicly owned institution) are consistently among the most efficient institutions and Botswana Development Corporation, African Bank Corporation and National Development Bank are the least efficient ones; (b) the most efficient banks are either small or large institutions in terms of their asset sizes; (c) due to the small sample size, the evidence of a relationship between the age of institutions and their technical efficiencies remains inconclusive. One can conclude that financial institutions can further enhance efficiency by adopting self-service technologies such as telephone and internet banking which can substantially reduce their service delivery costs.

Jingtao Yang (2005) quantified the Technical Efficiency of Canadian Library Systems Using Data Envelopment Analysis. This research focused on evaluating the level of efficiency of individual library systems in Canada with the specific objective of identifying the most efficient service agencies and the sources of their efficiency. By identifying the most efficient systems along with the influencing factors, it is possible that new service policies and management and operational strategies could be developed for improved resource utilization and quality of services. To achieve this objective, this research applied the analysis methodology called Data Envelopment Analysis (DEA) approach which is a mathematical programming based technique for determining the efficiency of individual systems as compared their peers involving multiple performance measures. Annual operating data from Canadian Urban Transit Association (CUTA) for Canadian library systems of year 2001, 2002 and 2003 were used in this analysis. Regression analysis was performed to identify the possible relationship between the efficiency of a library system and some measurable operating, managerial and other factors which could have an impact on the performance of library systems. The regression analysis also allows for the calculation of confidence intervals and bias for the efficiency scores in order to assess their precision.

Ahmed Salem Al-Eraqi etal. (2007) evaluated the Location Efficiency of Arabian and African Seaports Using Data Envelopment Analysis (DEA). In this paper the efficiency and performance is evaluated for 22 seaports in the region of East Africa and the Middle East. The aim of the study is was to compare seaports situated on the maritime trade road between the East and the West. These are considered as middle distance ports at which goods from Europe and Far East/Australia can be exchanged and transhipped to all countries in the Middle East and East Africa. All these seaports are regional coasters, and dhow trade was built on these locations, leading this part of the world to become an important trade centre. Data was collected for 6 years (2000-2005) and a non-parametric linear programming method, DEA (Data Envelopment Analysis) is applied. The ultimate goal of the study is: 1) to estimate the performance levels of the ports under consideration. This will help in proposing solutions for better performance and developing future plans. 2) to select optimum transhipment locations. Goncalves and Ricardo (2006) measured Management efficiency Using Data Envelopment Analysis (DEA) estimation for Banks in Brazil. This paper presented a new paradigm approach for quantifying a bank's managerial efficiency, using a data envelopment analysis (DEA) model that combines multiple inputs and outputs to compute a scalar measure of efficiency and management quality. The analysis of the largest 50 Brazilian banks over a twelve-year period from 1995 to 2006 shows significant differences in management quality scores between institutions. Hence, this new metric provides an important, but previously missing, modelling element for the early identification of troubled banks and can be used as a tool for off-site bank supervision in Brazil.

Susanne Rassouli-Currier (University of Central Oklahoma) assessed the efficiency of Oklahoma public schools. In this paper, the efficiency of the Oklahoma school districts using two different specifications is measured by the Data Envelopment Analysis (DEA) method. To determine the possible sources of inefficiency, a second stage Tobit regression was employed. Here, the specification of the inefficiency models includes(1) environmental variables that school districts have no control over (e.g., the percentage of students in special education and the poverty rate in the district) and (2) non-traditional inputs that school districts do have control over (e.g., teachers' salaries) but were not models were compared and both suggest that the key factors affecting efficiency measures among the Oklahoma school districts are primary environment.

For more than 20 years, libraries have been confronted with performance comparisons. Numerous publications deal with the theoretical development of performance indicators to cover the libraries‘ range of activities (e. (1989), Ceynowa (2001), Crawford et al. (1998), Mundt and Guschker (2003) and Van

House etal., (1990)). Other publications concentrate on the empirical assessment of library performance. Many authors use established performance indicators, such as the number of circulations per student or the number of requests processed per employee, with the main disadvantage being that each performance indicator only covers partial performance. Berghaus-Sprengel (2001) discussed the limits of benchmarking against the background of using multiple performance indicators in empirically assessing performance of university libraries.

Recently, several studies have attempted to derive an aggregate performance indicator based on the analysis of the overall performance of university libraries. From a methodological point of view many authors fell back on DEA: Chen (1997) compared Taiwanese university libraries, Kao and Lin (1999) particularly investigated the effect of library size on library performance, Kao and Liu (2000) addressed the problem of missing data in DEA-based performance assessment. Shim and Kantor (1998) and Shim (2000, 2003) provided an overview of the possibilities of DEA for library benchmarking. They discussed in detail the strengths and weaknesses of DEA in the context of library performance evaluation, thereby covering the fundamental problems of finding suitable input and output indicators.

Reichmann (2004) in his paper analyses the technical efficiency of 118 randomly selected university libraries from German-speaking countries (Austria, Germany, Switzerland) and English-speaking countries (the United States, Australia and Canada) using Data Envelopment Analysis (DEA). DEA efficiency scores were calculated using library staff, measured in fulltime equivalents, and book materials held as inputs, and the number of serial subscriptions, total circulations, regular opening hours per week, and book materials added as outputs. Reichmann and Sommersguter-Reichmann (2006) addressed the problems of differing environments and their effects on library performance. Vitaliano (1998) and Worthington (1999) analyzed the performance of public libraries in New York

(Vitaliano) and New South Wales, Australia (Wor-thington).

Kao and Lin (1999) compared the performance of University libraries of different University sizes. In an attempt to solve these problems, they adopted the concept of the Pareto optimality (Ferguson and Gould 1980; Zeleny 1982) to calculate the expected resources and services (hereafter generalised as services) to be provided by the university libraries of different university sizes from sampled university libraries. In their paper, Akdede and Kazancoglu (2006) investigated the relative efficiency of public (state) libraries of major cities in Turkey by applying a data envelopment analysis. Scale, technical, and overall efficiency scores are calculated. It is found that there is a negative correlation between economic and social development index of the cities and efficiency scores of state libraries of same cities.

CHAPTER 3

METHODOLOGY

This chapter outlines one of the fundamental DEA models, the CCR model which was initially proposed by Charnes , Cooper and Rhodes in 1978. DEA is a flexible, mathematical programming approach for the assessment of efficiency, where efficiency is defined as the maximum of a ratio of weighted outputs to weighted inputs subject to the condition that the similar ratios for every DMU be less than or equal to unity. In DEA modeling (CCR model), we assume that there are number (n) DMUs, each of which 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 employed in this study.

Indices:

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

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

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

Notation:

DMU_i is the i^{th} DMU,

DMU_o is the target DMU,

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

$X_i = (x_{ji})m \times 1$ is the column vector of inputs consumed by DMU_i,

$X_o = (x_{jo})m \times 1$ is the column vector of inputs consumed by the target DMU,

$X = (x_{ji})m \times n$ is the matrix of inputs,

yki is the amount of output k produce by DMU_i,

$yi = (yki)r \times 1$ is the column vector of outputs produced by DMU_i,

$yo = (xko)r \times 1$ is the column vector of outputs produced by the target DMU,

$Y = (yki)r \times n$ is the matrix of outputs,

uj is the weight of input j,

$U = (uj)m \times 1$ is the column vector of input weights,

vk is the weight of output k,

$V = (vk)r \times 1$ is the column vector of output weights,

$\lambda = (i)_{n\times1}$ is the matrix of outputs, £Rn is the column vector of a linear combination of n DMUS,

Θ is the objective value (efficiency) of the Charnes-Cooper-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 DMUO can be expressed by the following fractional programming model:

$$\begin{aligned} Max\theta &= \frac{\sum_{r=1}^{s} V_r Y_{ro}}{\sum_{m=1}^{n} U_m X_{mo}} \\ \text{s.t. } \frac{\sum_{r=1}^{s} V_r Y_{ri}}{\sum_{m=1}^{n} U_m X_{mi}} &\leq 1, \\ i &= 1, \cdots, n \\ u_1, u_2, \cdots u_m &\geq 0 \\ v_1, v_2, \cdots v_r &\geq 0 \end{aligned} \tag{3.1}$$

Let Θ^*, u* nd v* be the optimal objective value (efficiency value), the optimal input weights and the optimal output weights, respectively. The objective of this model is to determine the input weights and output weights that maximizes the ratio of a virtual output for DMUo. The constraints restrict the ratio of the vitual outputs to the virtual inputs for every DMU to be less than or equal to one (1). This implies that the maximum; 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, DMUo in the above model will be efficient if Θ^* is equal to 1. If $\Theta^* < 1$, it is possible to produce the given output $(y_{10}, y_{20}, \cdots, y_{r0})$ using a smaller vector of inputs which may be obtained as a linear combination of the input vectors of other DMUs. The efficiencies of all DMUs are obtained by solving model (3, 1) n times, once for each DMU as the target DMU: Charnes and Cooper 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:

$$\begin{aligned} Max\Theta &= v_1y_{10} + v_2y_{20} + \cdots + v_ry_{ro} \\ s.t\ u_1x_{10} + u_2x_{20} + \cdots + u_mx_{mo} &= 1 \\ v_1y_{1i} + v_2y_{2i} + \cdots + v_ry_{ri} &\leq u_1x_{1i} + u_2x_{2i} + \cdots + u_mx_{mi}, \\ i = 1, \cdots, nu_1, u_2, \cdots, u_m &\geq 0 \\ v_1, v_2, \cdots, u_r &\geq 0 \end{aligned} \tag{3.2}$$

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

$$
\begin{aligned}
(CCR) \max v^T y_o \\
s.t. \; u^T x_o = 1 \\
-u^T X + v^T Y \leq 0 \\
u \leq 0 \\
v \leq 0
\end{aligned}
\tag{3.3}
$$

$$
\begin{aligned}
(DCCR) \min \Theta \\
s.t \; \Theta x_0 - X\lambda \geq 0 \\
Y\lambda \geq 0 \\
\lambda \geq 0
\end{aligned}
\tag{3.4}
$$

Note that the Dual Charnes, Cooper and Rhodes (DCCR) model has a feasible solution, $\Theta = 1, \lambda_i = 0$ for $i \neq o$ and $\lambda_0 = 1$ Therefore, the optimal value Θ^* of the DCCR model is not greater than the constraint $Y\lambda \geq y_o$ forces λ to be a non zero vector. This along with $\Theta x_0 - X\lambda \geq 0$ implies that $\Theta^* > 0$

Therefore, $0 < \Theta^* \leq 1$. Thus, the DCCR model has an optimal solution. From the strong duality theorem of linear programming, the CCR models are equal.

3.2 INTERPRETATION OF THE CCR MODEL

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

3.3 INTERPRETATION OF THE DCCR MODEL

DMUo is efficient if no linear combination of other DMUs can produce the same or higher output levels using less of all inputs. Θ Indicates a possible proportional reduction in inputs (x_o). Reduction in inputs x_o can be viewed as a radial movement from (x_o, y_o) toward the production frontier.

$\Theta* = 1$ implies that no linear combination of other DMUs has $X\lambda < x_o$ and $Y\lambda \geq y_o$. Otherwise, we can further reduce $\Theta*$ while $X\lambda \leq \Theta * x_o$ still holds. Thus, $\Theta*$ is not an optimal solution because we can find $\Theta < \Theta*$ that satisfies all the constraints. On the other hand, $\Theta* < 1$ indicates that the resulting linear combination of DMUs acts as a benchmark for DMUo. $\Theta*$ can also be interpreted as the largest ratio of x_0 to $X\lambda$ which outputs are at least equalized, ie, $Y\lambda \geq y_o$.

3.3.1 Determination of Efficiency

To determine which DMUs are efficient, we introduce the definition of Pareto-Koopmans efficiency as follow:

Definition of Pareto-Koopmans Efficient: 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 DMUo with $\Theta* = 1$ may not be Pareto-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:

$s- = \Theta x_o - X\lambda,$ and $s^+ = Y\lambda - y_o$

where $s^- \geq 0, s^+ \geq 0$ are defined as slack vectors for any feasible solution (Θ,) of the DCCR model 3.4.

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

1. $\Theta * = 1$

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 $\Theta * < 1$, then the DMU is CCR-efficiency.

2. If $\Theta * = 1$, and there is nonzero slacks, i.e., $s^{-*} = 0$, then the DMU is CCR-efficient. 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 $\Theta * = 1$ is CCR-efficient if there is not at least one optimal u* and v* such that $u* > 0$ and $v* > 0$.

3. If $\Theta * = 1$ with zero slack, then the DMU is CCR-efficient. From the strong theorem of complementarity, there exist optimal u* and v* such that $u* > 0$ and $v* > 0$.

The inefficiency that occurs from the slack variable 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.

$$\begin{aligned} \text{Max} e^T s^- + e^T s^+ \\ s.ts^- = \Theta * x_o - x\lambda \\ s^+ = Y\lambda - y_0 \\ \lambda \leq 0 \\ s^- \geq 0, \quad s^+ \geq 0 \end{aligned}$$

Where $= (1, \cdots, 1)^T$, $e^T s^- = \sum_j^m = 1s^- j$ and $e^T s^+ = \sum_k^r = 1s_k^-, s_j^-$ is the input excess of the 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 the max-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 $\Theta* = 1, s-* = 0$ and $s+* = 0$, it is CCR-efficient.

For an efficient DMUo, a "reference set", Eo, is defined based on the max-slack solution as follows:

$$Eo = \{i1\lambda i* > 0, \ I = 1, \cdots, n\}.$$

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

$\Theta * x_0 = \Sigma_{i \pounds EO} x_i \lambda_{i*} + s^{-*}$

$y_0 = \Sigma_{i \pounds EO} y_i \lambda_{i*} + s^{-*}$

From this relationship, the efficiency of the DMUo with (x_o, y_o) can be improved by reducing the input values x_o radially by the ratio $\Theta*$ 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 DMUs. 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":

If output increases by that same proportional change then there are **constant returns to scale (CRS)**. If output increases by less than that proportional change, there are **decreasing returns to scale (DRS)**. If output increases by more than that proportional change, there are **increasing returns to scale (IRS).**

Example 3.3.1

In the DEA methodology, formally developed by Charles, Cooper and Rhodes (1978), efficiency is defined as a ratio of weighted sum of outputs to a weighted sum of inputs, where the weights structure is calculated by means of mathematical programming and constant returns to scale (CRS) are assumed. In 1984, Banker, Charnes and Cooper developed a model with variable returns to scale (VRS). Consider the following data In the DEA methodology, formally developed by Charles, Cooper and Rhodes (1978), efficiency is defined as a ratio of weighted sum of outputs to a weighted sum of inputs, where the weights structure is calculated by means of mathematical programming and constant returns to scale (CRS) are assumed. In 1984, Banker, Charnes and Cooper developed a model with variable returns to scale (VRS). Consider the following data

- Unit 1 produces 100 pieces of items per day, and the inputs are 10 dollars of materials and 2 labour-hours
- Unit 2 produces 80 pieces of items per day, and the inputs are 8 dollars of materials and 4 labour-hours
- Unit 3 produces 120 pieces of items per day, and the inputs are 12 dollars of materials and 1.5 labour-hours

To calculate the efficiency of unit 1, we define the objective function as

- maximize efficiency $= (u_1 * 100)/(v_1 * 10 + v_2 * 2)$
  which is subject to all efficiency of other units (efficiency cannot be larger than 1):
- subject to the efficiency of unit 1: $(u_1 * 100)/(v_1 * 10 + v_2 * 2) \leq 1$
- subject to the efficiency of unit 2: $(u_1 * 80)/(v_1 * 8 + v_2 * 4) \leq 1$
- subject to the efficiency of unit 3: $(u_1 * 120)/(v_1 * 12 + v_2 * 1.5) \leq 1$ and non-negativity:
- all u and $v \geq 0$.

But since linear programming cannot handle fraction, we need to transform the formulation, such that we limit the denominator of the objective function and only allow the linear programming to maximize the numerator. So the new formulation would be:

- maximize Efficiency $= u_1 * 100$

- subject to the efficiency of unit 1: $(u_1 * 100) - (v_1 * 10 + v_2 * 2) \leq 0$
- subject to the efficiency of unit 2: $(u_1 * 80) - (v_1 * 8 + v_2 * 4) \leq 0$
- subject to the efficiency of unit 3: $(u_1 * 120) - (v_1 * 12 + v_2 * 1.5) \leq 0$
- subject to $v_1 * 10 + v_2 * 2 = 1$
- all u and $v \geq 0$.

CHAPTER 4

RESULTS AND ANALYSIS OF DATA

4.1 INTRODUCTION

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

4.2 EFFICIENCY MODELING

With the inputs and outputs identified in the previous sections, the basic DEA model for a given campus system can be formulated as follows:

Target DMU (Max Θ) = $v_1y_{1o} + v_2y_{2o} + \ldots\ldots\ldots\ldots.+ \; v_ry_{ro}$

s.t $\quad u_1x_{10} + u_2x_{20} + \ldots\ldots\ldots\ldots\ldots\ldots.. + = 1,$

$v_1y_{1i} + v_2y_{2i} + \ldots + v_ry_{ri} \leq u_1x_{1i} + u_2i_{20} + \ldots + u_mx_{mi}$, i = 1 $\cdots$ n

$V_1, V_2, V_3, V_4, V_5, U_1, U_2, U_3, U_3, U_4 \geq 0$

y_r = amount of output r

v_r = weigut assigned to output r

x_i = amount of input i

u_i = weight assigned to input i

The linear programming formulated out of the data(refer to APPENDIX A for the data)

MAX : TAMALE $= 99V_1 + 21V_1$

Subject to $0.1042U_1 + 0.0462U_2 + U_3 + 8U_4 = 1$

$99V_1 + 21V_2 - (0.1042U_1 + 0.0462U_2 + U_3 + 8U_4) \leq 0$

$422V_1 + 141V_2 + V_3 + V_4 - (0.050U_1 + 0.0462U_2 + U_3 + 7U_4) \leq 0$

$421V_1 + 177V_2 + 45V_3 + 5V_4 + 4V_5 - (0.0852U_1 + 0.0714U_2 + 2U_3 + 8U_4) \leq 0$

$455V_1 + 74V_2 + V_3 - (0.04U_1 + 0.05U_2 + U_3 + 7U_4) \leq 0$

$V_1, V_2, V_3, V_4, V_5, U_1, U_2, U_3, U_3, U_4 \geq 0$

MAX: BANTAMA $= 422V_1 + 141V_2 + V_3 + V_4$

Subject to $0.0502U_1 + 0.0462U_2 + U_3 + 7U_4 = 1$

$99V_1 + 21V_2 - (0.1042U_1 + 0.0462U_2 + U_3 + 8U_4) \leq 0$

$422V_1 + 141V_2 + V_3 + V_4 - (0.050U_1 + 0.0462U_2 + U_3 + 7U_4) \leq 0$

$421V_1 + 177V_2 + 45V_3 + 5V_4 + 4V_5 - (0.0852U_1 + 0.0714U_2 + 2U_3 + 8U_4) \leq 0$

$455V_1 + 74V_2 + V_3(0.04U_1 + 0.05U_2 + U_3 + 7U_4) \leq 0$

$V1, V2, V3, V4, V5, U1, U2, U3, U3, U4 \geq 0$

MAX KVNYASE = $421V_1 + 177V_2 + 45E_3 + 5V_4 + 4V_5$

Subject to: $0.0852U_1 + 0.0714U_2 + 2U_3 + 8U_4 = 1$

$99V_1 + 21V_2 - (0.1042U_1 + 0.0462U_2 + U_3 + 8U_4) \leq 0$

$422V_1 + 141V_2 + V_3 + V_4 - (0.050U_1 + 0.0462U_2 + U_3 + 7U_4) \leq 0$

$421V_1 + 177V_2 + 45V_3 + 5V_4 + 4V_5 - (0.0852U_1 + 0.0714U_2 + 2U_3 + 8U_4) \leq 0$

$455V_1 + 74V_2 + V_3(0.04U_1 + 0.05U_2 + U_3 + 7U_4) \leq 0$

$V1, V2, V3, V4, V5, U1, U2, U3, U3, U4 \geq 0$

MAX BEKWAI = $455V_1 + 74V_2 + V_3$

Subject to: $0.04U_1 + 0.05U_2 + U_3 + 7U_4 = 1$

$21V_2 - (0.1042U_1 + 0.0462U_2 + U_3 + 8U_4) \leq 0$

$422V_1 + 141V_2 + V_3 + U_4 - (0.050U_1 + 0.0462V_2 + U_3 + 7U_4) \leq 0$

$421V_1 + 177V_2 + 45V_3 + 5V_4 + 4V_5 - (0.0852U_1 + 0.0714U_2 + 2U_3 + 8U_4) \leq 0$

$455V_1 + 74V_2 + V_3(0.04U_1 + 0.05U_2 + U_3 + 7U_4) \leq 0$

$V_1, V_2, V_3, V_4, V_5, U_1, U_2, U_3, U_4 \geq 0$

DEA solver software is used to run the CCR model. Table 4.1 summarizes the descriptive statistics tf the results. The maximum efficiency score is 1.00, while the minimum efficiency score is 0.22. The efficiency score average is 0.76. The means that the input for an average unit could be reduced by 24%.

Table 4.2 shows the scores of the four schools obtained from DEA using CCR

Table 4.1: Descriptive statistics for DEA results

Items	**Scores**
Total number of DMU_S	4.00
Number of efficient DMU_S	3.00
Number of inefficient DMU_S	1.00
Maximum efficiency	1.00
Minimum efficiency	0.22
Average efficiency	0.76

Source: Author's construct, January 2014

Table 4.2: Efficiency scores of the schools

Schools	Efficiency
Tamale	0.22
Bantama	1.00
Kenyase	1.00
Bekwai	1.00

Source: Author's construct, January 2014

model.

These efficiency scores were under the following conditions:

1. All data and all weights are positive

2. Efficiency scores must lie between zero and unity

3. The same weights for the target school are applied to all schools

From figure 4.1 it can be seen that Bekwai S.D.A Senior High School(BK), Bantama S.D.A Senior High School(BT) and Kenyase S.D.A Senior High School(KY) are on the efficiency frontier whiles Tamale S.D.A Senior High

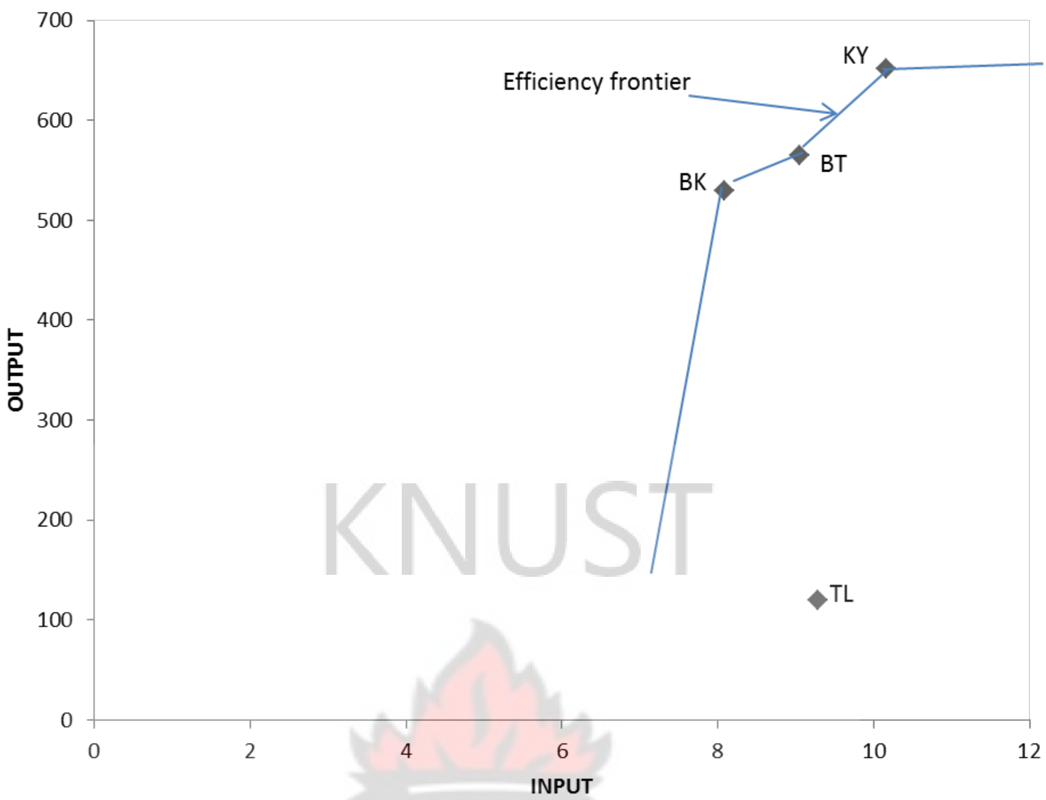

Figure 4.1: Efficiency Frontier For The Schools

School(TL) is not on the efficiency frontier which confirms its inefficiency.

The following schools (Bekwai , Bantama, Kenyase) are efficient and are considered to have better academic performance. The efficient schools have an efficiency score equal to one (1.00). They're on the efficient frontier. These schools are more efficient in converting the inputs into better academic performance of students as compared to Tamale S.D.A S.H.S (0.22), which is inefficient.

4.3 ANSWER REPORT ON BEKWAI AS A TARGET DMU

From tables 4.3 and 4.4, we can see that the optimal solution to the LP has the value of 1 and the best input and output weights are $U_1 = 0$ $U_2 = 0.0119,$ $U_3 =$

Table 4.3: TARGET CELL(MAX)

Cell	Name	Original Value	Final Value
$K9$	BEKWAI weighted output	530	1

Table 4.4: Adjustable cells

Cell	Name	Original Value	Final Value
$B11$	weight (V1)8 PASSES	1.0000	0.0022
$C11$	weight (V2)7 PASSES	1.0000	0.0000
$D11$	weight (V3)6 PASSES	1.0000	0.0000
$E11$	weight (V4)5 PASSES	1.0000	0.0000
$F11$	weight (V5)4 PASSES AND BELOW	1.0000	0.0000
$G11$	weight (U1)Teacher to student ratio	1.0000	0.0000
$H11$	weight (U2)TRAINED TO NON- T RATIO	1.0000	0.0019
$I11$	weight (U3)LIBRARY FACILITIES	1.0000	0.0000
$J11$	weight (U4)CONTACT HOURS PER DAY	1.0000	0.1429

Source: Author's construct, January 2014

0 , $U_4 = 0.1429$

$$V_1 = 0.0022,\ V_2 = 0,\ V_3 = 0,\ V_4 = 0,\ V_5 = 0$$

We now observe the difference between optimal weights $U_2 = 0.0119$, and $U_4 = 0.1429$. The ratio $U_4/U_2 = 12$ suggests that it is advantageous for, Tamale to weight input(contact hours per day 12 times more than input(trained to non trained teachers ratio) in order to maximize efficiency.This means that a reduction in contact hours per day has a bigger effect on efficiency than trained to non trained teachers ratio.

Table 4.5: Constraints of the Model

Cell	Name	Cell Value	Formula	Status	Slack
$N6$	TAMALE working	-0.9253	$N6$<=0	Not Binding	0.92527
$N7$	BANTAMA working	-0.0725	$N7$<=0	Not Binding	0.07253
$N8$	KENYASE working	-0.2176	$N8$<=0	Not Binding	0.21758
$N9$	BEKWAI working	0	$N9$<=0	Binding	0
$L9$	BEKWAI weighted input	1	$L9$=1	Not Binding	0

Source: Author's construct, January 2014

Table 4.5, also indicates that the three working constraints (Tamale, Kenyase, Bantama) with non zero slack values are said to be non binding they are not satisfied with equality at the LP optimal.

4.4 SENSITIVITY ANALYSIS

From table 4.6

$$U_1 = 0 \; U_2 = 0.0119, \; U_3 = 0, \; U_4 = 0.1429$$

$$V_1 = 0.0022, \; V_2 = 0, \; V_3 = 0, \; V_4 = 0, \; V_5 = 0.$$

Suppose we vary the coefficient of V_1 in the objective function. The solution value for for V_1 is 0.0022 and the objective function value is 455. The allowable increase or decrease suggests that provided the coefficient of V_1 in the objective function lies between 455+ 0 =455 and 455- 0 =455, the values of the variables in the optimal LP will remain unchanged. Similar conclusions can be drawn for other weights.

From table 4.7 we can study the effect of changing the right hand side of the Bekwai constraint. If the right hand side of the bekwai constraint lies between 0 + 0.078199053 = 0.078199053 and 0 – 1= -1, the objective function change will

Table 4.6: Adjustable cells

		Final	Reduced	Objective	Allowable	Allowable
Cell	Name	Value	Cost	Coefficient	Increase	Decrease
$B11$	weight (V1)8 PASSES	0.0022	0	455	0	0
$C11$	weight (V2)7 PASSES	0	0	74	0	1E+30
$D11$	weight (V3)6 PASSES	0	0	1	0	1E+30
$E11$	weight (V4)5 PASSES	0	0	0	0	1E+30
$F11$	weight (V5)4 PASSES AND BELOW	0	0	0	0	1E+30
$G11$	weight (U1)Teacher to student ratio	0.0119	0	0	0	1E+30
$H11$	weight (U2)TRAINED TO NON- T RATIO	0	0	0	0	1E+30
$I11$	weight (U3)LIBRARY FACILITIES	0	0	0	0	1E+30
$J11$	weight (U4)CONTACT HOURS PER DAY	0.1429	0	0	0	0

Source: Author's construct, January 2014

be exactly 0.

Table 4.7: Constraints of the Model

		Final	Shadow	Constraint	Allowable	Allowable
Cell	**Name**	**Value**	**Price**	**R.H. Side**	**Increase**	**Decrease**
$N6$	TAMALE working	-0.9253	0	0	1E+30	0.92527
$N7$	BANTAMA working	-0.0725	0	0	1E+30	0.07253
$N8$	KENYASE working	-0.2176	0	0	1E+30	0.21758
$N9$	BEKWAI working	0	1	0	0.0782	1
$L9$	BEKWAI weighted input	1	1	1	1E+30	1

Source: Author's construct, January 2014

4.5 ANSWER REPORT ON BANTAMA AS A TARGET DMU

Table 4.8: Target cell (Max)

Cell	Name	Original Value	Final Value
$K7$	BANTAMA weighted output	565	1

Source: Author's construct, January 2014

From tables 4.8 and 4.9, we can see that the optimal solution to the LP has the value of 1 and the best input and output weights are

$$U_1 = 0 \; U_2 = 0, \; U_3 = 0.008, \; U_4 = 0.1429$$

Table 4.9: Adjustable cells

Cell	Name	Original Value	Final Value	
$B11$	weight (V1)8 PASSES	1	0.002	
$C11$	weight (V2)7 PASSES	1	0.001	
$D11$	weight (V3)6 PASSES	1	0	
$E11$	weight (V4)5 PASSES	1	0	
$F11$	weight (V5)4 PASSES AND BELOW	1	0	
$G11$	weight (U1)Teacher to student ratio	1	0	
$H11$	weight (U2)TRAINED TO NON- T RATIO	1	0	
$I11$	weight (U3)LIBRARY FACILITIES	1	0.008	
$J11$	weight (U4)CONTACT HOURS PER DAY	1	0.1429	

Source: Author's construct, January 2014

$$V_1 = 0.0022, V_2 = 0.001, V_3 = 0, V_4 = 0, V_5 = 0$$

We now observe the difference between optimal weights $U_3 = 0.008$, and $U_4 = 0.1429$. The ratio $U_4/U_3 = 18$ suggests that it is advantageous for, Tamale to weight input(contact hours per day 18 times more than input(library facilities) in order to maximize efficiency. This means that a reduction in contact hours per day has a bigger effect on efficiency than library facility.

Table 4.10 , also indicates that the three working constraints (Tamale, Kenyase,) with non zero slack values are said to be non binding they are not satisfied with equality at the LP optimal.

Table 4.10: Constraints of the Model

Cell	Name	Cell Value	Formula	Status	Slack
$N6$	TAMALE working	-0.9204	$N6$<=0	Not Binding	0.92036
$N7$	BANTAMA working	0	$N7$<=0	Binding	0
$N8$	KENYASE working	-0.1088	$N8$<=0	Not Binding	0.10881
$N9$	BEKWAI working	0	$N9$<=0	Binding	0
$L7$	BANTAMA weighted input	1	$L7$=1	Not Binding	0

Source: Author's construct, January 2014

4.6 SENSITIVITY REPORT

From table 4.10

$$U_1 = 0 \; U_2 = 0.0119, \; U_3 = 0, \; U_4 = 0.1429$$

$$V_1 = 0.0022, \; V_2 = 0, \; V_3 = 0, \; V_4 = 0, \; V_5 = 0.$$

Suppose we vary the coefficient of V_1 in the objective function. The solution value for for V_1 is 0.0022 and the objective function value is 422. The allowable increase or decrease suggests that provided the coefficient of V_1 in the objective function lies between 422+ 0 =422 and 422- 0 =422, the values of the variables in the optimal LP will remain unchanged. Similar conclusions can be drawn for other weights.

From table 4.12 we can study the effect of changing the right hand side of the

Table 4.11: Adjustable cells

		Final	**Reduced**	**Objective**	**Allowable**	**Allowable**
Cell	**Name**	**Value**	**Cost**	**Coefficient**	**Increase**	**Decrease**
$B11$	weight (V1)8 PASSES	0.002	0	422	0	0
$C11$	weight (V2)7 PASSES	0.001	0	141	0	0
$D11$	weight (V3)6 PASSES	0	0	1	0	1E+30
$E11$	weight (V4)5 PASSES	0	0	1	0	1E+30
$F11$	weight (V5)4 PASSES AND BELOW	0	0	0	0	1E+30
$G11$	weight (U1)Teacher to student ratio	0	0	0	0	1E+30
$H11$	weight (U2)TRAINED TO NON- T RATIO	0	0	0	0	1E+30
$I11$	weight (U3)LIBRARY FACILITIES	0	0	0	0	1E+30
$J11$	weight (U4)CONTACT HOURS PER DAY	0.1429	0	0	1E+30	0

Source: Author's construct, January 2014

Bantama constraint.If the right hand side of the Bantama constraint lies between 0 + 0.072555378 = 0.072555378 and 0 – 0.072527473 = -072527473., the objective function change will be exactly 0.

Table 4.12: Constraints of the Model

		Final	Shadow	Constraint	Allowable	Allowable
Cell	**Name**	**Value**	**Price**	**R.H. Side**	**Increase**	**Decrease**
$N6$	TAMALE working	-0.9204	0	0	1E+30	0.92036
$N7$	BANTAMA working	0	1	0	0.07256	0.07253
$N8$	KENYASE working	-0.1088	0	0	1E+30	0.10881
$N9$	BEKWAI working	0	0	0	0.0782	0.23367
$L7$	BANTAMA weighted input	1	1	1	1E+30	1

Source: Author's construct, January 2014

4.7 ANSWER REPORT ON KENYASE AS A TARGET DMU

Table 4.13: Target Cell(Max)

Cell	Name	Original Value	Final Value
$K8$	KENYASE weighted output	652	1

Source: Author's construct, January 2014

From tables 4.13 and 4.14, we can see that the optimal solution to the LP has the value of 1 and the best input and output weights are

$$U_1 = 0.006\ U_2 = 0,\ U_3 = 0.000,\ U_4 = 0.1250$$

$$V_1 = 0.0018,\ V_2 = 0.009,\ V_3 = 0.022,\ V_4 = 0,\ V_5 = 0$$

Table 4.14: Adjustable Cells

Cell	Name	Original Value	Final Value
$B11$	weight (V1)8 PASSES	1	0.0018
$C11$	weight (V2)7 PASSES	1	0.0009
$D11$	weight (V3)6 PASSES	1	0.0022
$E11$	weight (V4)5 PASSES	1	0
$F11$	weight (V5)4 PASSES AND BELOW	1	0
$G11$	weight (U1)Teacher to student ratio	1	0.006
$H11$	weight (U2)TRAINED TO NON- T RATIO	1	0
$I11$	weight (U3)LIBRARY FACILITIES	1	0
J**11**	**weight (U4)CONTACT HOURS PER DAY**	**1**	**0.125**

Source: Author's construct, January 2014

We now observe the difference between optimal weights $U_1 = 0.006$, and $U_4 = 0.1250$. The ratio $U_4/U_1 = 21$ suggests that it is advantageous for, Tamale to weight input(contact hours per day 21 times more than input(teacher to student ratio) in order to maximize efficiency. This means that a reduction in contact hours per day has a bigger effect on efficiency than teacher to student ratio

Table 4.15, also indicates that the three working constraint (Tamale,) with non zero slack values are said to be non binding. They are not satisfied with equality at the LP optimal.

Table 4.15: Constraints of the model

Cell	Name	Cell Value	Formula	Status	Slack
$L8$	KENYASE weighted input	1	$L8$=1	Not Binding	0
$N6$	TAMALE working	-0.8058	$N6$<=0	Not Binding	0.8058
$N7$	BANTAMA working	0	$N7$<=0	Binding	0
$N8$	KENYASE working	0	$N8$<=0	Binding	0
$N9$	BEKWAI working	0	$N9$<=0	Binding	0

Source: Author's construct, January 2014

4.8 SENSITIVITY ANALYSIS

From table 4.16

$$U_1 = 0\ U_2 = 0.00,\ U_3 = 0,\ U_4 = 0.1250$$

$$V_1 = 0.0018,\ V_2 = 0.009\ V_3 = 0.0022,\ V_4 = 0,\ V_5 = 0.$$

Suppose we vary the coefficient of V_2 in the objective function. The solution value for for V_2 is 0.009 and the objective function value is 177.The allowable increase or decrease suggests that provided the coefficient of V_2 in the objective function lies between 177+ 0 =177 and 177- 0 =177, the values of the variables in the optimal LP will remain unchanged. Similar conclusions can be drawn for other weights.

From table 4.17 we can study the effect of changing the right hand side of the Kenyase constraint.If the right hand side of the constraint Kenyase constraint lies between 0 + 38.374996 = 38.374996 and 0 – 0.095210617 = -0.0952106., the objective function change will be exactly 0.

Table 4.16:

		Final	Reduced	Objective	Allowable	Allowable
Cell	**Name**	**Value**	**Cost**	**Coefficient**	**Increase**	**Decrease**
$B11$	weight (V1)8 PASSES	0.0018	0	421	0	0
$C11$	weight (V2)7 PASSES	0.0009	0	177	0	0
$D11$	weight (V3)6 PASSES	0.0022	0	45	0	0
$E11$	weight (V4)5 PASSES	0	0	5	0	1E+30
$F11$	weight (V5)4 PASSES AND BELOW	0	0	4	0	1E+30
$G11$	weight (U1)Teacher to student ratio	0	0	0	0	1E+30
$H11$	weight (U2)TRAINED TO NON- T RATIO	0	0	0	0	1E+30
$I11$	weight (U3)LIBRARY FACILITIES	0	0	0	0	1E+30
$J11$	weight (U4)CONTACT HOURS PER DAY	0.125	0	0	1E+30	0

Source: Author's construct, January 2014

Table 4.17: Constraints of the Model

		Final	**Shadow**	**Constraint**	**Allowable**	**Allowable**
Cell	**Name**	**Value**	**Price**	**R.H. Side**	**Increase**	**Decrease**
*L*8	KENYASE weighted input	1	1	1	1E+30	1
*N*6	TAMALE working	-0.8058	0	0	1E+30	0.8058
*N*7	BANTAMA working	0	0	0	0.06349	0.06315
*N*8	KENYASE working	0	1	0	38.375	0.09521
*N*9	BEKWAI working	0	0	0	0.0682	0.20446

Source: Author's construct, January 2014

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This chapter summarizes the major findings and conclusions. It also provides recommendations for Adventist Education Unit.

5.1 CONCLUSION

When considering this analysis as a whole, one must also give consideration to the variables selected as outputs and inputs. When grades obtained were selected as outputs and teacher to student ratio, trained to non trained teachers teachers ratio, library facilities and contact hours per day. were selected as inputs, they were selected in an attempt to show the most important attributes pertinent to the problem at hand. This paper contributes a DEA approach for academic performance of students. A point of departure for the DEA approach compared to existing methods is the input–output framework. Compared to each other, DEA measures the efficiency of academic performance of students in utilizing, teacher to student ratio, contact hours per day and staff to maximize the grades obtained by students. Therefore, the DEA approach relates resources expended on students to academic performance. The analysis identifies Bekwai, Kenyase and Bantama S.D.A S.H.S'S as efficient. They serve as the "benchmark" for the schools and can be utilized as role models to which inefficient School (Tamale S.D.A .,H.S) may adjust its resources in order to become efficient. There was an indication that when Bekawi S.D.A was set as target DMU for Tamale campus, the reduction in input that is contact hours per day has a larger effect on efficiency of Tamale

S.H.S than does trained to non trained teachers ratio (refer to Table 4.4). In otherwords, contact hours per day should be utilized effectively by management of Tamale S.D.A Senior High School.

Also there was an indication that when Bantama S.D.A was set as target DMU for Tamale campus, the reduction in input that is contact hours per day has a larger effect on efficiency of Tamale S.D.A S.H.S than library facilities(table 4.9)(. In otherwords, this confirms once more that contact hours for Tamale S.D.A should be effectively utilized by management.

There was also indication that Tamale constraint was not binding because it was not satisfied with equality at the LP optimal. This is true for both Bantama and Bekwai as target DMU'S.

Again, when Kenyase S.H.S was set as a target DMU for Tamale S.D.A Senior High School, it indicated that in order to achieve Tamale S.H.S as efficient, it is better not to decrease contact hours per day. In other words, management should effectively utilize contact hours per day on students in order to be at the frontier.

5.2 RECOMMENDATIONS

1. Adventist Education unit should implore the management of Tamale S.D.A Senior High School to utilize effectively contact hours per day . This challenge may be tackled by recruiting more permanent teachers instead of relying heavily on part time tutors who often waste teaching hours to commute from their main schools to the school.There should be regular roll calls for student regularity. Teachers should also be punctual and regular at school.This will enable the school match up with those that are efficient.

2. We recommend the findings of the Adventist Education Unit and students who conduct diverse studies on the efficiency of academic performance to

use DEA-CCR model to measure.

3. Further studies should involve comparative analysis of models for additional academic years.

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