Computing Malmquist Index Using Data Envelopment Analysis as an Improvement Measure for Educational Purposes

Adamu Musa Binyuy

Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the Degree of

Master of Science
in
Industrial Engineering

Eastern Mediterranean University
January 2015
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Prof. Dr Serhan Çiftçioğlu
Acting Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Industrial Engineering.

Asst. Prof. Dr. Gokhan Izbirak
Chair, Department of Industrial Engineering

We certify that we have read this thesis and that in our opinion, it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Industrial Engineering.

Asst. Prof. Dr. Sahand Daneshvar
Supervisor

Examining Committee

1. Prof. Dr. Bela Vizvari
2. Asst. Prof. Dr. Sahand Daneshvar
3. Asst. Prof. Dr. Gokhan Izbirak

ABSTRACT

With the introduction of “Malmquist indices”, MI, (Caves et al, 1982), it has rapidly grown into a standard approach for evaluating productivity over recent years. Meanwhile, Based on the concept of cost efficiency that was first mentioned by Farrell, (1957), the DEA has become a brawny quantitative and analytical tool for measuring and evaluating performance of public and private sectors. With the growth of civilization and vast increase in higher educational institutes around the world, the performance and efficiency of students became very important as far as their evaluation is concerned. Defining educational technology as all necessary resources needed by an institution for accurate student’s performance, we will compute MI using DEA considering some ABET’s accreditation criteria for student outcomes as an improvement measure for educational purposes. As the DEA measure the efficiencies of the student’s performance using a defined set of inputs and outputs, “Malmquist index” conflate the efficiencies with other factors such as surveys to compute an index (productivity) for a course or program which can be compared to unity. Based on this, an educational Malmquist index is defined called Malmquist Educational Index, MEI to evaluate Student Outcomes, performance and monitor continuous improvement of Educational programs. We used a case study example, with real data provided by the chair of the industrial engineering department to compute MEI for each course. Regarding the value MEI, it could be concluded that MEI < 1 indicates regress and need improvement, MEI> 1 indicates progress and MEI$= 1$ indicates no change for DMU under evaluation.

Keywords: Malmquist Index, DEA, Student Outcomes, and Student performance

ÖZ

"Malmquist Index" , MI (Caves et al, 1982) başlamasıyla, son yıllarda hızla üzerinde verimlilik değerlendirmek için standart bir yaklaşım haline geldi . Maliyet verimliliği kavramı ilk olarak 1957 yılında Farrell tarafından dile getirilmiştir. DEA, kamu ve özel sektör performansını değerlendirmek ve ölçmek için, brawny sayısal ve analitik araç haline gelmiştir. Dünyada yüksek öğretim kurumlarının ve uygarlığın gelişmesi ile ın büyüme ve geniş artması ile birlikte, öğrencilerin performans ve verimliliği değerlendirmenin önemi artmıştır. Öğrenci performansını değerlendirip, eğitim teknolojisini tanımlayan kurumların, öğrencinin eğitsel amaçlı gelişmelerini ölçmek için ABET akreditasyon kriterleri dikkate alınarak DEA kullanılıp MI'ları hesaplanacak. Öğrenci performans verimliliği ölçüm sonucuna ve yapılan ankete göre "Malmquist index" hesaplaması yapılacak. Bu hesaplama yapılırken referans alınan bir index kullanılacak. Buna dayanarak, Öğrenci Kazanımları, performans ve eğitim programlarının gelişimini sürekli izlemek için bir index oluşturulmuş olacak. Bu index de "Malmquist Educational Index" (MEI) olarak adlandırılacak. Endüstri Mühendisliği Bölüm Başkanı tarafından, bölümdeki bütün dersler için sağlanan bilgiler kullanılarak "Malmquist Educational Index" hesaplaması yapıldı. Sonuç olarak MEI < 1 ise gerileme söz konusudur ve DMU (course student, program, instructor etc.) da geliştirme ve yenileme gerekmektedir. MEI> 1 ise ilerleme söz konusudur. Son olarak MEI= 1 ise herhangi bir değişiklik söz konusu değildir

Anahtar Kelimeler: Malmquist Endeksi, DEA, Öğrenci Kazanımları ve Öğrenci performansı

DEDICATION

To My Family especially my late mum and My Wife to be who is going to take her place of love and care.

To My Family

ACKNOWLEDGMENT

We give Thanks to Allah Almighty for having let me to realize this all by His Grace. All my due respect, honor and thanks go, especially to Asst. Prof. Dr. Sahand Daneshvar for his continuous and always available support and guidance throughout this thesis. With the absence of his magnificent supervision, my efforts would be myopic. Not keeping behind Asst. Prof. Dr. Gokhan Izbirak, Chairman of the Department of Industrial Engineering, who said, “Musa you can do it, and I am sure your thesis will be good”, helped me with several issues during my thesis and sacrificed his time and private time for me. Professor, I say grand MERCI. More honor and thanks goes to Prof. Bela Vizvari for his strong scientific support and editing, may God bless you. I also acknowledge all my lecturers who put all their efforts at the very first beginning I enrolled in Industrial Engineering to ensure I succeed in my career by providing me with all I needed throughout my studies in industrial engineering. Special thanks and respect goes to Assoc. Prof. Dr. Adham MACKIEH for his fatherly advice and encouragement the very first day he saw me, he made me believe more in myself and I am very grateful.

Friends are always good instrument for success. So my close and casual friends, especially Ahmed (for his food, especially macaroni and spiritual assistant, brother no one has compared to you, شكرا), Ibrahim, toned, Alondi, Cliffort, Elvis, and Joel, I am grateful for your direct and indirect support you supported me throughout my stay in Cyprus. I won’t forget to say big thanks to Mr. and Mrs. Baris and My favorite group Tchaabooo for their financial and moral support during difficult times. I owe my debt and gratitude to my hostel manager (Barla) Mr. Yusuf and his entire

brothers Lutfullah and Fezullah who took me in and treated me with love and respect like I was their own son and brother. I say may Allah replenish your kindness above your expectation. Special thanks go to my best friend Maria Bokesa for her LOVE, spiritual and moral support throughout my days in Cyprus. Other intimate friends such as Anna, Colette, Kelly, are always in heart for their love and support through this period.

I am indebted to my family, especially my uncle and his wife Mr. Yusimbom Ibrahim and Mrs. Yusimbom Nuratou for having taken the challenge upon them after the death of my mum, to provide me with all my needs and above all made it possible for me to travel and supported me throughout my stay and studies in Cyprus. Special regards goes to my my uncles Yusimbom Hasan and Sunjo Hasan for their continuous and intense encouragement, brother Sulemanu, small Sulemanu, my brother from my father's house, my sister Rabi, my in-law Juliet and my aunts Ahjia, aunts Aisha, my mum twin sister, mami charley, and mami Abdel who financially or morally supported me through calls on several occasions to ensure my education and health was in good condition. Hmm, special regards to my children, Sakinatu, Sherifatou, Amiratou, Haman, and the king Omega for having given me the reason of responsibility to move forward after the tragic lost of my mum, hoping and promise to make you all happy. I won't forget my entire family; brothers and sister of the extended direction for their prayers, I appreciate you all. Specially, My Grand Mums and Grand Pa, for their prayers, they're always believing in me, giving me the go ahead courage, and above all the main root for my existence on earth today, I will say BERIN and BERINYUY for having you all.

I dedicate this thesis to my beloved Family.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION AND OBJECTIVES

1.1 Introduction

Education and or educational institutes or systems can be considered the building blocks for a powerful nation and society, hence private and public institutions such as colleges and universities need to be evaluated "for higher education is the backbone of development and economic growth in any country", (Salah R. et al, 2011). The request for auditing is needed to necessitate financial accountability. Performance indicators in some public and private sectors have often been criticized for being inadequate and not tributary in analyzing the efficiency of their respective institutions, (Mary N., et al, 2007). Rulers, doctors, engineers, lecturers, policemen, etc. that make up the functioning of a nation are outputs from educational institutes or systems, hence their behaviors and the way they help to build up the nation depend on how much they attained or acquired from these institutions. The world today is characterized by rapid and quick technological change that one could describe the speed as the speed of light, hence the importance of innovation of new processes, the level of academic attainment that students of a given country or institutes may achieve is fundamentally important for improving citizens' lives of wealth and welfare of any country. Hence, the measures and methods used by educational institutes to assess Student Outcomes (SOs) and performance must and need to be improved from period to period. Data Envelopment Analysis (DEA) and

Malmquist Index (MI) computation can be used for this purpose by computing efficiency and improvement index of educational units and their programs.

1.1.1 Data Envelopment Analysis

Data Envelopment Analysis (DEA) is an awesome and very powerful service tool in management science and "benchmark technique" introduced by Charnes A., et al, in 1978 based on the construct of cost efficiency that was first mentioned by Farrell, (1957) who aroused many of the fundamental ideas of DEA. Cost Efficiency (CE) evaluates the ability to produce specific outputs using specific inputs with minimal cost possible.

DEA is of non-parametric techniques based on linear programming. DEA is applied in operations research and economics that uses linear programming to construct a non parametric piecewise frontier. Note that within a very short notice, DEA has recently grown into a strong quantitative and analytical tool for measuring and evaluating performance, (William W. Cooper, Lawrence M., Seiford and Joe Zhu, 2012), for Decision Making units (DMU), especially higher education sectors and attractive frontiers.

A frontier can be regarded in terms of production for "production possibility frontier" and this frontier defines a curve or a limit which shows the combinations and possibilities of two or more goods and services that can be produced while using all of the available factor resources efficiently (Gillespie A., 2007), or market frontier which is regarded as a type of country that is not a developed market but attracts investors (Guerrero Tomás, 2013) or simply an undeveloped field of study that attract research and development.

We should note that the non-parametric approaches used in DEA requires no assumption for a particular functional form or shape for a given frontier, unfortunately, a general relationship (equation) relating output and input cannot be defined like in the case of parametric approach. Generally, the frontier represents a best practice technology in which observations that belong to it are called efficient by default and the others are inefficient. The efficiency of each observation in the frontier at any given time can be calculated by means of a distance function best described by Fare et al (1985, 1994), using the Malmquist index. This reflects the distance between the observation and the frontier. There are also parametric approaches which are used for estimating production frontiers (Lovell and Schmidt, 1988). These require that the shape of the frontier be forecasted by specifying a particular function relating output to input.

DEA is mostly data oriented approach and function more on Decision Making units (DMUs) which is capable of converting multiple inputs into multiple outputs with minimal cost possible. Regarding DMUs, we can conclude that the definition is generic and flexible. Due to this flexibility, DEA applications are using DMUs in several forms to evaluate the performance of many entities such as;

- Hospital and clinical centers, including pharmacies
- Universities, including both private and public
- Educational Systems
- US army force
- Cities, Countries and regions
- Courts
- Business firms and others, etc. since it requires very little assumptions.

DEA has so many applications on its own and many other applications couple with other approaches and some indices and the most importantly Malmquist index.

There are some limitations in using DEA (Abbott M., and Doucouliagos C., 2003). This includes the following;

- DEA is capable of identifying two or more DMUs that operate at their best level. That is, if in the case of universities; at least two or more universities and will be given a score of 1, when in real life, even the best performing university may not be operating on the frontier. “This may lead to a problem if all universities are inefficient to some degree”.
- Secondly, DEA is familiar with computing efficiency scores using only those inputs which managers easily control and later use the information on inputs that managers cannot easily control to assess their impact.
- Most importantly, there is also the issue of the quality of the output like in the case of Australian universities (Abbott, M., and Doucouliagos C., 2003), focusing on outputs without taking into consideration the standard and quality of education provided might bias the efficiency scores in favor of high output and low quality university.

However, DEA is capable of the following, (Sherman and Zhu, 2014).

- Data envelopment analysis, DEA evaluate and compares DMUs taking into consideration all available resources and the services provided, and select the best efficient DMU(s), from the inefficient DMU(s) in which real efficiency can be possibly improved.
- DEA evaluates the magnitude and type of a cost and resource savings available by making each inefficient DMU as efficient as the most efficient DMUs.

- Particular changes about the inefficient DMUs can be identified using DEA, which gives managers the power to implement changes in order to obtain a potential saving location.
- Managers can receives information about the performance of DMU(s) from DEA that can be used to help improve system and managerial experience. This has resulted in improving the efficiency and productivity of the inefficient DMUs, decreasing total operating costs and increasing profitability which are an important factor in management.

1.1.2 Malmquist Index

The term "Malmquist index'' was first intended by "Professor Sten Malmquist" in 1953, who had earlier actualized constructing input quantity indices as ratios of distance functions and used it to compare the productivity of two economies and based on his knowledge, Malmquist Index is regarded as a bilateral means of comparing the production technology of two economies in which each economy is having an identical part on each side of the index. This was introduced into the literature by Caves Douglas et al. (1982). Accordingly, Malmquist index (MI) can be defined as a bilateral index used to compare the production technology (productivity) of two economies. It is also called the "Malmquist Productivity Index", (MPI). MPI is a process where the production frontier shifts and the DMU is subjected to recover the productivity change (Caves Douglas et al, 1982). The MPI has recently grown into a standard approach to productivity measurement and evaluation over time within the "non-parametric" and "parametric literature" in recent years. It should be noted that Malmquist index provides an inaccurate productivity measure when it is operating under Variable Returns to Scale, VRS (Fare and Grosskopf 1996), in relation to the Constant Returns to Scale, CRS, which is the assumption used for estimating the distance functions and for, may be an accurate or standard Malmquish index.

The "term returns to scale" is frequently used to describe the firm's production function. It explicates the behavior of the rate of change in the output or production to the subsequent change in the inputs. Generally, in the long run all factors of production are variable and are subject to change due to increase in size and or scale of the production factor and unit. The "laws of Returns to Scale" are categories under three interconnected and chronological laws; "the Law of Increasing Returns to Scale, Law of Constant Returns to Scale, and the Law of Diminishing Returns to Scale", (Gelles Gregory M., & Mitchel Douglas W., 1996).

- If output/input increase by the same proportional change, i.e., constant rate, then there are constant returns to scale (CRS) which is assumed by the CCR model.
- If output/input increases by less than the proportional change in input/output, there are decreasing returns to scale (DRS).
- If output/input increases by more than the proportional change in input/output, there are increasing returns to scale (IRS).

The join view of DRS and IRS can be regarded as Variable Return to scale since an increase in output/input does not necessarily result in a proportional change in the input/output, hence we can regard it as variable return to scale, VRS. BCC model operates under the Variable Return to scale.

Moreover, in microeconomics and real life situation, the returns to scale, faced by most firms are purely technological and are imposed hence, are not influenced by economic decisions or by market conditions (Frisch R., 1965).

1.1.3 DEA-based Malmquist Productivity Index

Educational institutes, banks and financial institutions are expected to show changes in productivity as the results of innovation of Student Outcomes and or performance, therefore technical efficiency and technological efficiency, Farrell (1957) should be measured accurately. Färe et al. (1992, 1994, 1997) put together ideas about efficiency measurement from Farrell and productivity measurement from Caves et al., to construct a "Malmquist Productivity Index" that exposed clearly the other aspect of DEA, a Malmquist Productivity Index, especially when focusing on the inefficiency aspects of the non-parametric Method. Malmquist Total factor productivity assumed the competitive behavior of the producer with respect to the input as the key point of productivity. Regarding DEA, efficiency means preventing the waste of resources calculated through output to input ratio.

We note that using a DEA approach a number of indices can be used as alternative for measuring the productivity changes; some researchers have used Fisher index, Tomqvist index, Malmquist-Luenberger global index, and Malmquist Index. Malmquist index has been applied by a number of researchers in efficiency studies, (educational system efficiency and productivity studies, health efficiency studies, banks and commercial sector efficiency studies, e.t.c.) since it neither requires cost minimization or profit maximization assumptions. In addition, since the MI has panel data, this approach enables disintegration of "productivity change" into technical catch up (efficient change) and technological change which it is an important property to analyze larger size of data.

As mentioned above, DEA-based Malmquist productivity index makes use of distance functions to measure "productivity change". The approach was introduced by Caves Douglas, W., et al., 1982. DEA-based Malmquist productivity indexes provide us with the opportunity of comparing production changes within the banking industry as well as to compare productivity within two economies, and productivity within groups and would be applied in this thesis to evaluate the productivity changes of teachers and student outcomes. This gives the opportunity of poor performance to catch up. Total factor productivity as the word implies, refers to all factors relating the production of commercial sectors being it public or private, profit or nonprofit sectors (banks, industries, factories, frontiers etc.) more specifically, "the change in total factor productivity entails changes in efficiency and changes in technology" regarding the firm. (António A, et al 2013). When comparing and interpreting the Malmquist total productivity, we consider all of its components greater than one indicates improvement or progression on the other hand the values less than one refers to the deterioration or regression, whereas the value equal to one refers to as no improvement has been observed. Technological changes indicate shifts in the frontier or the development of a new technology and efficiency change indicate catching up with the frontier (António A, et al 2013). We can use DEAP program developed by Coelli to solve problems of productivity indexes, some properties of DEA-based Malmquist productivity index include:

- It can be disintegrated into efficient change and technological change, (Färe et al. 1992).
- "Malmquist productivity index" can be regarded as Hicks-Moorsteen index if the technology operates under constant returns to scale and inverse homotheticity, (A homothetic function is a monotonic transformation of a homogeneous function of degree one)

- Output-oriented and input-orientated Malmquist indexes coincide if the technology exhibits “constant returns to scale” common in CCR model.
- The Malmquist Productivity index does not adequately account for scale change.
- The MPI does not satisfy the transitivity property. So we need to use the EKS (Elteto, O., Koves P., and Schultz, B.) method to make them transitive.

In this thesis we shall see how the computation of Malmquist Index using DEA can be used to evaluate students’ performance, student outcomes and as a measure of educational improvement, it could be used to monitor the continuous improvement of educational programs. Most interestingly, the efficiency of lecturers can be evaluated using this computation. It should be noted that assessing universities efficiency, Student Outcomes (SOs), and Student Performance (SP) is vital for effective allocation and utilization of educational resources since with DEA, we can easily identify deficient activities, courses and even lecturers in the university and an appropriate action for improvement taken.

Moreover, studies on how Student Outcomes could be evaluated using DEA and Malmquist Index are somehow rare, and there are no previous studies analyzing explicitly how Student Outcomes and performance are analyzed using Malmquist index along side with DEA, as well as its components but other studies have been done on how the efficiency and productivity of educational systems can be compared and evaluated. However, in order to fully evaluate the performance of educational systems, it would be desirable to evaluate the change in performance over time (Victor G., et al 2013). For example, the evaluation of efficiency of educational systems using Malmquist Index, the productivity changes in basic and secondary education for 24 government schools in Tunisia over the period 2004-2008. (António A et al., 2013). A cross analysis, using the DEA to analyze the "efficiency and the maximum potential output of the educational system for 31 Countries" with data from TMSS 1999, (Gimener et al, 2007). More about this related literature will be discussed in the next chapter.

1.1.4 Educational Accreditation Programs

Accreditation is a process employed and used by educational programs by which institutes are reviewed and assessed if they meet certain quality standards of education. This status of evaluation is not permanent; the institution must request another evaluation after a given period of time and it varies from society to society, like in the case of ABET, the period of accreditation is a maximum of 6 years.

There are so many educational accreditation programs round the world, but we just named some few;

- Institution of Engineering and Technology (IET), England
- Accreditation Board for Engineering and Technology (ABET), USA
- Accreditation Council for Business Schools and Programs (ACBSP), USA
- Accreditation Commission for Acupuncture and Oriental Medicine (ACAOM), USA

As mentioned earlier, we will focus on ABET since our case study in this thesis is under the canopy of ABET. ABET *"Accreditation Board for Engineering and Technology"* was formerly formed in 1932 as an "engineer council for professional development" (ECPD) by seven engineers society. Today ABET consists of at least 32 federation of "professional and technical member societies" constituting the field of engineering applied science, computing, and technology. (From the ABET website)

ABET is an NGO, (Non-governmental Organization) ensuring the accreditation of post-secondary education and higher education programs in science, especially "computing, engineering, and technology engineering". In the early period of the program, it operated mainly in the United State; it has evenly spread to internationally involve about 3278 programs which are accredited over more than 670 universities and 23 countries. ABET Accreditation is not ranking system, it applies to programs only, not degrees, department, college, institutes or individually. ABET has a format in which report about a program is presented, and some criteria's to be followed by any program. This report is normally reported as a self-study report since it entails private information about a program in a particular institution and the University. These criteria's are classified uniquely by ABET and any program interested for ABET Accreditation must provide a self-study report following the criteria.

Self-study is a form of report describing in details how a program is structured and run according to ABET criteria's. With respect to ABET criterion 3 for accrediting engineering programs requires each program to have outcomes and moreover, it requires that "this program outcomes are being measured and indicate the degree to which the outcomes are achieved by student". More precisely, how this program can be continuously improved by implementing a Continuous Improvement Plan (CIP).

1.1.5 Direct and Indirect Methods Used in ABET Self-Study

When we examine ABET community and some of the self-study report carefully, we will realize that they have been a lot of discussion and description about direct and indirect assessments. The question is "do we include both of them in evaluating student outcomes or performance"?

As regards the degrees accredited by ABET, these degree programs are required to implement a Continuous Improvement Plan (CIP). With respect to this, ABET states that The program in question must use a documented process or method that constitute of relevant data to regularly evaluate and assess its “program educational objectives and program outcomes” according to criteria 3, and also evaluate the extent to which they are being accomplished. The outcomes of the evaluation of program educational objectives and program outcomes must be applied to effect “continuous improvement of the program through a documented plan”. Most importantly, the center of CIP must be the program or student outcomes, (Gloria R., 2006).

Direct methods of assessment expect students to produce work based on what they have achieved from a course administered by the instructor so that faculty can assess the level to which students meet expectations. A direct assessment method evaluates student outcomes or students’ performance and provides the means for direct observation of students’ knowledge skills and ability. The faculty is familiar with this aspect since the faculty or instructor conduct direct assessments of student learning throughout a course by the used of techniques such as “exams, quizzes, demonstrations, and reports, presentation, assignments, Senior thesis or major project, Portfolio evaluation, Case studies, Reflective journals Capstone projects, Internship and clinical evaluation”, (Mary J., 2008, External examiners/peer review). These methods may provide us with a sample of what students may know and/or can do and hence, provide strong evidence of student learning capability. This is not always true for an exam is not the “true test” of knowledge. When we look critically at some of the techniques regarding who students are, we cannot say for sure that whatever they provide as the case may be represent what they know or learning capability, since factors like cheating, copying from friends, knowing exams questions before the exams, etc. are possible in an educational milieu. Moreover, not all learning can be measured directly like Student creativity.

Indirect method of assessment provides a means for the faculty/instructor to ascertain, and then perceived the extent of students learning experiences. It also provides means for which students can echo on their “learning experiences” and capacity given a course and notify the faculty their awareness of their “learning experience” (Palomba and Banta, 1999), and how this learning can be appreciated by diverse constituencies. Some of these indirect methods include; Exit interviews, Alumni survey, Departmental survey, Employer survey, Course assessment survey, Student course-instructor survey, Job placement statistics, Graduation and retention rates, etc. However, as substantiation of student learning, indirect method of assessment is not as powerful as direct method. We should note that we must make some assumptions about what exactly a self-report means and how we can validate and evaluate students report attaining a particular learning objective, (Mary J., 2008). However, an indirect assessment is also very important since it can be used to measure some particular embedded qualities of student learning, which include, creativity, attitudes, and perceptions, from a range of perspectives which direct assessment cannot.

With regard to ABET, what most programs encountered as a drawback toward direct assessment is taking this data (from direct measures) and using it routinely in CIP without considering the indirect measures of assessment.

A meaningful and more understandable assessment program would use both direct and indirect assessment measures from various sources to assess student outcomes. The use of multiple assessment methods provides converging and more accurate and smaller variance evidence of student learning and outcomes, hence, we should note that indirect methods provide a good enhancement to direct methods and usually constitute a part of a robust assessment program which should be included in all programs as far as CIP is a concern, (Mary J., 2008). In this regard, this thesis suggests a good method in which both the indirect and direct method can be used to assess or evaluate student outcomes, student performance and monitor the continuous improvement of the program as far as CIP is a concern.

1.2 Research Problems and Objectives

1.2.1 Research Problems

Most of the educational institutes, colleges and universities try to be part of an accreditation program or society (ABET, APA, NAAC, DELLS, ACBSP, AACSB, ACAOM etc.) in order to present their educational quality and for the quality standard monitor by this accreditation program or societies. However, evaluation of a program(s) in an institution or educational systems is periodical hence, after each period of accreditation offered by an accreditation program, the institution or Educational System would need to request for another evaluation. In this re-evaluation process, they are forced to prepare a self-study report showing the methods of assessment and how these methods are used to assess student outcomes base on the criteria's proposed by the accreditation program in question. Moreover, and how this method is used for the continuous improvement of the program since the results achieved (output) during this process are a consequence of the resources used, the process itself as well as environmental variables and factors beyond educational authorities' control (Teddlie and Reynolds, 2000) and when measuring students' educational achievements (Students Performance and Student Outcomes) in a given point in time, it is difficult to extricate how much of it is attributable to the student himself, his family, or the strategies started by previous educational authorities (Victor et al, 2013), hence keeping records of past information about educational authorities and combining direct and indirect measures in evaluating educational achievements are of great importance.

The methods of assessing Student Outcomes have been a major problem in most self-study reports. The majority of universities, colleges, educational institutes and or programs, etc. is faced with the following problems;

- Most of the institutes or programs fail to use data generated from both indirect and direct measures to assess student outcomes (SOs) rather they concentrate on direct measures only.
- Most of the programs or institutes do not include the lecturer or course instructor when assessing the student outcomes and we should note that program objective has a general view of the program itself, but when each course is concerned, the objective differs. The persons concerned with these objectives and how it used to ensure that student attained, the student outcomes include the faculty and lecturers. So they should be a correlation/relation to show how these objectives are being administered to the students, i.e. how the lecturer delivers the message to the student also defined the extent to which the objectives are assimilated by students, hence this play a vital role in student outcomes achievement, hence they should be included in the determination of student outcomes and

performance directly or indirectly since the improvement of the program could still be changing the lecturer

- Most of the programs or institutes do not have a unique method in which Student Outcomes and or performance can be evaluated using data generated from indirect and direct measures of assessment. They find it difficult to use their method of assessment to monitor the continuous improvement of the program.

These problems faced by most educational institutes, university and programs have triggered my interest on this topic of research. Moreover, it is a worthy research in my University and other Universities will benefit from it. This will ease their self-study report and enhance quality control of their programs. Student Outcomes and Performance will be easily evaluated and the Continuous Improvement of their respective programs will be easily monitored.

As mentioned earlier, Education and Educational Institutes or system can be considered the building blocks for a powerful Nation. The survival and growth of a nation and our society depend on students since they are the future leaders, hence this factor also triggers my interest toward this research since it is important to assess Student Outcomes and hence reflects the quality and standard of education offered by the institution or educational systems from the service they provide for the society. For the above reasons, it is not surprising that, in the field of public policy in education, there is a growing concern in the assessment of student learning objectives (Denvir and Brown, 1986; Ercikan, 2006). Therefore, from the rationale presented above, some desirable properties of a good education system would relate not only for its ability to obtain high average students' academic achievement, but also to be able to ensure that all students make progress and poor average students improve and achieve basic standards of education. Therefore, an educational system that evolves satisfactorily will be the one which improves the average student's academic achievement while simultaneously minimizing the percentage of students not achieving the most basic learning standards (Victor G., 2013).

1.2.2 Objectives

The main goal or objective of this work is to be able to compute a Malmquist Index using DEA as a direct method to assess Student Outcomes using criteria provided by an accredited program. E.g. ABET

Some specific objectives include:

- To be able to use this computation for a continuous improvement plan of the programs offered by Department, faculty or university.
- To be able to use this computation to compare the programs offered by two different universities or the same university.
- To able to use this computation as a continuous improvement measure for Educational purposes.
- To be able to apply this method using a real life example as a case study.
- To be able to apply this computation as a measured to assess post graduate Education in some universities.
- To be able to used this computation to evaluate the Efficiency of a program and the efficiency of students differentiating efficient and inefficient students

Being a student does not only finish in class. I have been a student for close to 20 years today, and when I started secondary school, I started thinking about how my performance and outcomes are determined. At the University level, many factors made me to believe that direct measures of assessment are not enough to evaluate student outcomes and performance. Hence, computing a method to assess student outcomes and moreover, assess my own outcomes will be my greatest achievement.

In the preceding chapters, in chapter two, we shall discuss some literature review related to this work. In the same chapter will discuss the basic models used in both DEA and Malmquist Index and their applications as far as this project is concerned. We will also mention accreditation program, especially ABET accreditation. This is because ABET accredit mostly Engineering programs and is the accreditation program used in Eastern Mediterranean University (EMU). In chapter three, we will introduce the method of assessing student outcomes base on the thesis and compute Malmquist Educational Index (MEI) using DEA and show how it can be used to assess Student Outcomes, evaluate the continuous improvement of the program, compare the same programs in two different universities or compare programs/teachers/students in two different periods, used as a continuous improvement measures for Educational purposes, and to evaluates post graduate students, and most importantly in a real life example. In chapter four, we use the proposed method to compute the MEI of all courses offered by industrial engineering department in the Eastern Mediterranean university, EMU and consider them as criteria for measuring the improvement of attaining the desired criterion in ABET accreditation. We may further use the proposed method to compare engineering department within EMU. This will be done by collecting all necessary data which are needed in the MEI calculation from the department chair or dean. In chapter five, we shall conclude with reasons why our method is good and successful.

Chapter 2

LITERATURE REVIEW AND DEA BASIC MODELS

Many studies have been done on how education systems' productivity, achievement, efficiency and performance can be evaluated or assess by means of Data envelopment analysis and or Malmquist Index. Best of my knowledge, very little work has been done on how Student performance and student outcomes can be assessed using Data envelopment analysis and Malmquist index hence, this thesis will compute Malmquist index using DEA and show how it could be used to evaluate Student Outcomes and performance and even monitor the continuous improvement of a particular program in question.

In this chapter, we are going to discuss literature review on DEA, MI and ABET and basic DEA models, but note that very little information is known about the educational production function (Hanushek, 1986), hence, no clear decisive factor is available in selecting the inputs and outputs, hence the preference of the variables for educational analysis is a vital issue and is often difficult to decide upon. In recent writing, it is seen that school related variables such as; instructor experience, students, class size, instructor qualification, etc., and environmental factors such as parent's education, social and economic status of the family, etc. can be considered on input side and academic and non academic achievements on the output side, (Diamond et al, 1990; Beasely, 1995). Here we may face problems converting some variables (like the status of the family) into real data to evaluate the student outcomes and performance; hence the proposed method in this thesis might have the solution.

2.1 Data Envelopment Analysis, DEA

DEA is quite a new field regarded as a data oriented approach for evaluating the performance of a set of equal entities called Decision Making Units (DMUs) which are capable of changing several inputs into several outputs (William, W., Lawrence, M., and Joe Zhu, 2012). Generally, DMU is referring to as a unit capable of changing various inputs into outputs and whose performances, efficiencies, and productivities are to be measured in the process. As an application in management science, DMUs may include the following; banks, department stores and supermarkets, and have been extended to universities, car makers, hospitals, secondary schools, public libraries and so forth. In engineering, DMUs may be regarded in many forms as airplanes or their various components such as jet engines. For the reason of assuring relative comparisons and differentiation, a set of DMUs can be used to evaluate each other, whereas each DMU has an assured level of "managerial freedom" in decision making. We shall discuss the basic DEA models in the next section.

2.1.1 The Production Possibility Set and Postulate

The "production possibility set", PPS is a set that shows all potential combinations of output that an economy or firm can probably and willingly produce using a specific amount of inputs at a given time. We can also call this set "feasible allocations". If feasible allocations are not within the production possibility set, then there are infeasible. We can locate all efficient allocations in the production possibility set through the production possibility frontier, (Makoto T., 1980). Regarding the production possibility set, there are three time elements. They are the production time of the commodity (goods and services), the construction time of a production possibility set and the lifetime of capital goods. Production possibility curve provides vital information about a firm resources, scarcity, tradeoff and opportunity cost.

Recall that DEA is a mathematical optimization technique that evaluates the relative efficiency of DMUs with multiple input and output. The model commonly referred to as a CCR model, (Charnes, copper, Rhodes, 1978), operates under 'constant returns to scale". CCR model was auxiliary developed for "variable returns to scale", (Banker et al., 1984). Hence, consider as BCC model.

If we consider the observed output $Y_j = (y_{1j}, \ldots\ldots\ldots\ldots y_{nj}) \geq 0, and\ input$

$X_j = (x_{1j}, \ldots\ldots\ldots\ldots x_{mj}) \geq 0, X_j \neq 0, Y_j \neq 0$. For *DMUj*, j = 1… n., the DEA postulates that lead to PPS, $T = \{(XY) \mid output$ vector $Y \geq 0$ obtained from the input vector $X \geq 0$ } have the following properties; (Alirezaee, M.R., Afsharian, M. 2007)

1. Nonempty. They must be an observation such that $(X_j, Y_j) \in T, j = 1 \ldots n,$ is nonempty
2. Constant return to Scale. If we multiply each output and input by the same constant, then there should be a proportional change such that a constant return to scale is respected hence, $(X, Y) \in T$, the $(\lambda X, \lambda Y) \in T$ for all $\lambda \geq 0$
3. Convexity. T is a closed and convex set, i.e. if $(X_1, X_1) \in T$ and $(X_2, X_2) \in T$ then a linear combination of $(X_1, X_1) \in T$ and $(X_2, X_2) \in T$ for $\lambda \in (0,1)$, *hence*, $\lambda(X_1, X_1) + (1-\lambda(X_2, X_2) \in T$ must be convex.
4. Plausibility. The set must be apparently valid that is if $(X, Y) \in T$, then $(X_t, X_t) \in T$
5. Minimum extrapolation. T is the smallest set satisfying properties 1-4. All linear combinations of the above activities belongs to T hence, generally, the postulates defined above relate the following unique set:

$$T_C = \{(X_t, Y_t) I\ X_t \geq \sum_{j=1}^{n} \lambda_j X_j, Y_t \leq \sum_{j=1}^{n} \lambda_j Y_j, \lambda_j \geq 0, j = 1,2 \ldots n\} \qquad (2.1)$$

This unique set is true for the CCR model which will be discussed in the next section.With the exception of postulate 3, and an addition of the constraint, $\sum_{j=1}^{n} \lambda_j = 1$, we can define a new unique set for the above postulate as follows:

$$T_B = \{(X, Y) I\ X \geq \sum_{j=1}^{n} \lambda_j X_j, Y \leq \sum_{j=1}^{n} \lambda_j Y_j, \sum_{j=1}^{n} \lambda_j = 1, \lambda_j \geq 0, j = 1,2 \ldots n\} \qquad (2.2)$$

This set is applicable when using a BBC model which will be discussed later.

2.1.2 The Standard CCR Model

In this part, we are going to discuss “CCR model” which is one of the most important DEA models that produces an output vector having properties within T_c when applied. CCR model was first brought into writing by Charnes, Cooper and Rohdes (1978), thus the name “CCR” which has been used to appraise the relative efficiency of DMUs using an ordinary set of an uneven inputs to generate a common set of an uneven outputs. (Milan, M., et al., 2009, William, W., et al 2004). If we suppose the number of DMUs is *n* and each DMU uses *m* inputs to generate *s* outputs.

Letting x_{ij} and y_{rj} ($i = 1 \ldots m, j = 1 \ldots n, r = 1 \ldots s$), which are non-negative for all DMUs representing the inputs and outputs of DMU_j, respectively and with the following definitions:

x_{ij} *= the observed magnitude of i type input for entity j,* ($x_{ij} \geq 0, i = 1, 2 \ldots m, j = 1, 2 \ldots, n$)

y_{rj} *= the observed magnitude of r-type output for entity j,* ($y_{rj} \geq 0, r = 1, 2 \ldots s, j = 1, 2 \ldots, n$).

v_i = the weights to be determined for input i;

m = the number of inputs;

u_r = the weights to be determined for output r;

s = the number of outputs;

θ = the relative efficiency of DMU_k

n = the number of entities;

DMU_o = decision making unit (o = 1…,n), CCR model can be described step by step. With the postulates discussed above, the CCR input oriented model can be formulated in the following linear model. Note that minimization in the objective function indicates input oriented CCR model and maximization of objective function indicate output orientated BCC model. The general view of the input CCR model is as follows;

Min θ

Subjected to:

$$(\theta X_O, Y_O) \in T_C \tag{2.3}$$

The constraint above indicates that the inputs and outputs are all elements of T_C hence a possible pair in the production possibility set defined above.

The "relative Efficiency" θ, of any, DMU_k, is defined as "the ratio of the weighted sums of their outputs and the weighted sums of their inputs." The weights v_i and u_r show the magnificence of each input and output, and are generally determined in the model to ensure the efficiency of each DMU as much as possible hence;

$$Max\theta = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}}$$

Subjected to:

$$Max\theta = \frac{\sum_{r=1}^{s} u_r y_j}{\sum_{i=1}^{m} v_i x_j} \leq 1, j = 1,2..... j_k ....,n$$

$$u_r \geq 0, r = 1,2....s \qquad (2.4)$$

$$v_i \geq 0, i = 1,2....m$$

The first constraint above indicates that the efficiency must always be less than or equal to one for any decision making unit. Also, if the second constraint is true for every DMU, it indicates that each of them lies on the efficient frontier or beyond it and the value of relative efficiency should not be more than 1 for every DMU.

Note that efficiency defined above is nonlinear and not convex, with a "linear and fractional objective function and fractional constraints". We could use a simple transformation (Charme and Cooper, 1962) and the above, the DEA ratio model would be transformed into LP form which we can consider as the "Primal CCR" model and use LP software to solve. The input oriented CCR primal model is as follows;

Model 1:

$$\theta^* = Min\theta$$

Subjected to:

$$\sum_{i=1}^{m} x_{ij} \lambda_j \leq \theta x_{io}, i = 1,2...m$$

$$\sum_{r=1}^{s} y_{ij} \lambda_j \leq y_{ro}, i = 1,2,..s$$

$$u_r \geq 0, r = 1,2...s \qquad (2.5)$$

$$v_i \geq 0, i = 1,2..m$$

$$\lambda_j \geq 0, j = 1,2..n$$

Where $(\theta X, Y) \in T_c$

The first constraint shows the minimum input capable of yielding an efficient outputs while the second constraint indicates the maximum and efficient output obtained for each DMU. The above model is considered envelopment side of the input oriented CCR model. We can sometimes refer to the above model as "Farrell model" because it is the one used in Farrell (1957). Viewing DEA economically, it is said to have been adapted to the assumption of *strong disposal* because it ignores the existence of non-zero slack variables. Introducing a small positive value ε and adding the slack variable, we can write the above model as follows:

$$Min\theta \quad \varepsilon.\left(\sum_{r=1}^{s} s^{+} + \sum_{i=1}^{m} s^{-} \right)$$

Subjected to:

$$\begin{aligned}
&\sum_{i=1}^{m} x_{ij}\lambda_j + s^{-} \le \theta x_{io}, i = 1,2...m \\
&\sum_{r=1}^{s} y_{rj}\lambda_j + s^{+} \le y_{ro}, i = 1,2,..s \\
&u_r \ge 0, r = 1,2...s \\
&v_i \ge 0, i = 1,2..m \\
&\lambda_j \ge 0, j = 1,2..n
\end{aligned} \qquad (2.6)$$

Where s^{+} and s^{-} are slack variable used to convert the inequalities in model 1 to corresponding equations.

Definition 1

- *If an optimal feasible solution $(\theta^{*}, \lambda_j *, s^{+})$ of model 3 satisfies $\theta^{*}=1$ for all slack variables with zero value or coefficient, DMU_o is CCR-efficient. Also, if the DMU_o has no output deficits and input surpluses, it is considered CCR-efficient.*

- *If the optimal feasible solution above has* $\theta^* = 1$ *and also* $s^- \geq 0$ *and* $s^+ \geq 0$, *the* DMU_o *is considered as CCR-weak efficient.*
- *If* $\theta^* \neq 1$ *then* DMU_o *is also considered to be CCR-inefficient.*

The fundamental idea regarding DEA is easily conveyed in the Dual CCR model which can be solved easily because of its calculating size. Hence, in practice we often solve the dual task for the LP described by model 1. This model is also known as the multiplier side of an input oriented CCR model:

Model 2

$$Min\,\varphi = \sum_{r=1}^{s} u_r y_{rk}$$

Subjected to:

$$\begin{aligned}
&\sum_{i=1}^{m} v_i x_{ik} = 1, i = 1,2...m \\
&\sum_{r=1}^{s} u_r y_{ij} - \sum_{i=1}^{m} v_i, x_{ik} \leq 0, i = 1,2,..s \\
&\sum_{r=1}^{s} u_r y_{ik} \geq y_{rj}\varphi, r = 1,2....s \\
&u_r \geq 0, r = 1,2...s \\
&v_i \geq 0, i = 1,2..m
\end{aligned} \qquad (2.7)$$

Definition 2

- *If* $\varphi^* = 1$ *and* $v^* > 0$ *and* $u^* > 0$ *represent feasible optimal solutions of the CCR model for DMU being evaluated, the DMU is said to be CCR-efficient.*
- *If* $\varphi^* = 1$ *and* $v^* \geq 0$, $u^* \geq 0$, *represent feasible optimal solutions of the CCR model for DMU under evaluation and there is at least one* v^* *or* u^* *with a zero value, the DMU is said to be CCR-weaker efficient.*

- *On the other hand, DMU under evaluation is CCR-inefficient, if φ^* is different from 1.*

The above model is known as CCR model, (Cooper, Charnes, Rhodes, 1978).

2.1.3 The Standard BCC Model

Many different types of DEA models based on the CCR model have been developed. One of the most important is the one introduced by Banker, Cooper and Charnes which operates under Variable Return to Scale (RTS), this edition of the CCR model refers to as the BCC model (Banker, Charnes, Cooper, 1984), reviewed by William W. Cooper, Lawrence M. Seiford in 2004, and further updated again by William W. Cooper, Lawrence M. Seiford, Joe Zhu in 2012.

The pure technical efficiency that may ignore the impact of the scale size by only comparing DMUs to a unit of similar scale can be produced using a BCC model. Furthermore, small units qualitatively differ from large units and a comparison between the two may fortify and alter the measurements of proportional efficiency. The measured Efficiency should at least coincide with the one given by the CCR model. Note that the inclosure surface obtained from the BCC model Results in a convex hull, (Milan M., et al 2009).

With the postulates discussed above, the BCC model can be formulated in the following linear model:

$Min\theta$

Subjected to:

$$(\theta X_o, Y_o) \in T_B \qquad (2.8)$$

θ *free*

According to equation (2.2), the above model can be rewritten as follows:

$Min\theta$

Subjected to:

$$\sum_{j=1}^{n} \lambda_j X_j + \theta X_0 \geq 0$$

$$Y_o \leq \sum_{j=1}^{n} \lambda_j Y_j$$

$$\sum_{j=1}^{n} \lambda_j = 1 \tag{2.9}$$

$$\lambda_j \geq 0, j = 1,2....n$$

θ *free*

Since the above model depends on the DMU j, rewriting the above model in vector or envelopment form gives:

$Min\theta$

Subjected to:

$$\theta X_o - \lambda X \geq 0$$

$$Y\lambda - Y_o \geq 0$$

$$1\lambda = 1 \tag{2.10}$$

$$\lambda \geq 0$$

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

θ *free*

We can write the dual model of this problem as:

$$Max\theta = \sum_{r=1}^{s} u_r Y_{ro} + u_o$$

Subjected to:

$$\sum_{i=1}^{m} v_i X_{io} = 1$$

$$\sum_{r=1}^{s} u_i X_{io} - \sum_{i=1}^{m} v_i X_{ij} + u_o \le 0, j = 1,2...$$

$$u_r \ge 0, r = 1,2...s$$

$$v_i \ge 0, i = 1,2..m \qquad (2.11)$$

u_0 *free.*

Note that same as in CCR models, slack variables can be added to equation 2.10 as follows:

$Min\,\theta$

Subjected to

$$\theta X_o - \lambda X_j - s^- = 0$$

$$Y_j \lambda - Y_o - s^+ = 0$$

$$1\lambda = 1 \qquad (2.12)$$

$$\lambda \ge 0$$

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

θ *free*

Definition 3

- *If an optimal solution* $(\theta^*, \lambda^*, s^{-*}, s^{+*})$ *of model gratifies* $\theta^* = 1$ *and* $s^{-*} = 0, s^{+*} = 0$ *then we can conclude that DMU under evaluation is said to be BCC-efficient.*
- *If an optimal solution* $(\theta^*, \lambda^*, s^{-*}, s^{+*})$ *of model gratifies* $\theta^* = 1$ *and* $s^{-*} \ne 0, s^{+*} \ne 0$ *hence, the DMUs being evaluated are said to be BCC-weak efficient.*

- *If $\theta^{*} \neq 1$, then DMU under evaluation is BCC-inefficient.*

We should note the following between CCR and BBC models; If CCR models assume Constant Returns to scale if and only if an increase in the inputs ensures a balanced increase in the output levels the DMU is said to operate under “Constant Returns to Scale”. These models compute an overall efficiency in which both its pure technical efficiency and its scale efficiency are joined into a single value, (Milan M., et al 2009). From This constraint $\sum_{j=1}^{n}\lambda_j = 1$, BCC models facilitate “Variable Returns to Scale” and provides a reference set which can be used to determine a convex combination of DMUs, in which those having a positive value for λ are the optimal feasible solution. The DMU is said to function under “Variable Returns to Scale” if for any reason, an increase in inputs does not result in a relative change in the outputs. The rule of the “convexity constraint” is to ensure that the composite unit is of equivalent scale size as the unit under evaluation. Furthermore, DEA CCR models can be termed input oriented or output oriented CCR model. An input oriented model inefficient unit is made efficient through the proportional decrease of its inputs, while its output size are kept constant. The output oriented model expands the outputs as much as possible while controlling the inputs. For an output oriented model, an inefficient unit can be rendered efficient through the proportional increase of its outputs, while minimizing or keeping the inputs’ quantity unchanged, (Milan M., et al 2009).

Most interestingly, “the input and output measurements” are mostly the same in the CCR model, but always differs in the BCC model. Thus, if we solved a problem using the CCR model, we can give either interpretation, but if we solve a problem by computing the BCC input model, we can only give an input interpretation, hence, we must solve the BCC output model in order to have an output interpretation. The BCC and CCR models have differences which lie in the scalar transformations of all data for a given DMU.

2.1.4 Additive DEA Model

This model was first introduced in 1985 (Charnes A., Cooper, W. W., Golany B., Seiford L., Stutz J.) and has been used as a good model in classifying DMUs. This is because additive model is known to be the simplest non-radial model in DEA since one major disadvantage with a radial measure of technical efficiency is, it doesn't excogitate all identified potential for increasing output and reducing inputs, (Rezai Balf F., Shahverdi R., 2011).

Let us consider the additive model under interval data, and we assume that the number of DMUs is *n* and each DMU uses *m* inputs to produce *s* outputs.

We Let x_{ij} and y_{rj} ($i = 1 \ldots m, j = 1 \ldots n, r = 1 \ldots s$), which are non-negative for all DMUs, be inputs and outputs of DMU_j, respectively. Now considering the variable return to scale (VRS) in a technical inefficiency evaluation when DMU_k is under evaluation, we can define the linear programming as follows, (Rezai Balf F., Shahverdi R., 2011);

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

Subjected to:

$$\sum_{j=1}^{n} \lambda_j x_j - s^- = x_0$$

$$\sum_{j=1}^{n} \lambda_j y_j - s^+ = y_0 \qquad (2.13)$$

$$\lambda \in \Delta$$

Where,

$\Delta = \{\lambda I \lambda \geq 0, e^T \lambda = 1\}$

We can equally represent the above LP as follows:

$$Max\theta - \varepsilon\left(\sum_{r=1}^{s} s^{+} + \sum_{i=1}^{m} s^{-} \right)$$

Subjected to:

$$\sum_{i=1}^{m} x_{ij} \lambda_j + s \leq \theta x_{i0}, i = 1,2...m$$

$$\sum_{r=1}^{s} y_{rj} \lambda_j + s^{+} \leq y_{r0}, i = 1,2,..s$$

$$u_r \geq 0, r = 1,2...s$$

$$s^{-} \quad , s^{+} \geq 0$$

$$\lambda \in \Delta$$

Note that the duality of the model above can be written as follows (Reza Kazemi, M., et al, 2007);

$$Min \sum_{i=1}^{m} v_i x_{ik} + \sum_{r=1}^{s} u_r y_{rk} + u_o$$

Subjected to:

$$\sum_{i=1}^{m} v_i x_{jk} + \sum_{r=1}^{s} u_r y_{jk} + u_0 \geq 0$$

$$j = 1,2....,n \forall i,r \tag{2.14}$$

$$u_0 \ free$$

Definition 4 (ADD-efficient DMU)

DMU_0 is ADD-efficient if and only if $s^{-*} = 0$ and $s^{+*} = 0$ and can also be considered BCC-efficient.

2.1.5 DEA Related Studies

Maleki, G., and Klumpp, M., (2012), described possible solutions based on DEA modeling and they includes the additional problem of quality measurement and quality control in productivity analysis for the example of university service production. The models were divided into two general categories which include; quantitative-oriented and subjective models in operations research. Their research paper provides a comparison of DEA models based on data from 82 German universities. Their result shows the comparative characteristics of different DEA models and possibilities for the integration of quality control measures and outlines into university efficiency analysis and simulation. The Input parameters considered included the total budget and the staff counts of each university. Output parameters include the number of PhD graduates, third-party funds and the number of publications in a year, which will be considered in this work when assessing postgraduate studies of a name case study.

Salah, R., et al, (2011) applied DEA to evaluate the relative technical efficiency of the academic departments in the Islamic University-Gaza. The inputs they considered included; operating expenses, credit hours and training resources, while the outputs included; number of graduates, promotions and public service activities. The potential improvements and super efficiency were computed for inefficient and efficient departments respectively, hence, in this thesis, inefficient programs or courses will be considered, and potential improvement will be applied using the Continuous Improvement Plan with the respect of the department and course. Furthermore, Edward, M., et al (2011), analyzed inter temporal changes in productivity at Federal Higher Education Institutions, IFES from 2004 to 2008. They examined efficient frontiers using slacks-based and dynamic slacks-based measures for data envelopment analysis. However, the slacks-based DEA model was first mentioned earlier in 1997 Tone and Tsutsui and was later improved in 2001. It consists of the following two presuppositions; Measurement is constant in relation to the unit of measurement for each input and output item and measurement is monotonically decreasing at each input and output slack. Tsutsui and Tone (2010) used the model proposed by Fare and Grosskopf to carry-over variables in the dynamic DEA model to estimate the production frontier over several time periods leading to a slacks-based measure known as dynamic. These two models may be important to us if we have to minimize heterogeneity in any sector of this thesis.

Moreover, Nickolaos Tzeremes and George Halkos (2010), determined the performance levels of 16 departments of a publicly owned university using Data envelopment analysis, considering constant returns to scale and variable returns to scale models alongside with bootstrap techniques in order to determine accurate performance estimates. In their study, they used multiple inputs such as; number of academic staff, the number of auxiliary staff (assistants, staff, technical and administrative staff), the number of students (postgraduates, undergraduates, doctorate students) and total income which we may consider when assessing department and faculty efficiencies if needed. Meanwhile, Réka Tóth (2009) used DEA to compare efficiency of higher education systems. In his paper he examined whether their efficiency is influenced by the extent of the contribution of the state and or the private sector or socioeconomic factors like gross domestic product per capita and education level of parents. In his paper he applied one input and two output variables for comparing the European higher education systems; the input variable included the ratio of expenditure spent on higher education institutes to gross domestic product, the output variables included the ratio of people with diplomas in the total population and their employment rate, which based on my knowledge, others factors which may influence the efficiency of the system were not considered.

Preeti Tyagi, S., (2009) 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 using eight inputs; school resources such as teaching, physical and ancillary facilities, teachers' qualities and home environment of the schools' students such as parents' education and occupation while output consists of school wise average marks in environmental studies, mathematics, language which is important factors to be considered in our computation since a student outcome could be low due to Language barrier or lack of mathematical skills. Some could be due to illiterate parents at home, etc. We shall also use DEA to compute and compare efficiency differences of courses in a program under an accreditation society. Moreover, Abbott, M., and Doucouliagos, C., (2003) used the non-parametric techniques of DEA to estimate technical and scale efficiency of individual Australian universities. Scale efficiency is the extent to which an institution or educational system or a program can take advantage of returns to scale by changing its size to the optimal size. Hence, from the scale efficiency, they can tell when a university may be technically efficient, but may still be producing too little or too much output.

As mentioned by Jill Johnes (2006), on scale efficiency, we may use this knowledge when evaluating universities efficiencies and even the program efficiency since our work primary objectives is aimed at assessing Student Outcomes using criteria's from an accreditation society. In this paper, their main focused inputs included teaching and research. Also SClaudina Vargas and Dennis Bricker (2000) combined the CCR output-oriented model of data envelopment analysis and Factor Analysis to evaluate the performance of academic units of a university graduate program. They proposed DEA/FA as a means of increasing the utility of DEA for policy decisions when there is uncertainty about the outputs relevant to the programs. They discussed the concept that an academic program always, in many cases maximizes the levels of some constructed outputs, which may not themselves be directly observable. By means of FA, these constructed outputs can be deduced from the observation outputs, and can be expressed as a linear combination of observed and random components. They explored combining DEA and factor analysis (FA) to help overcome the limitations of the CCR-OO-CI model (note that this model is not discussed in this thesis). FA is a multivariate statistical technique used to identify a relatively small number of factors that can be used to represent relationships among sets of many interrelated variables, since in this study, some input involve DEA, the used of FA may be used in this thesis to increase the utility of DEA for policy decisions if we are faced with uncertainty about output structure.

2.2 Malmquist Index (MI)

2.2.1 Definition

Base on Professor Sten Malmquist who realized that the economy of two nations could be compared and base on his knowledge, he regarded Malmquist Index, MI as a bilateral means of comparing the production technology of two economies in which each economy having the identical part on each side of the index, his idea, concluded the following definition about the index:

If we consider S_a as the set of Labor and capital inputs to the production function of economy A and f_a (x) is the production function of this Economy.

Then we can define:

Q= $f_a\ (S_a)$, the production function relating to A.

In order to calculate the Malmquist Index of economy A with respect to economy B, we must substitute the labor and capital inputs of economy A into the production function of B, and vice versa.

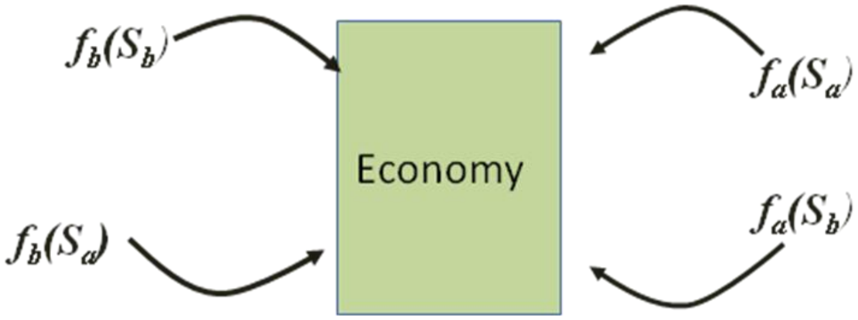


Figure 2.1: Figure shows capital and labor inputs relating production functions of two economies

Hence MI can be defined as follows:

$$MI = \sqrt{\frac{f_a(S_a)\,f_a(S_b)}{f_b(S_b)\,f_b(S_a)}} \qquad (2.15)$$

If MI >1, then the technology of economy A is superior or more advanced than that of B and vice versa.

2.2.2 Malmquist Index Related Studies

Giménez, V., et al (2013), presented an international comparison of educational systems with an application of Malquist-Luenberger global index. Here, 28 countries were involved and the performance changes of the systems were computed. This performance change was evaluated over time. This Malquist-Luenberger index was computed as a solution to remedy the two problems of circularity not assured, and the possibility of infeasibilities mentioned by Pastor and Lovell, (2005) and oh

(2010) when individual indexes (Malquist or Luenberger index) are used. Besides that, technical change is a necessary condition to hicks-neutral to ensure circularity, Balk (2001) and that a particular data structure ensures the absence of infeasibility, Harker and Xue, (2002). Based on their work, they were faced with the following problems;

- Using outcome Variable and efficiency indicators
- Considering Environmental factors beyond the educational authority control
- Considering the percentage of students failing to meet up minimum Learning Standards (LSs)

In this thesis, we may try to consider some of the above limitations in our computation to ensure good results. But in most cases, we will just use our proposed method for our calculation. For more precision in result, some of the factors will be considered.

Ahmad, H., et al., (2013) used the output orientated DEA-Malmquist index in estimating the productivity growth from panel data of 19 Faculties of Anbar University, FAUs in two academic years 2010-2011 and 2011-2012. The FAUs performance was determined on the change in total factor productivity and technical efficiency. The important finding in this paper is that two out of 19 FAUS are showing technological progress and the rest are experiencing technological regression. We intended to use this approach for the enhancement of technology-oriented systems and technical efficiency alongside with procedures that will enable educational institutions and their programs to always be of a standard not just regarding Student Outcomes and Performance but also considering the effectiveness of their technology and teaching methods by evaluating and comparing teachers and student's performance in two different periods of time. Meanwhile, António, A., et al, (2013) analyzed the productivity changes in basic and secondary education for 24 governors in Tunisia over the period 2004-2008 using Malquist Index as their methodology. In this work, four inputs were used; number of teachers per students, number of classes per students, number of schools per inhabitants, and expenditure on education per student which we may consider in this thesis to enhance efficiency, circularity and accuracy in our computation. Furthermore, Nadia Zrelli, B., (2013), proposed a dynamic analysis of the efficiency-quality relationship in higher education with the computation of indicators through non-parametric method, Data Envelopment Analysis, and demonstrates a possible disarray between these characteristics using Malmquist Index. Her technique facilitated the aggregation and weighting of the data used in the establishment of the indicator allowing to esteemed the higher education characteristics of every country. It uses linear programming techniques to define a best practice frontier that serves as a benchmark for estimating the performance of a given set of units. To ensured quality assessment, she used different types of DEA model; the radial model without inputs. This may be of great importance in this thesis to direct all the partial indicators towards their maximum values.

Aleksandra, P., and Joannan, W., (2011), presented patterns of productivity change in a large set of 266 public higher education institutions (HEIs) from seven European Countries across the time period 2001-2005. They adopted consistent bootstrap estimation procedures to establish confidence intervals for Malmquist indices of HEI productivity and their components. The bootstrapped Malmquist productivity index helps the establishment of the confidence interval. They mentioned some important factors that bring about changes in TFP, which may be considered in this thesis which included; changes in the relative position of DMU, evaluated with respect to the efficient DMUs forming the frontier, and changes in the position of the frontier itself.

Adela, GA., and Davinia PM., (2008), used the Malmquist non-parametric approach to analyze productivity changes in Spanish public universities from 1994 to 2004. According to them, the selection of inputs and outputs used to delimit the production function for modeling university behavior such as teaching, research and technology transfer was complicated. Many researchers concluded that there is no definitive method for selecting inputs and outputs (Beasley, 1990, 1995). Since studying output is problematic, in the case of teaching, for example, it is more preferable to consider measures of the learning such as competencies and concepts that may result from teaching, such as number of students enrolled, full-time equivalent students enrolled, student credit, number of degrees chaffered and the number of PhD graduates. Since, credit hours can differ significantly among programs for full-time students like science students involved in laboratory research against humanities students. These differences may likely reflect input differences when compared to learning differences. This is an important aspect to be considered when computing Student Outcomes using Malmquist index, and when monitoring the continuous improvement of the educational programs.

In 2007, Mary Caroline N.C., and Emilyn C., analyzed the efficiency and productivity growth of State Universities and Colleges (SUCs) in the Philippines. Firstly, they computed the output-orientated DEA-Malmquist index from panel data of 59 SUCS over the period 1999-2003 and from the results; they estimated DEA multi-stage model. They used the following inputs and outputs variables; number of faculty members, property, plant and equipment, and operating expenses as inputs and considered the educational institutions' outputs as; students enrolled graduates, and total revenue. We intended considering these inputs and output variables in computing since these variables may affect Student Outcomes.

Jill Johnes (2006), used data envelopment analysis (DEA) and a distance function approach to compute Malmquist productivity indexes for 113 English higher education institutions (HEIs) over the period 1996-1997 to 2002-2003 which he used to assess efficiency and productivity changes over time using distance functions. He defined and computed the following; Technical efficiency, scale efficiency and productivity growth. From his work, It was straight forward to relax the CRS assumption and assume variable returns to scale (VRS). Moreover, the Malmquist productivity index has also been used to obtain productivity on interval data, Hosseinzadeh L F., et al (2006). In their work they proposed a method for obtaining Malmquist Productivity index for interval data in which using DEA models, progress and or regress of DMUs can be evaluated.

We see from the above literature review that most of the evaluations deals with efficiency and performance, not linking student outcomes to a set of criteria to enable accurate evaluation of their performance. Secondly, most outputs and inputs differs, hence, in this thesis we try to compute a Malmquist index in which student outcomes can be evaluated and hence conclude performance using a single value compare to unity.

2.2.3 Relationship between MI and DEA

Malmquist indices were introduced in 1982 by Caves, et al. It was named after Sten Malmquist, who had earlier originate constructing input quantity indices as ratios of distance functions, and with this he used it to compare the productivity of two economies. Hence, MI functions in a situation where the production frontier shifts and the DMU is subjected to recover the productivity change Caves, et al (1982). DEA uses mathematical models to observe the data and to recognize relations such as the efficient frontiers and the production functions which are essential concepts of engineering and social science. However, a frontier represents a best practice technology in which observations that belong to it are called efficient by default and the others are inefficient. The efficiency of each observation at a given point in time is measured by means of a distance function best described by Fare et al using the Malmquist index, which reflects the distance between the observation and the frontier. Base on this relation, MI base on DEA can be derived using distance functions. To illustrate the concept of a distance function, let consider that in time period *t* the DMUs are using inputs $X^t \in m^+$ to produce outputs $Y^t \in s^+$. The input distance function $D(X^t, Y^t)$ can be defined on the technology Φ^t *as* the maximal feasible contraction of *cost* that still yields the production of Y^t;

$D(X^t, Y^t) = max \;\; \lambda : \;\; \{(\frac{X^t}{\lambda}, Y^t) \in \;\; \Phi^t\}$. The technology of production Φ^t consists of all input–output vectors that are technically feasible for a certain production process and the constant λ is the maximum feasible contraction between the inputs and outputs.

Note that $D(X^t, Y^t) \geq 1$ *if and only if* $(X^t, Y^t) \in \Phi^t$.

Malmquist index can be applied in many indices the above distance function was used by Fare et al., in 1994 to define an input-oriented productivity index as the geometric mean of the two Malmquist indices showing the technologies at time periods t and $t + 1$, yielding the following Malmquist-type measure of productivity:

$$MEI^{t,t+1} = \sqrt{\frac{D^t(X^{t+1},Y^{t+1})}{D^t(X^t,Y^t)} \cdot \frac{D^{t+1}(X^{x+1},Y^{x+1})}{D^{t+1}(X^t,Y^t)}} \qquad (2.16)$$

They went further to decompose the above index $M^{t,t+1}$ into an index reflecting the change in technical efficiency and an index reflecting the change in the frontier of the production possibility set which represent an index of technological change. This hence explains clearly the knowledge of Sten Malmquist, since with this technological change the efficiency of many firms, industries and or economies can be compare couples with their productivity and above all the estimation of their production frontiers. This is a great importance to DMUs. The decomposition was done as follows:

$$MEI^{t,t+1} = \frac{D^{t+1}(X^{t+1},Y^{t+1})}{D^t(X^t,Y^t)} \sqrt{\frac{D^t(X^{t+1},Y^{t+1})}{D^t(X^t,Y^t)} \cdot \frac{D^{t+1}(X^{x+1},Y^{x+1})}{D^{t+1}(X^t,Y^t)}} \qquad (2.17)$$

The ratio outside the bracket measures the input technical efficiency change between time periods t and $t + 1$. The geometric mean of the two ratios indicated inside the bracket captures the shift in technology (technological change) between the two periods, evaluated at the input–output levels (X^t, Y^t) at time period t and the input-output levels (X^{t+1}, Y^{t+1}) at time period $t + 1$. It should be noted that Malmquist index provides an inaccurate productivity measure when it is evaluated under variable returns to scale (Fare and Grosskopf 1996), In relation to the returns to scale assumption used for the estimation of the distance functions and for may be an accurate Malmquish index, constant returns to scale should be applied first, making use of CCR model.

2.3 ABET and Related Self-study Review

2.3.1 ABET

ABET is a "non-governmental organization that accredits post-secondary educational programs in science, computing, engineering, and technology engineer". In the early stage of the program, it operated mainly in the United State; it has evenly spread to internationally involve about 3278 programs which are accredited over more than 670 universities and 23 countries. ABET Accreditation is not ranking system, it applies to programs only, not degrees, department, college, institutes or individually. ABET has a format in which report about a program is presented, and criteria's to be followed. This report is normally reported as a self-study report since it entails private information about a program in a particular institution and the University in question. These criteria's are classified uniquely by ABET and any program interested for ABET Accreditation must provide a self-study following this criteria's, (ABET. Retrieved 2012-01-31, www.abet.org).

Self-study is a form of report describing in details how a program is structured and run according to ABET criteria's. With respect to ABET criterion 3 for accrediting engineering programs requires each program to have outcomes and more so, it requires that "this program outcomes are being measured and indicate the degree to which the outcomes are achieved by students. More precisely, how this program can be continuously improved by implementing a Continuous Improvement Plan (CIP). ABET accreditation is used in this thesis because ABET accredit mostly Engineering programs and is the accreditation program used in Eastern Mediterranean University (EMU).

Criterion 3 is one of the most important criteria in the ABET criteria's. Many programs round the world have written self-study report and some explain how direct and indirect measures can be used to measure students attainability of student outcomes (criterion 3), while some programs could not. Since as the word self-study implies, the information about their direct methods are confidential and private so little is known.

2.3.2 ABET Related Self-Study

One of the most important report on an ABET self - study is the one from the Civil engineering Program at the college of engineering and Islamic architecture Umm Al-Qura University Makkah, Saudi Arabia 2013-2014. This program successfully organized the program, according to ABET criteria's. Most interestingly, at the level of the Student Outcomes (criterion 3) data were obtained from direct and indirect measures. Lecturer involved in each course provides course learning objectives. Data were obtained from students using the Course Learning Objectives (CLO) and are used to evaluate Student Outcomes (SO) using a program call CLOSO. This program correlates CLO and SO. The program also provides and generates satisfaction survey forms that are used for the indirect measurement.

This program targeted performance of students called Program satisfactory Criterion (PSC) which specifies the percentage of students that must attain a certain level of ability represented by their percentage marks in each CLO and SO. In order to know where improvement is needed in the program, the program considered any level of satisfaction for a CLO or SO less than PSC, will trigger the alarm for the instructor to implement a course continuous improvement plan.

The program evaluation of SOs attainment through core courses, for each course, CLOSO Software performs analysis of the collected assessment data, producing two types of result.

- CLO satisfactory results: CLOSO software analyses and determines the percentage of students satisfying the Program Satisfactory Criterion for each assessment. Then weighted average is calculated for each CLO
- SO satisfactory result: CLOSO performs SO satisfactory analysis of each course using a conversion formula base on the CLO-SO map of the courses and produces percentage of students satisfying the program satisfactory criterion for each SO that is relevant to the course. See more about CLOSO at http:/www.smart-accredit.com

A self-study report for the Aeronautical and Astronautical engineering program at the University of Washington, 2013 showed a detailed description of the program according to ABET criteria's. No special method was mentioned on how direct and indirect measures can be used to measure student's response toward the Student outcomes. From the report, evidence shows that they have been continuous improvement of the program after each quarter for the interest of the student outcomes. Prior to specific improvement, their previous ABET review 2007 indicated that students were not receiving adequate preparation in the use of engineering computer analysis software. To solve this, the program changed their curriculum and replaces a CSE142 course with AMATH 301 (Beginning scientific computing. From this, we can say that the program has a unique and powerful tool for evaluating student performance and student outcomes hence easily monitor areas of improvement. Furthermore, June 2013 self-study from the school of mechanical engineering at Perdue University show adequate organization of the program, according to ABET, but how the indirect and direct measures for assessing student outcomes are used to measure student attainment was not mentioned. Moreover, in the same 2013, ABET self-study report for Civil Engineering at the University of Washington in Seattle, well followed the ABET criteria's in its program organization, but little information about how direct and indirect measures are used to assess the student outcome was mentioned.

Alex Koohang and Terry Smith presented a systematic approach to direct assessment of student learning adopted by ABET in 2012. They focus on the systematic process for regularly assessing and evaluating the extent to which the direct assessment of the student outcomes are being attained. They also explain how the results obtained from the method are used to effect continuous improvement of the program. The systematic approach included the following;

- Identifying sources of assessment for each student outcome
- Defining high-level Performance indicators (PI)
- Fine tuning
- Establishing strategies
- Establishing target for performance
- Designing the assessment methods
- Developing rubrics

They used two important points in setting the target for performance.

- Curriculum Support: The more courses that support student performance for each indicator, the more likely it is that students will receive the anticipated performance.

- Cognitive level: this included knowledge, comprehension, application, analysis and evaluation.

For each performance indicator students' performance was scored in four categories

1. Developing
2. Unsatisfactory
3. Satisfactory
4. Exemplary

As for the systematic data collection, an assessment package was developed to include the following.

- A description of the assessment entrustment
- The student outcomes matrix
- The recommended action of improvement
- The rubric
- Detailed result of the assessment

For more understanding, read the example presented by Alex koohandg and Smith. As the result entails, individual percentage of each course was calculated. The percentage obtained for each course in the PI were comparable to the target performance and from this, areas which do not meet up the target performance were noted for required improvement. This method did not show how indirect measures are used.

In the same year 2012, an ABET self-study report for the computer engineering program at the university of Florida adequately followed the ABET criteria's in organizing the program. At the level of student performance, they used both indirect and direct measures to assess students. This program reported a self-study in 2005 which they had an extensive reexamination of their objectives and outcomes. They didn't mention any direct method used to assess student outcomes from the direct and indirect measures used by the program to assess student outcomes, but did mention the use of a primary process for assessing and evaluating the objectives; Alumni-survey Analysis. This was used for the continuous improvement of the program. The questions were designed to entail Yes/No. See more details on ABET CEN-self-study. A unique process was used to evaluate student outcomes, where quantitative data were obtained in direct form from assessment administered by course instructors. Students' performance was normalized using a scale called Likert scale. See more ABET CEN-self-study. Here the target of performance was kept at 80% and the Average Likert Value at 3.0. If any outcome for a particular course is less than 80% indicate improvement, their analysis based on student achievement of the objective and Average Likert Value. Nothing was mentioned how this Average Likert Value was calculated. Also, the indirect data were not used to assess student outcomes, but the program is strongly monitored i.e. the implementation of COT 4501, numerical methods in fall 2011. Moreover, in 2012, the ABET self-study report for the bachelor of engineering in communication and electronics at Beirut Arab University Debbieh, Lebanon mentioned nothing about direct methods used to assess direct measures on how students attained the student outcomes. Also the self-study report for the Bachelor of Science in Electrical Engineering at Lemar University, Beaumont, Texas uses appropriate courses offered to organize the program to meet up the a-k Abet student outcomes Objectives. No information was mentioned on how the direct and indirect measures were used to assess student outcomes a-k.

The self-study report in June 2010 for the Electrical engineering program at the university of New Mexico, Albuquerque, NM, adequately followed the ABET criteria's in organizing the program. In this report, no clear information was given on how the direct and indirect measures are used to assess student outcomes. Meanwhile July 2009 self-study report from the department of Ocean and Resource Engineering at the University of Hawait in Monoa Honolulu, adequately organized the program according to ABET criteria's. One of the most important direct measures used to assess student outcomes and performance was the Masters Qualification exams. This measure is rare in most engineering program round the world, and it is a great way to evaluate student performance couple to student outcomes at the master's level. And on the indirect measures was the ABET course review done at the end of each course by both students and faculty. This is also an excellent tool in indirect measure. No special method was mentioned on how student outcomes were determined using the indirect and direct measures.

In 2008, Hakan Gurvacak, Washington State University Vancouver presented a direct measure for course outcomes assessment for ABET accreditation. His approach explained how direct measures are used to measure the extent to which each student does achieving each course outcomes couple to SOs. In this approach, the instructor keeps track of the performance of each student throughout the semester. At the end, each student received a "SCORE" on a scale of 1-5 (for every outcome indicating how well he/she achieved each student outcomes. The course outcomes were measured by assessing targeting these skills on homework and exams. This approach worked on basic requirements;

- Grading are broken down each course outcome on assignments and/exams using a grade box

- At the beginning of the semester, a course plan is prepared by course instructor and faculty including assessment

The Grade is then entered into grade spreadsheet for each outcome for further analysis. After all the above steps were done, in assigning an outcome Score (1-5 Scale) to a student, the following formula was used:

$$SCORE = \frac{\sum_{k=0}^{n} all\ point\ earn\ by\ students\ in\ outcomes\ k}{\sum_{k=0}^{n} all\ possible\ points\ in\ outcomes} \quad (2.18)$$

This provides a starting point. Here the instructor can carefully review these scores and make adjustment depending on the observation of the performance of a particular student throughout the semester since the student factors we discussed above in the introduction could still make a student passed. The achievement of the outcomes of the course level and general student outcomes was assessed by taking the overall average of all student Score in each outcome.

We should note that for the selected Self-study reported examined above, the majority of the report related to the Program Educational Objectives (PEOs) of the program and the ABET criterion 3 (a-k outcomes) successfully with clear expected achievement of students at the end of the program. They failed to use indirect measures to assess this a-k objective. We know so well that examination and assignment that most programs used as direct measure is not the alternate best since we know the factors that lead to student passing this assessment. Some indirect measures like alumni survey, Student course Abet report, industrial report, etc. are very important when it comes to assessing these outcomes, since some student may be so good in practical issues not theory. Hence, I suggest the indirect and direct measure should be used maybe 40%-60% or 50% each in assessing student outcome.

We also know program objective has a general view of the program itself, but when each course is concerned with the objective differs. The person concerned with these objectives and how it's used to make sure student attained, the student outcomes are the faculty and lecturers. So they should be a correlation relating how these objectives are being administered to students i.e. how the lecturer delivers the message to the student also defined the extent to which the objectives are assimilated by students, therefore they play a vital role in student outcomes turn out, hence they should be included in the determination of Student outcomes and performance directly or indirectly since the improvement of the program could still be to change the lecturer of a particular course.

Chapter 3

COMPUTING MALMQUIST INDEX AS AN EDUCATIONAL MEASURE FOR EVALUATING STUDENT OUTCOMES (SOs)

The goal, aim or main objective of this thesis is to be able to compute Malmquist index that can be used for educational purposes particularly assessing student outcomes. We have seen how Malmquist index is defined according to production technology of an economy according to professor Sten Malmqist. This knowledge will be used in this chapter to defined malmquist index suitable for educational purposes hence instead of production technology used in chapter two, we will use Educational technology where technology indicates all necessary resources, lecturers, assessments measure, surveys, and even students, etc., that is used by an educational institute to ensure the accurate assimilation of student outcomes by the student and maximum delivery of information that entails the student outcomes and course outlines by the lecturers. We will start with a rough definition of the Educational Malmquist index and later show how it can be used as an important tool for educational purposes.

3.1 Malmquist Educational Index Computation, MEI

Based on Professor Sten Malmquist who realized the economy of two nations could be compared, we will consider MI as a bilateral means of comparing the educational technology of two universities/institutes or outcomes of student and instructor in which each university/institute or student/instructor is having an identical part on each side of the index. Base on his idea, we would call it the Malmquist educational Index (MEI).

Each university/institute provides a functional frontier, but however they do not provide a general relationship or equation relating output and input. However, each frontier represents a best practice technology in which observations that belong to it would be called efficient by default and the others are inefficient, this will depend on MEI. The productivity of each observation at a given point in time is measured by means of a distance function using the Malmquist Educational index, which reflects the distance between the observation and the frontier. This explains why with the used of distance functions, the performance or outcomes of a program taking students and lecturers into considerations can be compare giving two different periods. Based on Malmquist Sten idea, the Malmquist educational index can be defined as follows:

So let us consider the following definitions:

S_i = *the set of inputs to the educational function of a course or program,*

i= student(s) or teacher/instructor (t)

Q = the Educational results of a course or program

f_i = *educational function,*

s = students in the faculty or department

t = teachers/instructor in the faculty or department

Hence, $f_i(S_i) = Q$ *is* the educational result relating the course or program under evaluation by accepting that the educational function can be changed considering the instructor and or student's point of view in the educational function as f_t and or f_s where f_t and f_s represents the educational function of the instructor or teacher and student respectively. In order to calculate the Malmquist Educational Index (MEI) of a course or program, we must substitute the inputs of the instructor S_t into the educational function of the student to have an educational result $f_s(S_t)$ from the student's point of view and also considering the student educational result of a course or program $f_t(S_s)$ from the teacher's point of view and vice versa. The formula for MEI can be written simply as follows;

$$MEI=\sqrt{\frac{Q_1Q_2}{Q_3Q_4}} \tag{3.0}$$

Where,

$f_s(S_s)$ = Q1, $f_s(S_t)$ =Q2, $f_t(S_s)$ =Q3 and $f_t(S_t)$ =Q4

Hence, (note that the equation reflects students, for teachers, we take the inverse)

$$MEI=\sqrt{\frac{f_s(S_t)f_s(S_s)}{f_t(S_t)f_t(S_s)}} \tag{3.1}$$

Note that if the MEI of a course or program is greater than 1, then the aggregate educational technology of the program is good and efficient and if MEI<1, the aggregate educational technology of the course or program is inefficient and need improvement. Efficient programs fall within a set of criteria provided by an accredited program under which the program is being evaluated. To relate the above definitions and formulations to how we can use it to assess Student Outcomes, SOs, we need to review the general criterion 3 according to ABET Accreditation.

3.2 Evaluating Student Outcomes (SO) using ABET Criterion 3

The MEI above can be modify considering the ABET student outcomes and use to evaluate student outcomes. Based on ABET general criterion 3,

- “The program must have documented Student Outcomes that prepare graduates to attain the program educational objectives”.
- “There must be a documented and effective process for the periodic review and revision of these student outcomes”.

For the purpose of this criterion, broadly defined activities are those that involve a variety of resources; that involve the use of new processes, or techniques and materials in innovative ways; and that require knowledge of standard operating procedures. Narrowly defined activities are those that involve limited resources or knowledge, that involve the use of conventional processes and materials in new ways, and that require knowledge of basic operating processes. To meet up the General Criterion above, Student Outcomes, ABET classified into a-k. Moreover, each university or department can add other student outcomes or separate any of the student outcomes regarding their aims into subgroups for a particular course in the ABET a-k student outcome criterion without changing the ABET objectives.

a) An ability to apply knowledge of mathematics, science, and engineering
b) An ability to design and conduct experiments, as well as to analyze and interpret data
c) An ability to design a system, component, or process to meet desired needs
d) An ability to function on multi-disciplinary teams
e) An ability to identify, formulates, and solves engineering problems
f) An understanding of professional and ethical responsibility
g) An ability to communicate effectively
h) The broad education necessary to understand the impact of engineering solutions in a global and societal context
i) A recognition of the need for, and an ability to engage in lifelong learning

j) A knowledge of contemporary issues

k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Looking briefly at the a-k expected students Outcomes according to ABET, especially (c), we see that (c) is a very important point to note from graduates, especially for the engineering programs, since some educational institution does not have Up-to- Standard (UTS) laboratory to run engineering programs and engineers deals mostly with real life and practical issues but yet offers the program. Graduates from such institution won't meet up with the a-k objectives. Our proposed method for evaluating student outcomes for each course for a given program, according to ABET criterion 3 listed above involved two parties; the teachers and the students. Here the course outlines (consider as course learning objective, CLO) and the ABET a-k students outcomes are used together where information on how much a course can be matched to the a-k student outcomes using CLO from the teacher point of view and how much the students can be matched to the course using the a-k criterion from the teacher's point of view are obtained on one side and on the other side, information on how much the course is matched to the a-k criterion from the student point of view using the course assessment survey, CAS and how much the teacher can be matched to a-k criterion from the student's point of view using a student course-instructor evaluation survey. This information obtain from the two parties can be used to make the MEI for evaluating the student outcomes more explicit. We should note that the above mentioned criterion relates the Student Outcomes and to evaluate it using the above definition of MEI, we must show how each parameter from the index could be obtained for a particular course or program.

Let us consider the figure below:

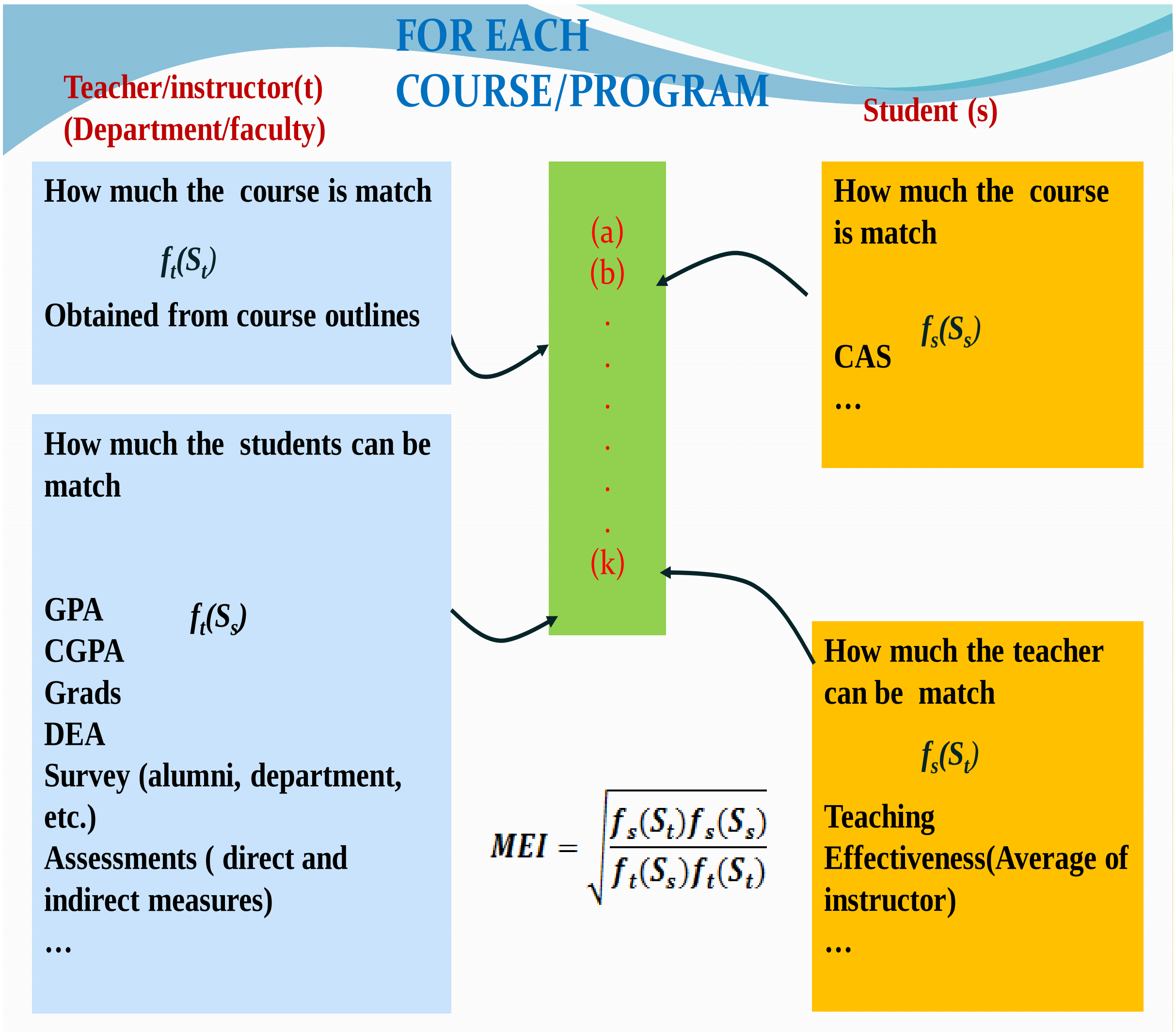


Figure 3.1: Diagram showing how teachers and students can be matched onto the a-k criterion.

From figure 3.1, we can define the following:

s = students in the faculty or department

t = teachers or instructor in the faculty or department

Regarding the department or faculty offering the program;

a) $f_t(S_t)$ = how much the course can be matched to the a-k outcomes, according to the teacher's point of view with respect to the course learning objectives and or outlines of the course.

b) $f_t(S_s)$ = how much the students can be matched to the a-k outcomes provided the aims and objectives of the course were realized. This can be obtained by evaluating student's performance based on the a-k outcomes using the indirect and direct measures discussed earlier in the opening chapter. An average or efficiency is calculated using DEA considering series of input(s) and output(s). We will consider each student registered for a program as DMU and their output(s) and input(s) are shown on the following figure below considering the previous CGPA and teaching effectiveness (average of instructor or teacher) as inputs and the ratio of final grades to course class average for each student and continuous assessment grades as outputs.

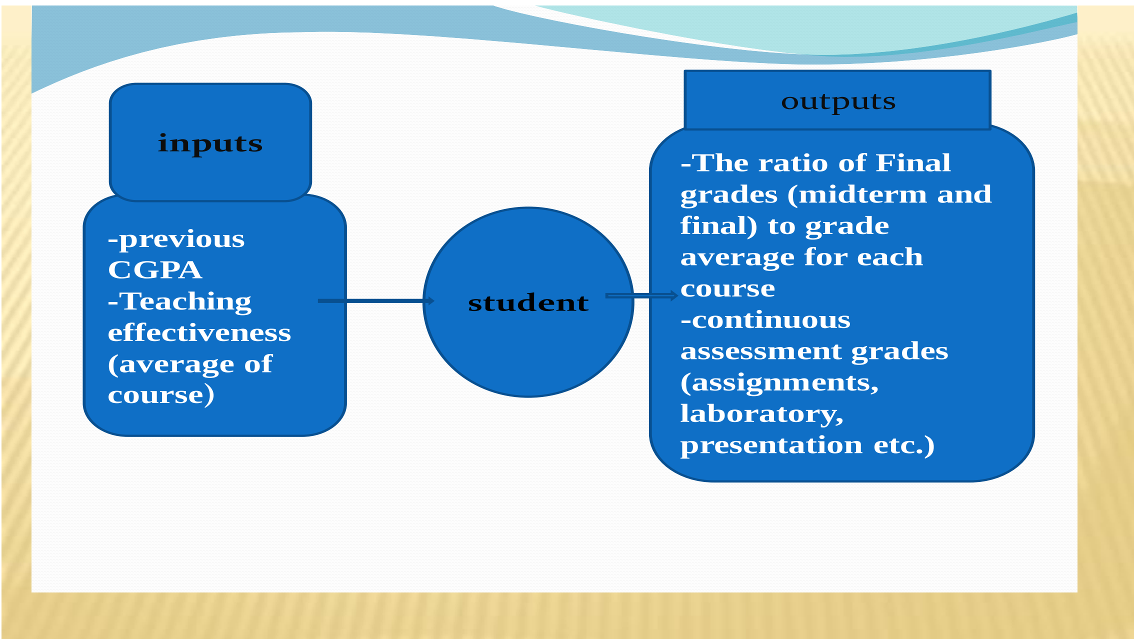


Figure 3.2: Diagram showing the inputs and outputs for a given course

Note that GPA, CGPA, and grades are obtained from direct measures, while surveys, presentation, graduation and retention rates etc. are obtained from indirect measures. This parameter includes the indirect and direct measure which most self-study report failed to include.

Regarding the students taking the program;

c) $f_s(S_s)$ = how much the course can be matched to the a-k outcomes from the student's point of view obtained from CAS (Course Assessment Survey) of the course provided by the department or faculty.

d) $f_s(S_t)$ = how much the teacher can be matched to the a-k outcomes, according to the student's point of view. This also determines the teaching effectiveness. This is obtained from the student course-instructor evaluation survey provided by the university at the end of the semester.

Thus the Malmquist educational index with regard to teacher and student is as follows:

$$MEI=\sqrt{\frac{f_s(S_t)\,f_s(S_s)}{f_t(S_t)\,f_t(S_s)}} \qquad (3.2)$$

<u>EXMAPLE 1.</u> Let us consider IENG314.

$f_s(S_s)$ *=4.76 *4/5=3.8 (CAS Avg shifted to [0,4])*

$f_s(S_t)$ *=3. 85 (Teaching effectiveness obtained from the average of instructor)*

$f_t(S_t)$ *=1.27*2=2.54 (obtained from the course outlines, Avg shifted to [0,4])*

$f_t(S_s)$ *=3 (Grade Avg) in this example we considered Grade average*

$$MEI=\sqrt{\frac{f_s(S_t)\,f_s(S_s)}{f_t(S_t)\,f_t(S_s)}} = \sqrt{\frac{3.8x3.85}{2.54x3}} \quad =1.382., MEI > 1$$

MEI is greater than one, hence we can conclude that the student outcomes, according to the course IENG314 were successfully attained by the student and the teaching effectiveness and educational technology is of standard at that particular moment.

3.3 Evaluation for Continuous Improvement Plan (CIP) of the Program

3.3.1 Generally Interpretation and CIP

The MEI value defined above represents a value which could be greater than 1 or less than 1 or equal to 1. The following can be interpreted from the index.

1. $MEI < 1$, observe regress in student outcomes with respect to the course

2. $MEI > 1$, observe progress in student outcomes with respect to the course.

3. $MEI = 1$, do not observe any change, that is neither progress nor regress, but is a good sign for student outcomes than when $MEI < 1$. Specifically, a course in a program having MEI less than one needs an improvement. This would call for the immediate attention of the instructor responsible for the course to quickly develop measures on how to remedy the situation according to CIP. This may follows by continuous departmental meetings depending on the level of the problem.

Generally, if the average of all the MEI of the courses offered by a program is greater than one, then the program is in progress and need no improvement. And if less than one, the courses with less than one MEI values must implement the defined, documented rules to improve the course MEI value thereby improving the MEI of the program. If the average MEI is equal to 1, the program will equally need improvements since the objective for any program is always being in progress not constant according to the Criteria's provided by ABET. This method is suitable as a continuous improvement measure for educational purpose because just evaluating the

MEI for any course or the Averages of MEIs for a given program, we can conclude with respect to MEI value(s) if the program offer by the university/department is improving or not by comparing the value to unity.

3.3.2 How to Improve the MEI Value Less than 1

Recall that;

$$MEI=\sqrt{\frac{f_s(S_t)\,f_s(S_s)}{f_t(S_t)\,f_t(S_s)}}$$

Two values from the formula above can make the value of MEI less than one. This includes all the values in the denominator. Note that these values include only the teacher's point of view, hence, to improve the value of MEI we consider the individual values separately as follows;

- The first value indicates how the students are matched to the a-k Abet criteria from a teacher's point of view. Remember that this value is obtained from grades or an efficient average obtained from DEA as we have seen above. To improve this value we verified if our model was output oriented model, if so, then we need not to concentrate more on the student outputs, but on the inputs provided by the university (teachers, laboratories, teaching effectiveness, etc.) needed by the students to produce the required output performance and outcomes needed by the instructor, hence the model should be changed to input oriented CCR model to improve MEI. If in the case where Average of grades were considered, then the instructor need to revise his grading policy and readjust the grades of the students.
- The second value indicates how much the course can be matched to a-k from a teacher's point of view. As we mentioned above, this is usually obtained from the course outlines showing course learning objectives. In this case the

instructor and the department need to revise the grading of the a-k student outcomes with respect to the course. Maybe a value of 2 or 1 was given to an outcome, not highly needed in the course which even students themselves did not see it important for them and hence increasing the expected outcomes of the course. This value given to each outcome in the course outlines must be revised again in order to improve the Value of MEI of that course.

3.4 Comparing the same Programs Offered by Two Different Universities.

In this case, we will consider u_1 as university 1 and u_2 as university 2 offering the same program as the case may be. In order to calculate the Malmquist Educational Index of university 1 with respect to university 2, we must substitute the student outcomes of university 1 into the educational function of university 2, and vice versa. The formula will be reconsidered as:

$$MEI=\sqrt{\frac{f_{u_1}(S_{u_1})\, f_{u_1}(S_{u_2})}{f_{u_2}(S_{u_2})\, f_{u_2}(S_{u_1})}} \qquad (3.3)$$

Note that we can equally compare the students abilities and teachers' abilities separately for two different universities in a particular program using the same formula above. Note the following can be defined:

a) $f_{u_1}(S_{u_1})$ *is the student outcomes of university 1 when the educational function of university 1 is used.*

b) $f_{u_1}(S_{u_2})$ *is the student outcomes of university 1 when the educational technology (inputs) of university 2 is used.*

c) $f_{u_2}(S_{u_2})$ *is the student outcomes of university 2 when the educational function of university 2 is used.*

d) $f_{u_2}(S_{u_1})$ *is the student outcomes of university 2 when the educational technology (inputs) of university 1 is used.*

e) S_{u_1} *is the set of inputs (educational technology) to the Educational function of university 1*

f) S_{u_2} *is the set of inputs(educational technology) to the Educational function of university 2.*

The above parameters are obtained same as we described above for each course/program. The educational functions of a university here represent the educational functions of the teacher/instructor or student that depend on whether we are comparing students' outcomes of the separate universities or the instructor/teacher outcomes of the separate universities. Note that the MEI of university 1 with respect to 2 is the reciprocal of the MEI of university 2 with respect to university 1. If the MEI of university 1 with respect to 2 is greater than 1, the aggregate educational technology of university 1 is superior to that of university 2 and hence offers the best programs and vice versa.

3.5 Comparing the Performance of a Program in Two Different Periods Using Distance Functions

To compare the performance of a program in two different periods, we consider the performance of students as time period changes and the performance of teachers as time period changes separately since the teacher or student improvement in performance depend on each other and the teachers could observe an improved in performance moving from year one to year two while the students' performance remains unchanged or observed regress and vice versa. This is because the majority of the students during that period might have been bad students. Bad students here refer to students who failed to do their assignment, stayed away from classes, etc. Period changes could be from one year to another or one semester to another. Let us consider the figure below considering changes in the time period from year one to year two:

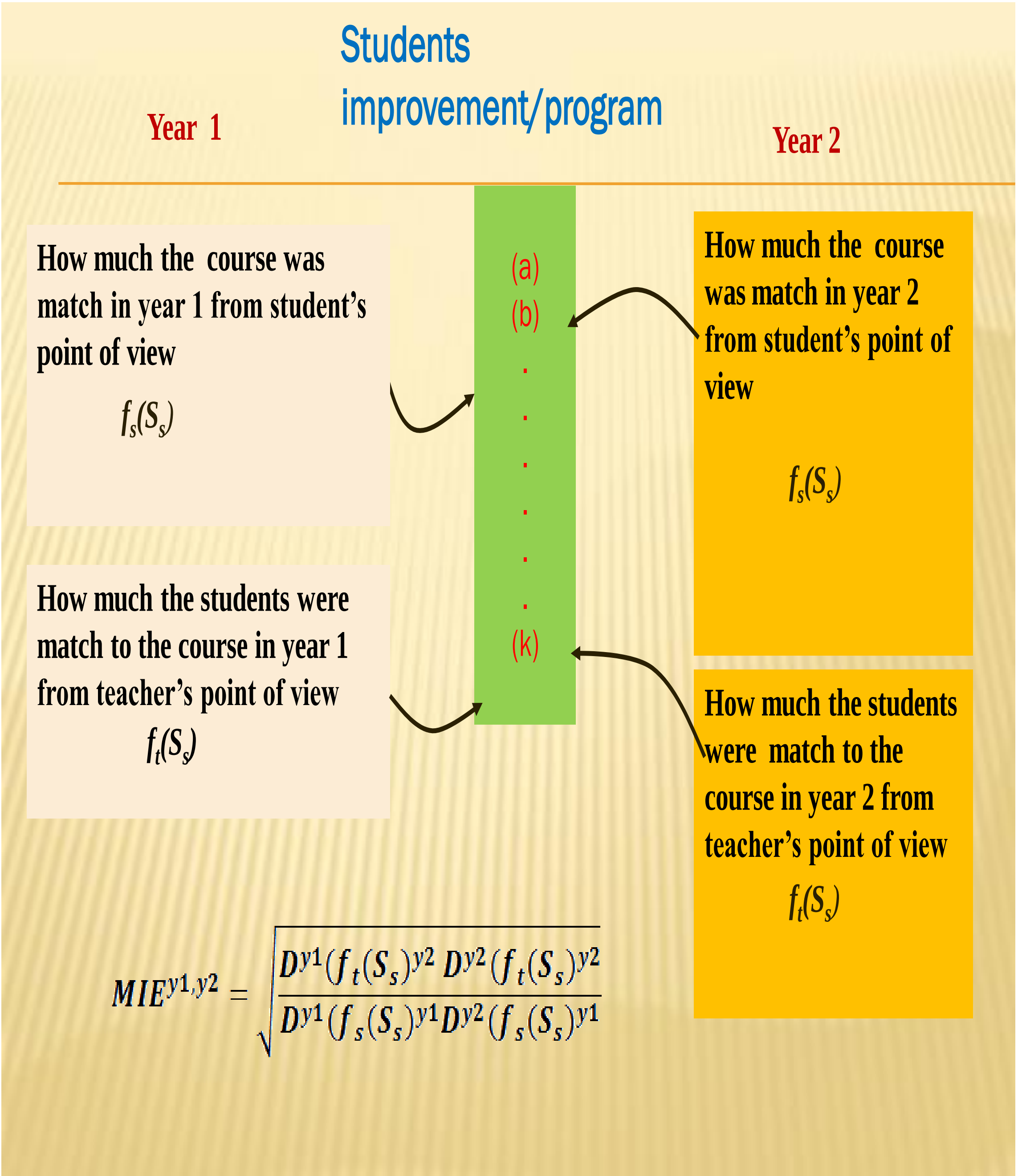


Figure 3.3: Diagram showing student performance/outcomes in two different years

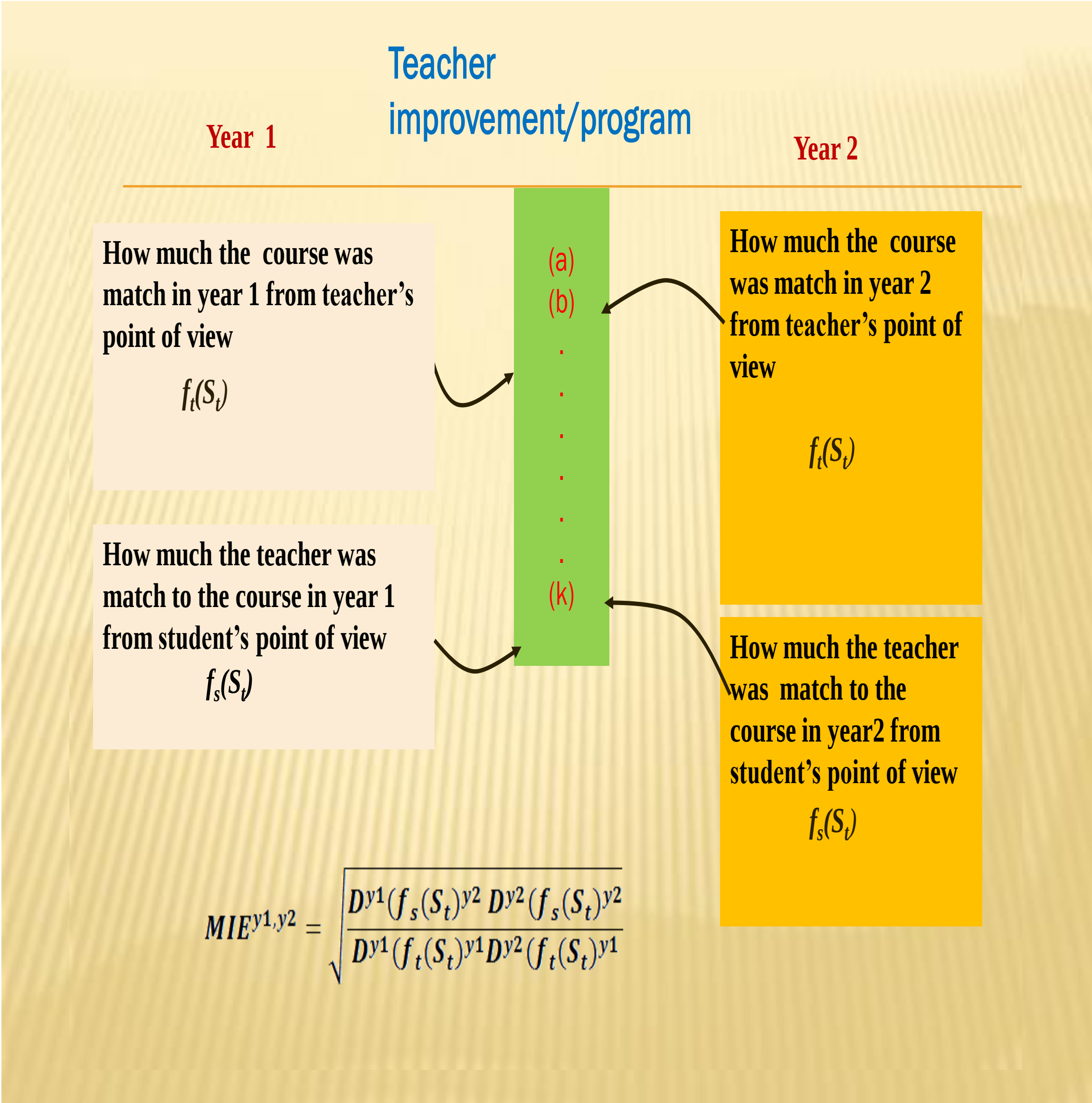


Figure 3.4: Diagram showing teachers' performance in two different years

From the diagrams above, the following MIE equations are defined.

$$MEI^{y1,y2} = \sqrt{\frac{D^{y1}(f_t(S_s))^{y2}}{D^{y1}(f_s(S_s))^{y1}} \cdot \frac{D^{y2}(f_t(S_s))^{y2}}{D^{y2}(f_s(S_s))^{y1}}} \tag{3.4}$$

$$MEI^{y1,y2} = \sqrt{\frac{D^{y1}(f_s(S_t))^{y2}}{D^{y1}(f_t(S_t))^{y1}} \cdot \frac{D^{y2}(f_s(S_t))^{y2}}{D^{y2}(f_t(S_t))^{y1}}} \tag{3.5}$$

Equation 3.4 is used to compare student's performance for a given program in two different years as shown on figure 3.3 while equation 3.5 is used to compare teacher's performance for a given program for two different years as shown on figure 3.4. We can note the following:

I. The value, $D^{y1}(f_t(S_s))^{y2}$, $D^{y1}(f_s(S_t))^{y2}$ is obtained when the inputs S_t, S_s Of the year 2 is substituted in the distance education function in the year 1

II. The value, $D^{y2}(f_s(S_s))^{y1}$, $D^{y2}(f_t(S_t))^{y1}$ is obtained when the inputs S_t, S_s Of the year 1 is substituted in the distance education function in the period 2.

III. $D^{y1}(f_s(S_s))^{y1}, D^{y1}(f_t(S_t))^{y1}$ is obtained when the inputs S_t, S_s of the year 1 are used in the year 1

- $D^{y2}(f_s(S_t))^{y2}, D^{y2}(f_t(S_s))^{y2}$ is obtained when the inputs S_t, S_s In the year 2 is used in the year 2. Note also that the values listed below are the same if and only if the educational technology from year one to year two remain unchanged and the number of students and lecturers remains unchanged and the course instructors of the program were not changed either
- $D^{y1}(f_t(S_s))^{y2} = D^{y1}(f_t(S_s))^{y1}$
- $D^{y2}(f_t(S_t))^{y1} = D^{y2}(f_t(S_t))^{y2}$
- $D^{y2}(f_s(S_s))^{y1} = D^{y2}(f_s(S_s))^{y2}$
- $D^{y1}(f_t(S_s))^{y2} = D^{y1}(f_t(S_s))^{y1}$

If we observed a change in any of the above being it an increase or decrease in the number of teachers or students or change of course instructor and or improve in technology when moving from year one to two, we must calculate the new value as indicate on the formula.

Since the above compares' the performance of students and teachers of the same program in different periods of time and includes a series of inputs and outputs that were considered during each period, each value can be obtained the same way as described from *figure 3.1* above. We should note that outputs and inputs for each course may change from period to period since new courses and measures of improvement are being introduced and applied. It could be further decomposed into technical efficient change and technological change as follows

$$MEI^{y1,y2} = \underbrace{\frac{D^{y2}(f_t(S_s))^{y2})}{D^{y1}(f_s(S_s))^{y1}}}_{A} \underbrace{\sqrt{\frac{D^{y1}(f_t(S_s))^{y2}}{D^{y2}(f_t(S_s))^{y2}} \cdot \frac{D^{y1}(f_s(S_s))^{y1})}{D^{y2}(f_s(S_s))^{y1}}}}_{B}$$

Where A= technical efficiency change, B= technological change. "A" indicate the relative efficiency change of the student from year 1 to the year 2 while "B" indicates how much the technology (teaching, laboratories, teachers, classrooms, students, benches, etc.) of the school has changed from year 1 to year 2 with respect to student and teacher performance and outcomes.

From the decomposition above, we can conclude the following:

I. If the $MEI^{y1,y2} > 1$, then the program is efficient and the educational technology of the program is in progress. Hence the program offered in year 2 is efficient and educationally ok when compared to the year 1 and vice versa.

II. If the $MEI^{y1,y2}$ < 1, the program in year 2 is inefficient and observe no progress in it educational technology of the program offer by the University/Department hence need improvement from year one to year two.

Also note that a program can observe efficient changes in the year 2 when compared to year 1 but observed no technological change, or observed regression in its technological change (i.e. A>1 and B<1 or B >1 and A<1) as the case may be and vice versa.

3.6 How to Obtain Value for MEI Calculation Considering ABET Criterion 3

The values $f_s(S_s)$, $f_t(S_s)$, $f_t(S_t)$, $f_s(S_t)$ can be considered on a scale of 0-4 since GPA and CGPA are always calculated within the scale 0-4. Here, qualitative information could be transformed into quantitative information by assigning 0, 1, 2, 3, 4 or 5 depending on the magnitude or level of contribution the a-k student outcomes contribute to the course outline or objectives for a given program. For qualitative information regarding the surveys (CAS, student course-instructor evaluation surveys, etc.), the scale assigned to the a-k student outcomes contribution to the surveys differs.

3.6.1 How much the Course can be matched to a-k Outcomes from the Instructor or Department's point of view, $f_t(S_t)$.

This value can be obtained from the course outlines or Course Learning Objectives and this value depend on the teacher/instructor's opinion teaching the course and also the departmental meeting. The course outlines is produced by the instructor, usually after the departmental meeting. The course outlines is design considering ABET a-k student outcomes in which each outcome is considered and the level of contribution of each outcome of the course is determined by the instructors and department heads during the departmental meeting. The level of contribution is then classified either as moderate, high and or No contribution. The scale of 0-2 is used to assign real values to each a-k student outcomes to indicate each level of contribution to the course. A higher value is assigned to an outcome highly needed in the course outlines by the students. An average of these values is calculated for each course outlines. From the instructor and department agreement, a course outline can be designed as shown below:

Table 3.1: Showing a sample of course outlines and course of the student outcome relationship

	Level of Contribution		
Student Outcomes	**Moderate**	**High**	**No**
(a) An ability to apply the knowledge of mathematics, science and engineering			
(b) An ability to design and conduct experiments, as well as to analyze and interpret data			
(c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability			
(d) An ability to function on multi-disciplinary terms			
(e) An ability to identify, formulate, and solve engineering problems			
(f) An understanding of professional and ethical responsibility			
(g) An ability to communicate effectively			
(h) The broad education necessary to understand the impact of			

engineering solutions in a global, economic, environmental, and societal context			
(i) A recognition of the need for, and an ability to engage in lifelong learning			
(j) A knowledge of contemporary issues			
(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice			

3.6.2 How Much the Students can be matched to a-k Student Outcomes from Teacher's Point of View, $f_t(S_s)$

This can be obtained by evaluating student's performance based on the a-k outcomes using the indirect and direct measures discussed earlier in the opening chapter. An estimate of this value can be obtained by calculating the average of grades in each course, considering the grade score of each student commonly refers to as course average. For more accuracy when calculating $f_t(S_s)$ an average of efficiencies can be calculated using DEA, considering each student as DMU with the previous CGPA and Teaching effectiveness (average of instructor) as inputs and the ratio of Final grade (final and midterm exams) to grade average for each student and continuous assessment grades as outputs. Other inputs and outputs can still be considered. The teaching effectiveness is considered as input because the instructors affect the student outcomes and performance directly and this can be easily obtained from student course-instructor evaluation survey provided by university usually opens two weeks before and ends on the last day of the courses for the semester. A previous CGPA of the student is also considered as input because it initially indicates the level of the student at the start of the semester. The ratio of the final grades to the class average is considered as output since it provides normalized ratio of what each student know as far as the direct measure of assessment is concerned while the continuous assessment grades provide information on how the students were being assessed indirectly or directly. These factors ensure that the indirect and direct measures are considered alongside with the department surveys in the evaluation of student outcomes for a given course. Here the direct and indirect measures are decided by the course instructors who best understand the course outlines and objectives relating the a-k outcomes.

3.6.3 How Much the Course is Matched to a-k Outcomes from Student's Point of View, $f_S(S_S)$

This is obtained from CAS (Course Assessment Survey) of the course provided by the department usually ABET oriented. This survey usually open two weeks before and ends on the last day of the courses for the semester. Here some questioners are designed by the department considering the ABET a-k student outcomes for each course, according to the objectives of the course provided by the instructor at the beginning of the semester. This is provided for students to fill usually online. The course assessment survey questionnaire is usually organized in blocks. The first block requires information about student understanding of the course, the second block requires information about the student's skills, and the third requires information about a student's knowledge about the course. The questionnaire is organized such that a scale number 0-5 is assigned to the student's opinion with the opinion strongly agreed by students given the scale number 5, while opinion strongly disagreed is considered blank or given the number zero. The average and percentage of each row is calculated and column averages calculated which represent the result of the survey in terms of average in the scale between 0-5. Percentage calculated less than 75% is considered a problem as far as that objective is concerned and will call for immediate action by the instructor to remedy the situation, but when it becomes too low, the departmental meeting is called upon. A sample of the questionnaire is shown below:

Table 3.2: Showing a sample of a course assessment survey relating student outcome relationship, Spring 2012-13

Part	**Opinion**							**Average**
I have developed knowledge and understanding of:	**Number of responses**	**5**	**4**	**3**	**2**	**1**	**Blank**	
1.use of modeling in optimizing problems								
2. Modeling real life situations								
3. Solving linear programming problems by Lingo and WinQSB								
4. Basic concept in linear programming								
5. Applying modeling and optimization in diverse field								
6. Role of integer programming g models in IEs problems								
7.Transportation type models								
8. Formulation of network models								
I have developed skills in:								
9. Formulation of linear models of optimization problems								

10. Use of computer software in optimization								
11.Understanding of integer programming as a powerful modeling tool								
12.graphical analysis of simple linear models								
13.developing network models								
I have developed an appreciation of and respect for the values and attitudes to:								
14.Role of linear in IE								
I5. Importance of modeling and optimization in diverse fields of science and engineering								
16. Impact of optimization software in solving models for real life situations								
17. Professional and ethical responsibility								
The course makes a significant contribution to the following program outcomes								
a) An ability to apply knowledge of mathematics, science, and engineering								
b) An ability to design and conduct								

experiments, as well as to analyze and interpret data								
c) An ability to design a system, component, or process to meet desired needs								
d) An ability to function on multi-disciplinary teams								
e) An ability to identify, formulates, and solves engineering problems								
f) An understanding of professional and ethical responsibility								
g) An ability to communicate effectively								
h) The broad education necessary to understand the impact of engineering solutions in a global and societal context								
i) A recognition of the need for, and an ability to engage in lifelong learning								
j) A knowledge of contemporary issues								
k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice								

The course assessment survey process provides the department with one of the few opportunities to discuss course content with each other and, based on the results of the assessment; determine how they can improve student learning and performance in the course. The result obtained from this survey is usually confidential hence information needed to evaluate student outcomes can be provided by the department chair or dean.

Using course assessment results as evidence, instructors might decide to;

- Search for active learning strategies and other teaching methods
- Research for technological enhancements (CD tutorial, labs, equipment, more assignments, presentation, more practical examples, etc.),
- Revised the course outcomes and outlines to involve much more higher thinking and greater intellectual asperity.
- Put more effort on research and invest more on research.
- Explore and introduce more other ways of assessing outcomes

3.6.4 How much the Teacher can be matched to a-k Student Outcomes, $f_s(S_t)$ from Student's Point of View

This determines teaching effectiveness of the teachers/instructors and can be obtained from student course-instructor evaluation survey provided by the university at the end of every semester. This survey ends usually open two weeks before and on the last day of the courses for the semester. Here the questionnaires are prepared by the university for each course and provided for students to fill through their portal. This survey is university oriented and the university is interested in knowing the opinion of students regarding specific instructors. The survey is also arranged in a way that the opinion of students is classified under strongly agreed, agreed, strongly disagreed, disagreed and blank or neutral. Scale numbers are assigned to these opinions and average calculated as in CAS.

This survey reviews two important results; average, of course and average of instructor. The average of instructor gives the theoretical input of the lecturer as far as the course is concern for that semester, while the average of the course theoretical gives expected performance of the students according to students' opinions. This survey is an important survey as far as the student outcomes are a concern. A sample of this survey is shown below.

Table 3.3: Table showing a sample of student course-instructor evaluation survey for IENG314 and course of student outcome relationship, Spring 2013-14

EMU Student Ratings of Instructor / Course

Student course-instructor evaluation survey

A- COURSE INFORMATION (DERS)	
Academic Year/Term	2013-14/2
Course Code/Group	IENG314/01
Course Name	Operations Research - II
Instructor Name	
# of Students Enrolled	

B- STUDENT INFORMATION (ÖĞRENCİ)									
I) The grade I expect to receive in this course: / Bu dersten almayı öngördüğüm not:						**II)** The approximate number of hours spent each week studying for this course: / Bu dersiçin haftada ortalama çalışma süresi:		**III)** I visited hours: / Öğret ziyaret ettim:	
A	**0**	C+	**0**	D-	**0**	None/Hiç	**0**	None/Hiç	
A-	**0**	C	**0**	F	**0**	1-3 hours/1-3 saat	**3**	1-3 times/1-3	
B+	**0**	C-	**0**	NG	**0**	4-6 hours/4-6 saat	**1**	4-6 times/4-6	
B	**0**	D+	**1**	Empty	**2**	7-10 hours/7-10 saat	**0**	7-10 times/7-	
B-	**2**	D	**0**			More than 10 hours/10 saatten fazla	**0**	More than 10	

		Empty/Boş cevap	1	Empty/Boş cevap	
Average/Ortalama	2,23	Average/Ortalama	1,25	Average/Ortalama	

C- INSTRUCTOR / COURSE RATING SCALE ÖĞRETİM ELEMANI / DERS DERECELEME ÖLÇEĞİ		Scale / Ölçek						
Items / Maddeler		AVERAGE ORTALAMA	AGREE STRONGLY KESİNLİKLE KATILIRIM	AGREE KATILIRIM	NEUTRAL FİKRİM YOK	DISAGREE KATILMAM	DISAGREE STRONGLY HİÇ KATILMAM	TOTAL TOPLAM
1	The course increase my knowladge of the subject. Ders bu konudaki bilgimi artırdı.	**4**	**5**	**0**	**0**	**0**	**0**	**5**
2	The instructor clearly stated the course objectives. Öğretim elemanı dersin hedeflerini açıkca belirtti.	**3,8**	**4**	**1**	**0**	**0**	**0**	**5**
3	The instructor was well-prepared. Öğretim elemanı derse hazırlıklı geliyordu.	**3,6**	**3**	**2**	**0**	**0**	**0**	**5**
4	The instructor communicated the subject matter in the target language. Öğretim elemanı konuyu öngörülen öğretim dilinde aktardı.	**4**	**5**	**0**	**0**	**0**	**0**	**5**
5	The instructor's presentation of the content was clear. Öğretim elemanı ders içeriğini anlaşılır bir biçimde	**3,6**	**3**	**2**	**0**	**0**	**0**	**5**

	sundu.							
6	The instructor developed a good rapport with students. Öğretim elemanı öğrencilerle iyi bir iletişim kurdu.	**4**	**5**	**0**	**0**	**0**	**0**	**5**
7	The course challenged me intellectually. Ders düşünsel anlamda ufkumu genişletti.	**3,8**	**4**	**1**	**0**	**0**	**0**	**5**
8	The instructor stimulated my interest in the subject. Öğretim elemanı derse olan ilgimi artırdı.	**3,8**	**4**	**1**	**0**	**0**	**0**	**5**
9	The instructor provided feedback on my work. Öğretim elemanı çalışmalarımla ilgili geribildirimde bulundu.	**3,8**	**4**	**1**	**0**	**0**	**0**	**5**
10	The assignments were effective learning tools. Verilen ödevler etkin öğrenme araçlarıydı.	**3,8**	**4**	**1**	**0**	**0**	**0**	**5**
11	The exams were effective learning tools. Sınavlar etkin öğrenme araçlarıydı.	**3,6**	**3**	**2**	**0**	**0**	**0**	**5**
12	The instructor was available during specified office hours. Öğretim elemanı belirlenen ofis saatlerinde yerindeydi.	**4**	**5**	**0**	**0**	**0**	**0**	**5**
13	My grades reflected my performance in the course. Sınav sonuçları dersteki	**3,8**	**4**	**1**	**0**	**0**	**0**	**5**

	performansımı yansıtıyordu.							
14	The course materials were relevant. Kullanılan materyaller ders ile ilgiliydi.	**3,4**	**3**	**1**	**1**	**0**	**0**	**5**
15	The instructor was punctual. Öğretim elemanı ders saatleri konusunda duyarlıydı.	**3,6**	**3**	**2**	**0**	**0**	**0**	**5**
16	The audio-visual aids (e.g. videos, slides, charts, etc.) used were effective Görsel-işitsel malzemeler(video, slayt, tablo, vb.) öğrenmemde etki	**3,25**	**2**	**1**	**1**	**0**	**0**	**5**
17	The instructor treated all students fairly. Öğretim elemanı tüm öğrencilere adilce davrandı.	**4**	**5**	**0**	**0**	**0**	**0**	**5**

Avg Of Course(1,7,10,11,13,14,16)	**3,66**
Avg Of Instructor(2,3,4,5,6,8,9,12,15,17)	**3,82**

In order to improve student learning, “we do not change the structure”. We modify the instructional practices of teachers/lecturers. “The schools or programs that seem to do most excellent are those having an apparent idea of what kind of instructional practice they desire to produce, and then plan a structure and policies to go with it", (Elmore Richard, and In Wong H., 2009).

By studying the models of instruction that detain and define explicitly what is it that "effective teachers" know and do, connecting to a set of behaviors that effective teachers put together or involve into their daily professional duties, "teaching effectiveness" can be well understood. These comprise a clear appreciation of the subject matter, knowing individual students planning, earning theory and student differences, classroom instructional strategies, and assessment of student understanding and proficiency with learning outcomes. Moreover, teacher's aptitude to reflect, collaborate with colleagues and continue enduring professional development and enhancement, are of great importance, (Robert A. Barry, 2010). The evaluation of teaching effectiveness is very important since it provides good information for parents to know if their children are being trained and equipped for college, future work and for real life opportunities. It provides a reasonable and desirable evolution in our thinking about improvements in the way teaching and learning takes place in our universities.

Here the information obtained from this survey is confidential and can only be provided by the chair of the department or the dean of the department.

The CAS and student course-instructor survey questionnaire differ from year to year and semester to semester since continuous improvement policy is expected to be continuously implemented. Apart from the above surveys, other surveys carried out by the department may include:

- Alumni survey open for the whole month of December and conducted once in two years.
- Exit survey usually held after the final exams on the last course of the program that is the eve before graduation. This targets the graduating students.
- Employers survey held in the whole month of February
- Meeting with alumni and professional engineers.

3.7 Postgraduate Evaluation and Some Suggestions for Engineering Programs

Postgraduate students are the most credited students in our society; hence, their evaluation on how they attained student outcomes should be well evaluated taking account in every method of assessment used to evaluate them by the lecturers.

3.7.1 Suggestions for Postgraduate Engineering Programs.

Nowadays, many graduates aimed at doing a masters or PhD in a field different from their post or undergraduate field. The majority of these graduates is from the science background, having a bachelor degree or masters in chemistry, physics, biology, biochemistry, microbiology, environmental sciences, without keeping behind the art field of study. When they reached the level of masters or PhD, the majority may choose the professional fields with the masses moving toward engineering. Studying masters or PhD in most schools in Europe does not matter if the student came from the same background, but requires some background knowledge about the field of interest and once the student has them, he/she would be admitted to the program. Due to this aspect of admission, several questions are pending on our minds;

1. If a student was admitted into an engineering program, at the end of his/her graduation provided the student has completed the requirements of the program, can we call this student an engineer regarding the program?
2. Can we say that the student has obtained professional and ethical accountability or responsibility.
3. Can we say that the student has obtained the ability to function on multi-disciplinary terms?
4. Can we say that the student has obtained ability to recognize, formulate, and solves engineering problems?
5. Can we compare the student with other students having taken the program from undergraduate level?
6. Can we say that the student has obtained the ability to use the techniques, skills, and modern engineering tools necessary for engineering practice?
7. Can we say that the student has obtained the ability to communicate effectively? Etc.

With these questions, it seems like taking master in a field different from your undergraduate field is a very critical issue and must be treated with care before admission. Such students taking these programs, especially the engineering programs (professional program) must be ready to study no matter how long it will take in order to become engineers, hence, making the duration of the program a three year program for those coming from different science background with the first year taken for all necessary deficiency courses and all laboratory studies that would be required and necessary to build up the student to the level of an engineer. We know student from post graduate reasons more quickly than undergraduate students, hence they are able to take more courses at the deficiency level. This will increase the cost of the program, but will also increase the quality of graduates from the program. The rest of the two years can be used for the masters program. Two years can be given to students having a degree from the same field. Furthermore, this level of education is very important as far as engineering is concerned and must be highly considered since graduates from this level are expected to know better and companies/universities expect more from them.

3.7.2 Evaluating Postgraduate Students Using MEI

Studying post graduate in any university in any part the world is different from studying undergraduate because the lecturers treat students maturely and expect students to understand fast. About 60% (depending on the university) of the work is done by the students. Lecturers are there to guide students.

Having a postgraduate degree being its master or PhD, the society expects from you a master or academic Doctor in your field of studies and should virtually know almost everything. With this respect, regarding engineering programs, we can suggest the following consideration in evaluating the students;

- There should be a final and midterm exams in both the theory and the practical part of each course provided the course required laboratory sections
- There should be qualification exams in all postgraduate courses being it masters of PhD.
- Postgraduate students should be expected to have written and published at least one paper before graduating from a program.
- Presentation of what studies have achieved for each course for all postgraduate students should be compulsory. This will help students have courage and confidence in expressing themselves in front of an audience.
- Industrial training should be implemented, making the master or PhD students as supervisor for five or more undergraduate students.

To use the MEI to evaluate post graduate programs, the course outlines must be organized in a way that the instructor will be able to match the course outlines to the set of student outcomes provided by the accreditation program. This is easy for postgraduate programs already under the canopy of an accreditation program. In the absence, of course outlines, course project could be considered at the end of each semester. The objectives of the course can be divided among the students enrolled in the course; each student will be expected to provide a project relating to the topic and objective given. The average grade score of each student per project is calculated for each course. Grade less the 3.0 is assumed that the objective in question was not attained by the students and an overall average less than 3.0 indicate the objectives were not attained by students and the instructor and students must develop a means to remedy the situation. This value can give us how much the course is matched to any accreditation criteria from a teacher's point of view, like in Abet

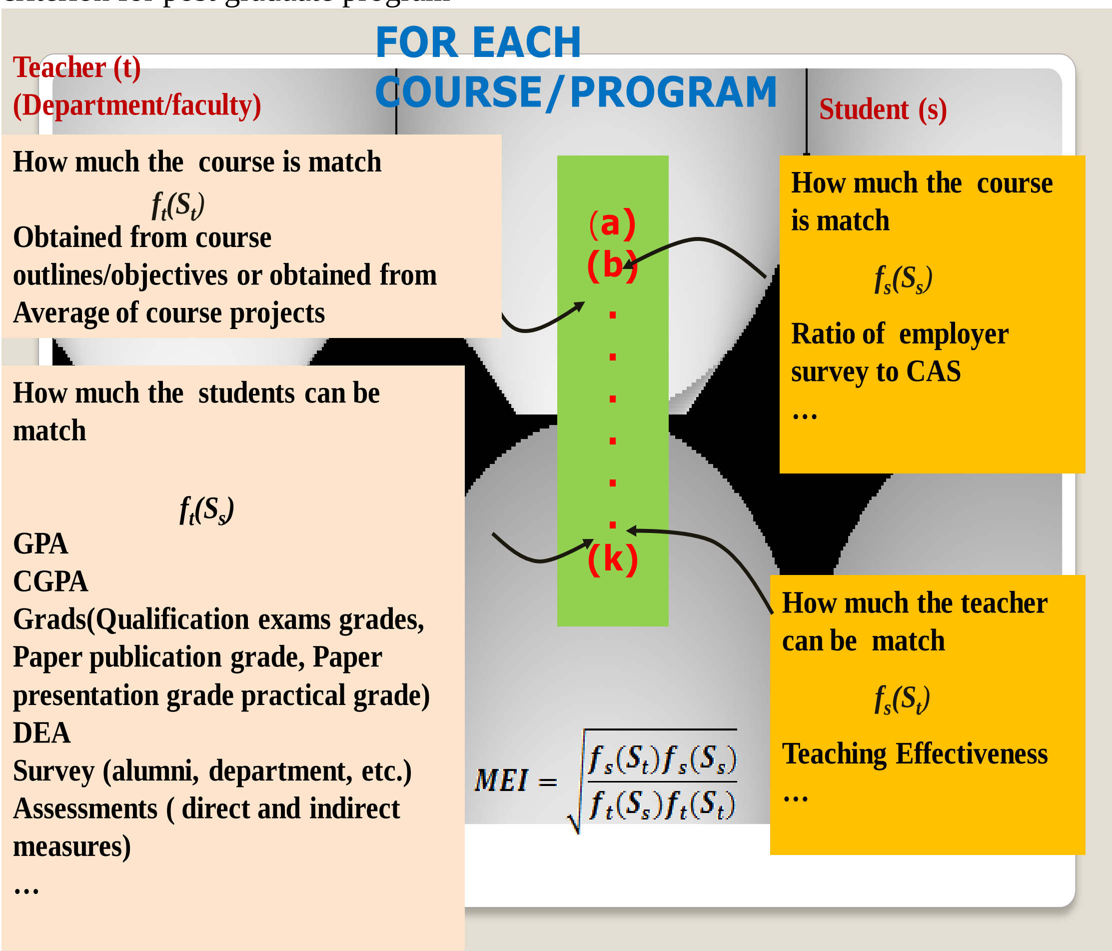
A joint survey of Course assessment survey (CAS) and Employer survey should be conducted for graduate students, by the students and a ratio of employment survey to CAS taken to define how much the course can be matched to the set of student outcomes provided by the accreditation program from the student’s point of view. This will do for all courses in the program since each course has a function in real life which must be included in the survey. The employer survey must be conducted by the students while the department prepare and provide course assessment survey questionnaire. The ratio of the two surveys is considered because it may confirm the following information about students;

- CAS provides information showing that the students have developed knowledge and understanding, skills, and have developed an appreciation of and respect for value and attitudes from the engineering program they registered for. This information is very important since the result indicates the fractions of students that have achieved the course objectives since the result is obtained from student's opinion and are ready to apply or are applying the outcomes they obtained from each course in real life situations including teaching as well.

- The employer survey gives the number of student working which reflects the actual number of students who actually attained, the student outcomes and are able to apply them in real life situations. This also explains that, no student will be able to work if he or she didn't actually attain the student outcomes.

Let consider the figure below with ABET a-k outcomes:

Figure 3.5: Diagram showing how teachers and students can be matched onto the a-k criterion for post graduate program



From figure 3.5, the value $f_s(S_t)$ can be obtained from the student course-instructor evaluation survey described above. The value $f_t(S_t)$ can equally be obtained same as describe above using the course outline match to student outcomes from instructor point of view or using average of course project grade as described above. The value $f_s(S_s)$ can be obtained from the ratio of an employer survey CAS as suggested above. In the case where CAS is absent, we can consider just the employer survey to find the value.

The value $f_t(S_s)$ can also be obtained using the average of grades for each course. DEA can be used for ensured accuracy, but the number of outputs in the post graduates programs is more when compare to undergraduate programs. The inputs may also differ.

Chapter 4

CASE STUDY: COMPUTING MEI FOR COURSES OFFER BY INDUSTRIAL ENGINEERING DEPARTMENT, EASTERN MEDITERRANEAN UNIVERSITY, EMU

4.1 EMU

Eastern Mediterranean University (EMU) with its highly developed infrastructure, famous academic staff members, with a population more than 16,000 students and about 1,000 academics from 35 different countries around the world, excellence programs in English, the chance of learning a second foreign language, student exchange programs, rich sports, social and cultural activity opportunities, international accreditations such as ABET, an international teaching background, and a diploma known throughout the world, EMU gives its students the objective to be ready for their international careers by educating them to become creative, active, proactive and competitive individuals facing real life with entrepreneurial skills.

The university's library is among one the largest on the island having a collection of more than 120,000 books, and provides free access to hundreds of information databases and sources to the users. The inter-library loan system can also be provided for students in the library, which it seems competitive, thus making it easy for research activities. Compilation of Physical Sciences information (databases, books, journals, etc.) is significantly sufficient for undergraduates and beginning and final post-graduates students. The library is very rich in the following areas: important collection on Applied Mathematics and Computer Science, English Literature both advance and for beginner learners, basic related Engineering literature and a considerable amount of theoretical and practical physics. Engineering sections are mostly separated into specialized areas of relevant existing and available departments in the university. Sections on international relations, communication studies, philosophy and law are expanding rapidly compare to initial established materials. (EMU website for more details)

The faculty of engineering in the EMU is accredited by ABET. Since ABET only accredit programs, not a school nor department or faculty, the engineering programs offered by the Engineering faculty in EMU accredited by ABET include;

- Electrical and electronic engineering
- Mechanical engineering
- Computer engineering
- Civil engineering
- Industrial engineering

Each program is accredited differently. These programs in EMU are under the canopy of departments and to gain ABET accreditation, they are obliged to organize their programs starting from the students' level according to criteria's provided to them by ABET. This is always provided in the form of self-study report in which each of the programs provides. At the level of the students, ABET is very interested in how student outcomes are evaluated and how continuous improvement of the program is monitored. This attribute on how student outcomes and continuous improvement plan is assessed differ from department to department or program to program but uses the criteria provided by ABET.

In this chapter, we will briefly describe the industrial engineering department, according to some ABET criteria's, after which we will use real data provided by the department chair and dean to evaluate the student outcomes and performance, and show how we could monitor the improvement of the program using MEI described above. This method is not exclusively applicable to Industrial engineering, but to all programs accredited by ABET.

4.2 Industrial Engineering Department

In brief, it can be said that the foundations and background of industrial engineering as it looks today, began to be built in the twentieth century. The first part of the century concentrated on increasing efficiency and reducing industrial organization's costs. Industrial engineering is a bough of engineering that deals with the development, improvement, implementation, and evaluation of integrated system involving especially money and people. Moreover, equipment, energy, material, knowledge and information, and process are also a vital aspect of industrial engineering. In lean manufacturing systems, industrial engineers work to get rid of and minimize wastes of time, money, materials, energy and many other resources needed by any manufacturing system hence minimizing cost of production.

Industrial engineering can refer to as "operations management", systems engineering, production engineering, manufacturing engineering. In healthcare, industrial engineers are more normally known as management engineers or health system engineers.

Virtually, most engineering disciplines relate skills in precise areas, but industrial engineering is applied in virtually everything involving any industry.

For an industrial engineering program to obtain accreditation from ABET, the following general criteria must be fulfilled through a self-study report;

- Students Program
- Educational Objectives
- Student Outcomes
- Continuous Improvement
- Curriculum
- Faculty
- Facilities
- Institutional Support

In which detail description of each criteria is provided in the self-study report. Some of these criteria that directly affect student outcomes will be considered and discussed in this chapter starting with students and their admission and including academic objectives since some survey questionnaires are constructed with the help of these objectives.

4.2.1 Students

4.2.1.1 Student Admissions

Students from many different countries are admitted into the program with the majority of the students coming from Turkey even though the students increase rate from turkey is reducing, follow by the Turkish Republic of North Cyprus and the remaining list continues with the Arabs population experiencing an increase in number include Iran, Nigeria, Palestine, Cameroon and north Arica and Middle East countries. In Turkey, all university programs admit their student through a nationwide university competitive placement exam.

The university founded in Turkish Republic of North Cyprus provides admission requirements for citizens of the Turkish Republic. It stated that students with Turkish nationality who have gained the right to register to the industrial department can complete their registration within the specific dates either at the EMU registrar's office or at the Registration Promotion and Location Office in Turkey. They have alternative admission requirements for citizens of the Turkish Republic of North Cyprus and citizens of the other countries. The citizens of the Turkish Republic of Northern Cyprus and maybe other countries are admitted according to the following criteria:

- Registration according to the TRNC University Exam or EMU entrance Exam Results. The selection and placement of students in a four year or two year programs take place according to the EMU Entrance Exams Results. This is specifically needed for the citizens of the Turkish Republic of North Cyprus.
- Registration procedures according to GCE results. EMU admits high school graduate from base on the IGSE/GCE/GCSE quota. Students who become successful at a minimum of 5 GCE O-level and exams in relevant fields (mathematics, physics, and mostly computer sciences is of preference) or any other exams, according to the English education system are pre-registered in a program within the quota.
- Registration procedures for the TRNC citizens who finish high school abroad. TRNC students who complete high school abroad can apply to EMU with an

equivalency certificate obtained from the Turkish Republic Ministry of Education.

- Moreover, students from 68 different countries studying at EMU are admitted based on their performance in their high school diploma/certificate. Such a student with a minimum average diploma grade “C” is admitted to the program. These students could alternatively be admitted if they hold IGSE/GCE/GCSE Ordinary Level examination results in 5 different subjects, two of which must be mathematics and physics with a minimum grade of “C”.

We should note that the student outcome performance depends on the type of students admitted into the program. Students admitted into the program during the spring and fall semesters are granted admission into two categories.

1. Admission to the English Preparatory year program
2. Admission directly to freshman level.

4.2.1.2 Evaluating Student Performance

Student performance is evaluated using continuous assessment mechanisms involving direct and indirect measures (midterm and final examinations, quizzes, laboratory and project studies, assignments, presentations, survey etc.). These mechanisms are arranged in a way to check the students’ ability in meeting the course and program objective base on ABET a-k criterion. The examination consists of the midterm exam, a final examination and any number of quizzes/tests, homework, or presentation or individual creativity and interaction in class. How we evaluate our students also affects the student outcomes. Note that there is no unique method explaining how student outcomes could be calculated using their continuous assessment mechanisms describe above, hence, not meeting up with the ABET criterion 3.

4.2.2 Program Educational Objectives and Mission Statement

4.2.2.1 Mission Statement

The mission of the Industrial Engineering program is to provide a scholarly environment to generate and propagate new knowledge and technological innovation through research and to equip future industrial engineers with sound professional background for the benefit of the society and their career. This is very important since it provides a welcoming atmosphere for education.

4.2.2.2 Program Educational Objectives

The undergraduate program provides students with a diverse range of professional objectives with the necessary knowledge, skills, and tools to:

1. The design develops and to provide systems oriented engineers solutions to problems as well as improve and manage the integrated systems of people, materials, equipment, energy, information, technology, and financial resources.
2. Apply critical thinking skills in mathematics and other scientific methods
3. Uphold ethical and social values in professional life
4. Nature professional development through lifelong learning
5. To successfully work in multidisciplinary teams and be able to present work or ideas effectively in both oral and written communication
6. Pursue advance programs in graduate schools.

4.2.3 Program Outcomes

4.2.3.1 The Process for Establishing and Revising Program Outcomes

The department council accepted the program outcomes suggested and mandated by ABET. They have been widely used and cover all the knowledge, skills, social, and behavioral attributes that graduating students are expected to have by the time of graduation, but lack a unique method to prove to ABET their graduating students have attained the student a-k outcomes. Hence, in this thesis, a new method is proposed to be used as a process for establishing and revising program outcomes and evaluating student outcomes.

4.2.3.2 Students Outcomes

The student outcomes (SOs) highlighted by ABET and approved by the department were listed in chapter three (review chapter 3).

4.2.4 Continuous Improvement

Program improvement is a continuous process designed by the department to monitor and update academic programs in order to keep apace of scientific progress, up to the standard of the program offerings and changing career options. The industrial engineering programs in EMU are regularly updated on the basis of inputs from various sources kept in place for such a purpose. To meet up with a more updated and standard program required by ABET, a list of sources and process were organized that help the department in a given program course correction.

- Exit Survey
- Course Assessment Survey
- Student discussion, by sampling
- Student Course-Instructor Evaluation survey
- Alumni survey

- Issue base student meets
- The external advisory board meets (this board comprises of student and faculty members, employer, alumni and industrialists.
- Meeting with alumni and professional engineers
- Brainstorming meetings between faculty and student representations
- Periodical departmental meetings
- Employer survey
- ABET committee

We should note that the industrial engineering department has no direct method that is being used to evaluate student outcomes and monitor continuous improvement of their programs. Moreover, they yet have a list of sources and processes that guide them toward their conclusion.

These lists of processes and sources generate data, how are these data used to conclude on SOs, and continuous improvement plan? In chapter 3, a method is proposed that will combine the most relevant of the data generated from the above mentioned processes (indirect measures) listed above by the department along side with the direct measures (midterm exams, final exams, grades, etc.) to calculate a single value which will help the department conclude on student outcomes and the improvement of the programs. In this chapter, we will use the method proposed in chapter three to compute values using data provided by the department chair or dean.

Other criteria provided by ABET (curriculum, faculty, etc.) are better described in the self-study report provided by the department to AET. In the next section in this chapter, we will discuss data collection, processing and analysis (computations of

MEI), and clearly show how the student outcomes and continuous improvement are evaluated.

4.3 Data Collection, Processing and Analysis

4.3.1 Data Collection

The courses considered in this case study include strictly all the industrial engineering courses only which their information was easily obtained. The raw data needed was provided by the department chair. Information concerning the surveys was totally confidential, and only values were read and copied. (See appendix A, B and C for raw data provided by the chairperson of the department). In order to convert grade to grade point equivalent, the letter grades description according to the registrar office was considered (see Appendix G for the letter grades description).

4.3.2 Data processing

Processing of data involved calculation of averages obtained from scale numbers assigned to the survey questions concerning the course outlines, CAS, and student course-instructor evaluation survey usually between scale of 0-2, 0-3, 0-4 and 0-5. This number indicates the level of importance a certain point on the course outlines or CLO contribute to the a-k student outcomes or the level at which the students strongly agreed or strongly disagreed, agreed or disagreed and or are blank about a point relating CAS or students course-instructor evaluation survey. Also the decision taken by the departmental meeting regarding course outlines and student outcomes. Data involving direct assessments were processed according to the information mentioned in chapter three. Recall that all averages must be between 0-4; hence any scale not between 0-4 must be converted to the scale 0-4 by simple scale calculation. For example, consider the following scales below;

a ——Y——→ b   c ——→ d,

To convert any value say Y obtained from the scale a-b to the scale c-d we do the following simple calculation.

$\frac{d-c}{b-a} \times Y$

The courses and calculated (processed) averages for each course needed for MEI calculations are summarized in the tables below;

Table 4.1: shows the courses available in the industrial engineering department and calculated averages/grade averages (fall 2013-2014).

#	Courses	$f_t(S_t)$ (obtained from course outlines)	$f_t(S_s)$ (obtained from average of grades)	$f_s(S_s)$ (obtained from CAS)	$f_s(S_t)$ (obtain from Student course-instructor evaluation survey)
1.	IENG112	1.64	-	-	-
2.	IENG210	0.18	Satisfactory	-	3.74
3.	IENG212	1.82	1.39	2.90	2.48
4.	IENG263	2.73	2.05	2.84	-
5.	IENG301	2.91	2.58	3.51	3.16
6.	IENG310	0.18	Satisfactory	3.50	3.53
7.	IENG313	2.18	1.96	3.58	3.13
8.	IENG314	2.18	2.80	3.64	3.47
9.	IENG323	3.09	2.00	3.61	3.57
10	IENG332	3.09	2.07	3.74	3.45
11	IENG355	2.91	2.90	3.66	3.57
12	IENG372	2.73	2.98	3.54	-

13	IENG385	1.60	2.06	3.54	3.42
14	IENG409	3.45	2.42	2.98	3.31
15	IENG410	0.36	Satisfactory	3.78	3.41
16	IENG419	2.55	3.10	3.70	3.58
17	IENG420			3.28	3.67
18	IENG431	2.00	1.50	3.12	2.84
19	IENG441	3.64	2.16	-	2.59
20	IENG444	2.00	-	-	3.48
21	IENG450	-	-	3.70	-
22	IENG458	1.28	2.33	3.64	3.69
23	IENG461	3.27	2.89	-	-
24	IENG484	2.91	2.00	3.68	
25	IENG490	4.00	3.00	3.86	2.96
26	IENG492	4.00	2.53	3.30	3.72

The above table 4.1 is used in calculating MEI when the average of grades for each course is considered. If the average of efficiencies is needed (for more accuracy in the result), it would be obtained using DEA taking each student as *DMU* as discussed earlier, and considering the outputs and inputs in the following table;

Table 4.2: shows the inputs and outputs considered per DMU fall 2013-2014.

Input/output/DMU	**Inputs/outputs considered/DMU**
Inputs	1. Previous CGPA
	2. Teaching Effectiveness (average of instructor
Outputs	1. The ratio of Final grades (midterm and final) to grade average for each course
	2. Continuous assessment grades (assignments, laboratory, presentation etc.)

In calculating MEI when the efficiencies are required, we consider a class and calculate the value of $f_t(S_S)$ for each course using DEA for the defined set of inputs and outputs listed in table 4.2 above. If not, simply used the average of grades for each course as an approximate value for $f_t(S_S)$ since the calculation involving DEA is long and required software hence, using an average of grades is approximately correct. INGN314 is the course which efficiency is considered in this chapter for information about the course is readily available. The following table summarizes the information needed to calculate $f_t(S_S)$ for INGN314 using DEA. *Note that the average of all the efficiency values obtained from each DMU (student) is* $f_t(S_S)$.

Table 4.3: shows the input and output values for INGN314 for each student in fall 2013-2014.

Student	**Inputs**		**Outputs**	
#	**Previous CGPA**	**Teaching Effectiveness (average of instructor**	**The ratio of Final grade (midterm and final) to grade average for each course**	**Continuous assessment grades (assignments, laboratory, presentation etc.)**
1	1.79	3.85	0.82	2.64
2	1.69	3.85	1.32	3.40
3	1.93	3.85	1.07	2.60
4	1.68	3.85	0.61	2.53
5	1.64	3.85	0.82	2.88
6	1.78	3.85	0.71	2.80
7	1.82	3.85	0.71	2.42
8	1.87	3.85	1.18	3.74
9	2.35	3.85	1.32	3.45
10	2.08	3.85	0.36	1.45
11	3.26	3.85	1.07	2.93
12	3.42	3.85	1.43	3.49
13	3.00	3.85	1.17	3.01
14	3.28	3.85	1.07	3.29

4.3.3 DATA ANALYSIS (COMPUTATION OF MEI)

The computation of MEI involves two ways;

- Firstly, computing MEI considering the value of $f_t(S_s)$ as the efficiency average of all the efficiency scores from each DMU (student) obtained when the outputs and inputs of each student is considered as shown on table 4.2 above. To calculate $f_t(S_s)$ using DEA, and table 4.2 above, we write linear programming equations using the Output Oriented CCR model as follows;

Table 4.4: Shows all the Input oriented CCR LP model for the DMUs

Student	***Objective function and specific constraint***	***Common constraints***
1.	$Max\ 0.82u_1 + 2.64u_2$ $s.t\ 1.79v_1 + 3.85v_2 = 1$	$0.82u_1 + 2.64u_2 - 1.79v_1 - 3.85v_2 \leq 0$ $1.32u_1 + 3.40u_2 - 1.69v_1 - 3.85v_2 \leq 0$ $1.07u_1 + 2.60u_2 - 1.93v_1 - 3.85v_2 \leq 0$ $0.61u_1 + 2.53u_2 - 1.68v_1 - 3.85v_2 \leq 0$ $0.82u_1 + 2.88u_2 - 1.64v_1 - 3.85v_2 \leq 0$ $0.71u_1 + 2.80u_2 - 1.78v_1 - 3.85v_2 \leq 0$ $0.71u_1 + 2.42u_2 - 1.82v_1 - 3.85v_2 \leq 0$ $1.18u_1 + 3.74u_2 - 2.35v_1 - 3.85v_2 \leq 0$ $1.32u_1 + 3.45u_2 - 2.35v_1 - 3.85v_2 \leq 0$ $0.36u_1 + 1.45u_2 - 2.08v_1 - 3.85v_2 \leq 0$ $1.07u_1 + 2.93u_2 - 3.26v_1 - 3.85v_2 \leq 0$
2.	$Max\ 1.32u_1 + 3.40u_2$ $s.t\ 1.69v_1 + 3.85v_2 = 1$	
3.	$Max\ 1.07u_1 + 2.60u_2$ $s.t\ 1.93v_1 + 3.85v_2 = 1$	
4.	$Max\ 0.61u_1 + 2.53u_2$ $s.t\ 1.68v_1 + 3.85v_2 = 1$	
5.	$Max\ 0.82u_1 + 2.88u_2$ $s.t\ 1.64v_1 + 3.85v_2 = 1$	
6.	$Max\ 0.71u_1 + 2.80u_2$ $s.t\ 1.78v_1 + 3.85v_2 = 1$	
7.	$Max\ 0.71u_1 + 2.42u_2$	

	s.t $1.82v_1 + 3.85v_2 = 1$	$1.43u_1 + 3.49u_2 - 3.42v_1 - 3.85v_2 \leq 0$
8.	Max $1.18u_1 + 3.74u_2$ s.t $1.87v_1 + 3.85v_2 = 1$	$1.17u_1 + 3.01u_2 - 3.00v_1 - 3.85v_2 \leq 0$ $1.07u_1 + 3.29u_2 - 3.28v_1 - 3.85v_2 \leq 0$
9.	Max $1.32u_1 + 3.45u_2$ s.t $2.35v_1 + 3.85v_2 = 1$	$v_1 \geq 0$ $v_2 \geq 0$
10.	Max $0.36u_1 + 1.45u_2$ s.t $2.08v_1 + 3.85v_2 = 1$	$u_1 \geq 0$
11.	Max $1.07u_1 + 2.93u_2$ s.t $3.26v_1 + 3.85v_2 = 1$	$u_2 \geq 0$
12.	Max $1.43u_1 + 3.49u_2$ s.t $3.42v_1 + 3.85v_2 = 1$	
13.	Max $1.17u_1 + 3.01u_2$ $3.00v_1 + 3.85v_2 = 1$	
14.	Max $1.07u_1 + 3.29u_2$ s.t $3.28v_1 + 3.85v_2 = 1$	

Note the following;

- Output Oriented CCR model maximizes the value of θ. This value is between 0 and 1. Here the inputs are all set to 1 while maximizing the value of the outputs;
- Since the DMUs subject to the same constraints, we summarize the LP on a table above.

The above LP is solved using lingo software. The model for each student is the same but differ in the objective function. A sample of the lingo LP is shown below;

```
Max = 0.82*u1 + 2.64*u2;

1.79*v1 + 3.85*v2 = 1;

0.82*u1 + 2.64*u2-1.79*v1 - 3.85*v2<=0;

1.32*u1 + 3.40*u2-1.69*v1 - 3.85*v2<=0;

1.07*u1 + 2.60*u2-1.93*v1 - 3.85*v2<=0;

0.61*u1 + 2.53*u2-1.68*v1 - 3.85*v2<=0;

0.82*u1 + 2.88*u2-1.64*v1 - 3.85*v2<=0;

0.71*u1 + 2.80*u2-1.78*v1 - 3.85*v2<=0;

0.71*u1 + 2.42*u2-1.82*v1 - 3.85*v2<=0;

1.18*u1 + 3.74*u2-2.35*v1 - 3.85*v2<=0;

1.32*u1 + 3.45*u2-2.35*v1 - 3.85*v2<=0;

0.36*u1 + 1.45*u2-2.08*v1 - 3.85*v2<=0;

1.07*u1 + 2.93*u2-3.26*v1 - 3.85*v2<=0;

1.43*u1 + 3.49*u2-3.42*v1 - 3.85*v2<=0;

1.17*u1 + 3.01*u2-3.00*v1 - 3.85*v2<=0;

1.07*u1 + 3.29*u2-3.28*v1 - 3.85*v2<=0;

v1>0;

v2>0;

u1>0;

u2>0;

END
```

See LP results sample for a student, appendix D. Note that the efficiency score for each student stand for their optimal value from the LP and the average of the efficiencies yield the efficiency of the course. These results can be summarized in the table below;

Table 4.5: Shows all the efficiency of each DMU (student) obtained from Lingo

Student	Efficiency
1.	0.765
2.	1.000
3.	0.801
4.	0.748
5.	0.872
6.	0.822
7.	0.698
8.	1.000
9.	0.990
10.	0.402
11.	0.813
12.	1.000
13.	0.854
14.	0.886
Average	0.83

Since the efficiency value is always between 0 and 1, the average value must be converted to a value between 0 and 4 using the technique defined above. Hence the value 0.83 is 3.34 between 0 to 4 intervals. The value of $f_t(S_s)$ using DEA is 3.34.

Secondly, we could also calculate the value of $f_t(S_s)$ simple by computing the course average, usually obtained from an average of grades as shown in table 4.1 above.

Note the value of $f_t(S_s)$ obtained from DEA is more accurate since many factors were considered.

The value of MEI can be calculated using equation 3.1 described in chapter three thus;

$$MEI=\sqrt{\frac{f_s(S_t)f_s(S_s)}{f_t(S_t)f_t(S_s)}}$$

The values of MEI for each course, calculated using equation 3.1 are summarized in the following table;

Table 4.6 shows MEI values for each course

#	Courses	$f_t(S_t)$ (obtained from course outlines)	$f_t(S_s)$ (obtained from average of grades)	$f_s(S_s)$ (obtained from CAS)	$f_s(S_t)$ (obtain from Student course-instructor evaluation survey)	MEI
1.	IENG210	0.18	Satisfactory	-	3.74	-
2.	IENG212	1.82	1.39	2.90	2.48	1.69
3.	IENG263	2.73	2.05	2.84	-	-
4.	IENG301	2.91	2.58	3.51	3.16	1.21
5.	IENG310	0.18	Satisfactory	3.50	3.53	S
6.	IENG313	2.18	1.96	3.58	3.13	1.62
7.	IENG314	2.18	2.80/3.34	3.64	3.47	1.42/ 1.32
8.	IENG323	3.09	2.00	3.61	3.57	1.42
9.	IENG332	3.09	2.07	3.74	3.45	1.42

10	IENG355	2.91	2.90	3.66	3.57	1.24
11	IENG372	2.73	2.98	3.54	-	-
12	IENG385	1.60	2.06	3.54	3.42	1.92
13	IENG409	3.45	2.42	2.98	3.31	1.08
14	IENG410	0.36	Satisfactory	3.78	3.41	S
15	IENG419	2.55	3.10	3.70	3.58	1.29
16	IENG420	-	-	3.28	3.67	-
17	IENG431	2.00	1.50	3.12	2.84	1.72
18	IENG441	3.64	2.16	-	2.59	-
19	IENG444	2.00	-	-	3.48	-
20	IENG450	-	-	3.70	-	-
21	IENG458	1.28	2.33	3.64	3.69	2.21
22	IENG484	2.91	2.00	3.68	3.77	1.58
23	IENG490	4.00	3.00	3.86	3.69	1.09
24	IENG492	4.00	2.53	3.30	3.72	1.10
					Average of MEI	1.46

Courses with no MEI values calculated indicate insufficient information needed for the computation since results above surveys are confidential and private.

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the results obtained above, we see that all the courses offered during academic semesters, fall 2013-2014 have MEI > 1. This show that the courses experience progress, hence, we can conclude that the student outcomes (a-k) was attained by the students and the teaching effectiveness of the courses were good and of a standard. If any course had observed an MEI <1, this will indicate the course needs of improvement. Many factors can cause MEI of a course be less than 1. Some of these factors include;

- The teaching effectiveness and or method of teaching by the instructor may be poor.
- Instructor not regularly in class and due to time constraint, the instructor tries to cover much material toward the end of the semester; hence, students are forced to read much material in a little time possible in order to pass their final examination ending up with poor grades.
- The instructor may concentrate mostly on theory with little assignment, exercises and examples.
- Students might not be serious and some may stay away from lectures and only feature during the exams with poor attendance ending up with poor grades or failing the course.

- Students fail to do their assignment and submit on time.
- A student may not understand the course but fail to ask questions. This has always been the case in misinterpretation of exam questions or language barrier.
- The expectation of the a-k student outcomes for a course may be high and students only attained little at the end of the course.
- The student - instructor relationship may be poor.
- Poor project presentation due language barrier and expression.

One or all of the above mentioned factors could lead to MEI of any course be less than 1. The only solution is to be able to identify the cause of the course MEI less than 1 through the departmental meeting and implement the documented procedures of the continuous improvement plan. Note that the instructor is in a better position to explain why his course MEI is less than one and how he intends to improve it.

The average of the MEIs =1. 46 >1. This led to the conclusion that the industrial engineering program offered in EMU during fall semester 2013-2014 need no improvement and meet up the ABET a-k student outcomes criterion which is one of most important criterion among eight criteria. If this value is less than one, it would indicate that the program offered during this period experience regresses instead of progress, hence, implying the need of improvement which requires the use of continuous improvement plan. We see that just calculating the mean of the MEIs or considering the MEI of a course, we can conclude with certainty if a program or course needs improvement or not reflecting the continuous improvement plan of the program or course. Hence, we can use this method as a continuous improvement plan measures for educational purposes.

Recall that the values $f_t(S_t)$ and $f_t(S_s)$ are the values how much the a-k student outcomes can be matched to the course outlines and how much the students attained the a-k student outcomes according to the teacher's point of view respectively. Both of them are related, hence the value of $f_t(S_s)$ can be very large for a particular course but having an MEI >1 like in most cases shown in table 4.5 above. This is because the value $f_t(S_s)$ does not compare to the scale of four, but compare to $f_t(S_t)$. $f_t(S_t)$ indicates how much is expected from students as far as the course outlines and the a-k students outcomes are concerned while $f_t(S_s)$ indicates how much was actually attained by the students from $f_t(S_t)$ after all the educational technology and educational functions of the course has been explored by the students and instructor. So we could conclude that, the value of MEI does depend on all the four parameters. From table 4.5, we see that at least more than half of the $f_t(S_t)$ was used by $f_t(S_s)$ for almost all the courses indicating a good turnover of the program and student outcomes.

Looking at table 4.5, only students 2 and 8 score a value 1 which led to the conclusion that the students are efficient, but the majority of the students have an efficiency value less than one and different from zero, hence we conclude from the average that the course was CCR-inefficient, while student 2 and 8 are CCR-efficient. Hence, we could use DEA to differentiate between efficient student and inefficient students knowing precise students affecting the outcomes of the program or course and use the information to concentrate on them when implementing the continuous improvement plan mentioned and confirmed by Victor, G., et al, 2013 in an international comparison of educational systems.

The MEI value is obtained from both direct and indirect measures of assessment as described in chapter 3 and preceding chapters. This value is simply compared to unity, hence, we could conclude that this method is one of the best methods that can be used to assess student outcomes, performance and monitor continuous improvement of the program since both indirect and direct measures are included in the computation of MEI. Also, from MEI value, we can easily know if a course or program needs an improvement or not. Moreover, we can use it to compare many factors (universities, same programs, outcomes of students and instructors, and above all compare outcomes and performance of students or instructor in different period of time) as describe in chapter 3. Note that chapter three explains to us how we could achieve all or most of our objectives.

Critical examination of the data in table 4.5 shows that no general conclusion can draw from information gotten from course average or class average of a course since some courses (e.g. IENG 212, IENG 313, IENG 431) with lower course average score an MEI still greater than 1. This helps us to conclude that student outcomes do not depend only on direct measures of assessment, but indirect measures of assessment are of great importance in evaluating student outcomes. Note from the results in table 4.5 show that we could evaluate course efficiency or student efficiency using specific inputs and outputs described above using DEA (output oriented or inputs oriented CCR model).

5.2 Recommendation

It is a common thing that most public and private schools or universities have the benefit of grants from both the private and governmental sectors like private companies and or government of the country. These sectors need to know the outputs, outcomes, and performances of these schools specially individual departments of the school to know exactly where to grant, hence, since schools or universities need also to know their efficiency and productivity and DEA and Malmquist index easily evaluate efficiency and productivity, I recommended further research on this method using real examples already assessed by a different method to compare the effectiveness of the different methods.

I also recommended further research with real examples comparing same programs offer in two different universities, comparing the performance of teachers or students in two different periods of time using the respective methods and MEI formulae described in chapter three above.

Most importantly, I recommended that MEI software be developed to ease manual calculations.

REFERENCES

1) Abbott M., & Doucouliagos C. (2003). The efficiency of Australian universities: a data envelopment analysis, Economics of Education Review 22.

2) ABET Self-Study Report (2010) for the Electrical Engineering Program at The University of New Mexico Albuquerque, NM.

3) ABET Self-Study Report (2012) for the Bachelor of Science in Electrical Engineering At Lamar University Beaumont, Texas.

4) ABET Self-Study Report (2012) for the Bachelor of Engineering in Communications and Electronics at Beirut Arab University Debbieh, Lebanon.

5) ABET Self-Study Report (2013) for Civil Engineering Program At College of Engineering & Islamic ArchitectureUmm Al-Qura University Makkah Saudi Arabia.

6) ABET Self-Study Report (2013) for the B.S.c., in Computer Science At Lamar University, Beaumont, Texas.

7) ABET Self-Study Report (2013) for the program in Civil Engineering at the University of Washington., Seattle, WA.

8) ABET Self-Study Report (2014) for the Engineering Technology Program at Upper State University.

9) ABET Self-Study Report (2009) for the Department of Ocean and Resources Engineering, University of Hawaii at Manoa Honolulu, Hawaii.

10) ABET Self-Study Report, (2012) for the Computer Engineering Program at the University of Florida Gainesville, Florida.

11) ABET Self-Study Report (2013) for the Aeronautical and Astronautical Engineering Program at the University of Washington.

12) ABET Self-Study Report, (2013) for the School of Mechanical Engineering at Purdue University West Lafayette, IN 47907-2088.

13) ABET. Retrieved 2012-01-31., www.abet.org *16*, 57-75.

14) Adela García-Aracil & Davinia, Palomares-Montero, (2008). Evaluation of Spanish Universities: Efficiency, Technology and Productivity Change.

15) Andrew, G., (2007). Foundation of economics.

16) Ahmad, H.B., Ali S. A., & Subhi J. (2013). Total productivity growth in the faculties of Anbar University is using a Malmquist productivity index, *International Journal of Global Education.*

17) Aleksandra, P., & Joannan Wolsczczak-nderlacz. (2011). Dynamics of productivity in higher education-cross-European Evidence based on a Bootstrapped MalmquistIndex.

18) Alex, K., & Terry, S. (2012). Direct Assessment of student Outcomes: A Systematic Approach. Volume 13, Issue 2, pp. 1-10

19) Alirezeae, M.R., & Afsharian, m., (2007). A Complete Rranking of DMUs using restrictions in DEA models. *Applied Mathematics and Computation*

20) António, A., Mohamed, A., & Sourour, R. (2013). Assessing productivity performance of basic and secondary education in Tunisia: A Malmquist analysis.

21) Balk, B.M., (2001). Scale, efficiency and productivity change. *Journal of Productivity Analysis*, 15 (3): 159183.

22) Beasely, J., (1995). Determining teaching and research efficiencies. *Journal of the Operational Research Society,* 46,441-452.

23) Bessent, A.M., & Bessent E.W., (1980). Determining the comparative efficiency of schools through data envelopment analysis. *Educational Administration Quarterly.*

24) Bessent, A.M., Bessent, E.W., Kennington, E.W., & Regan, B., (1982). An application of Mathematical Programming to the Productivity in the Houstan independent school District. *Management Science*, *28*, 1355-1367.

25) Caves Douglas, Christensen & Diewert. (1982). "Multilateral Comparisons of Output, Input, and Productivity Using Superlative Index Numbers," *Economic Journal, Royal Economic Society, vol. 92.*

26) Charnes, A., Cooper W.W., & Rhodes E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6):429–444.

27) Chames, A., Cooper, W.W., Golany, B., Seiford, LM & Stutz, J., (1985). Foundations of Data Envelopment Analysis for Pareto-Koopmans Efficient Empirical Production Functions," Journal of Econometrics, Vol. 30, pp. 91-107.

28) David, S., & Joe, Z. (2014). Data Envelopment Analysis explained.

29) Denvir, B., & Brown, M., (1986). The Importance of Teaching.

30) Diamond, A.M., & Medewitz, J. N. (1990). Use of data envelopment analysis in an evaluation of efficiency of DEEP program for economic education. *Journal of Economic Education, 21, 337-54.*

31) Edward Martins, C., et al. (2011). Static Versus Dynamic DEA in federal higher education institutions – IFES.

32) Eric, AH., (1986). The Economics of Schooling: Production and Efficiency in. Public Schools. pp. 1141—1 1 77

33) Elteto, O., Koves P., and Schultz, B., (1964). STASTICAL METHOLOGY. EKS INDEX AND INTERNATIONAL COMKPARISON.

34) Elmore, R., & In Wong H., (2009). "Teachers are the Greatest Assets." Teachers Net Gazette.

35) Hosseinzadeh, F L., et al. (2006). Application of Malmquist Productivity Index on Interval Data in Education Groups International Mathematical Forum.

36) Fare, R., Grosskopf, S., Lindgren, B., & Roos, P. (1989). Productivity developments in Swedish hospitals: A Malmquist output index approach. Discussion Paper no. 89-3, Southern Illinois University, Illinois, USA,

37) Farrell, M.J., (1957), "The Measurement of Production Efficiency", Journal of statistical society, Series A, CXX, Part 3, 253-290.

38) Fare, R., Grosskopf, N.M., & Zhang, Z., (1994). Productivity growth, technical progress, and efficiency change in industrialized countries. *American Economic Review. 84, 66-83.*

39) Fare, R., & Grosskopf S., (1996). Intertemporal Production Frontiers: with dynamic DEA.

40) Giménez, V., Prior D., & Thieme C., (2007). Technical efficiency, managerial efficiency and objective setting in the educational system: An international comparison. *Journal of the Operational Research Society*, 58 (8): 996–1007.

41) Gelles, Gregory M., Mitchell, & Douglas W. (1996). Returns to Scale and Economies of Scale: Further Observations. *Journal of Economic Education*. 0022-0485, ZDB-ID 4105357. - Vol. 27.1996, 3, p. 259-262

42) Guerrero, Tomas., (2013). Frontier Markets. A world of opportunities.

43) Gloria Rogers, (2006). Direct and Indirect Assessment. Journal of Applied Research in the Community College.

44) http://en.wikipedia.org/wiki/Isoquant

45) http://en.wikipedia.org/wiki/Isocost

46) http://en.wikipedia.org/wiki/Data_envelopment_analysis

47) Hakan, G., (2008). Direct Method for Course Outcomes Assessment for Abet Accreditation.

48) Hanushek, E.A., (1986). The Economics of Schooling. *Journal of Economic Literature, 24, 1141-1177.*

49) Hei shi, J., & China P.R., (2013). A DEA-based Malmquist Productivity index Approach in Assessing performance of Commercial Banks, evidence from Tanzania, Vol No. 6.

50) Jill Johnes, (2006). Efficiency and productivity change in the English higher education sector I21, C14, D24.

51) Lovell, C.A.L., & Schmidt, P., (1988) "A Comparison of Alternative Approaches to the Measurement of Productive Efficiency, in Dogramaci, A., & R. Färe (eds.) *Applications of Modern Production Theory: Efficiency and Productivity*.

52) Makoto Tawada., (1980). The Production Possibility Set with Public Intermediate Goods. vol. 48, issue 4, pages 1005-12. *Econometrical.*

53) Maleki, G., & Klumpp M., (2012). Higher Education Productivity and Quality Modelling with Data Envelopment Analysis Methods, *European Simulation and Modelling Conference p. 231-233.*

54) Mary Caroline, N., & Castano Emilyn, C., (2007). Sources of Efficiency and Productivity Growth in the Philippine State Universities and Colleges: A Non-Parametric Approach. *International Business & Economics Research Journal.*

55) Mary Allen, J. (2008). Assessing General Education Programs.

56) Milan Martic, M., Marina Novakovic, S., & Alenka Baggia. (2009). Data Envelopment Analysis Basic Models and their Utilization.

57) Nadia, Z., & Ben, H. (2013). Efficiency and Quality in Higher Education, A Dynamic Analysis. Vol. 5, No. 4.

58) Nickolaos Tzeremes, & George Halkos. (2010). A DEA approach for measuring university department's efficiency. *MPRA Paper No. 2402.*

59) Oh D., (2010). A global Malmquist-Luenberger productivity index. *Journal of Productivity Analysis*, 34 (3): 183–197. *Operational Research Society, 46,441-452.*

60) Palomba & Banta, (1999). Assessing for Improvement. Innovation Insight Series Number 11.

61) Pastor J.T., & Lovell C.A.K., (2005). A global Malmquist productivity index. *Economics Letters, 88 (2): 266–271.*

62) Preeti, T., Shiv Prasad, Y., & Singh S. P., (2009). Efficiency analysis of schools using DEA: A case study of Uttar Pradesh state in India.

63) Réka Tóth (2009). Data envelopment analysis and the efficiency of the higher education. *International Conference on Applied Economics.*

64) Robert Barry, A. (2010). *Teaching effectiveness and why it matters.*

65) Reza, Kazemi, M., Gholam, Reza, J., & Abdollah, Hadi, V., (2007). Inefficiency Evaluation with an additive DEA Model under Imprecise Data, An Application on Iauk departments.

66) Rezai, Balf, F., & Shahverdi, R., (2011). A Method for DMUs Classification in DEA.

67) Salah Agha, R. et al. (2011). Assessment of academic department's efficiency using data envelopment analysis.

68) Santa Rosa Junior College, (2006). *Project LEARNS SLO Assessment Handbook.*

69) SClaudina Vargas, & Dennis Bricker. (2000). Combining DEA and factor analysis to improve evaluation of academic departments given uncertainty about the output constructs.

70) Sengupta, J.K., (1987). Production frontier estimation to measure efficiency: A critical evaluation in light of data envelopment analysis. *Managerial and Decision Economics, 8,* 93-99.

71) Teddlie, C., & Reynolds, D., (2000). The International Handbook of School Effectiveness Research. Routledge, London.

72) Thieme, C., Giménez, V., & Prior, D., (2011). A comparative analysis of the efficiency of national educational systems. *Asia Pacific Education Review.*

73) Tone, K., & Tsutsui, M., (2001). A Slacks-based Measure of Efficiency in Data Envelopment.

74) Tone, K., & Tsutsui, M., (2010). Dynamic DEA: A slacks-based measurement approach. *Omega, vol. 38, p. 145-156.*

75) Vector G., Diego P., &, Claudio T., (2013). An international comparison of educational systems: with an application of the Malmquist-Luenbergerglobal index.

76) William Cooper, W., Lawrence Seiford, M., & Joe Zhu. (2012). Data Envelopment Analysis. History and Interpretation

77) William, Cooper, W., Lawrence Seiford, M., & Joe Zhu. (2004). Data Envelopment Analysis. History and Interpretation.

78) Xue, M., & Harker, P. T., (2002). Ranking DMUs with infeasible super-efficiency DEA models. *Management Science*, 48(5): 705–710.20.

APPENDICES

Appendix A: Grades of Students in Each Course for the Academic Year 2013-2014 (fall)

	Sem.	Per.	Dept.	C. Code	Grade
1	2013-14	1	26	IENG431	B
2	2013-14	1	26	IENG441	C
3	2013-14	1	26	IENG490	A-
4	2013-14	1	26	IENG461	B+
6	2013-14	1	26	IENG484	B
7	2013-14	1	26	IENG419	A
8	2013-14	1	26	IENG212	A-
12	2013-14	1	26	IENG323	B+
13	2013-14	1	26	IENG355	B
20	2013-14	1	26	IENG323	C
21	2013-14	1	26	IENG355	B+
24	2013-14	1	26	IENG441	C
25	2013-14	1	26	IENG461	B
27	2013-14	1	26	IENG484	B+
28	2013-14	1	26	IENG492	B
29	2013-14	1	26	IENG409	C
30	2013-14	1	26	IENG419	B+
32	2013-14	1	26	IENG461	B
36	2013-14	1	26	IENG492	A-
37	2013-14	1	26	IENG419	A-
41	2013-14	1	26	IENG372	C
42	2013-14	1	26	IENG431	D+
43	2013-14	1	26	IENG441	C
44	2013-14	1	26	IENG484	D
45	2013-14	1	26	IENG492	C
46	2013-14	1	26	IENG372	B
47	2013-14	1	26	IENG441	A-
48	2013-14	1	26	IENG461	C+
52	2013-14	1	26	IENG492	C+
53	2013-14	1	26	IENG372	B-
54	2013-14	1	26	IENG441	D+
55	2013-14	1	26	IENG490	B
56	2013-14	1	26	IENG409	B+
57	2013-14	1	26	IENG410	S
58	2013-14	1	26	IENG484	B+
59	2013-14	1	26	IENG458	C
60	2013-14	1	26	IENG301	C-
61	2013-14	1	26	IENG372	C
62	2013-14	1	26	IENG490	C
64	2013-14	1	26	IENG409	B-
65	2013-14	1	26	IENG484	C-
67	2013-14	1	26	IENG323	C
68	2013-14	1	26	IENG372	C+
69	2013-14	1	26	IENG441	D

70	2013-14	1	26	IENG490	C
71	2013-14	1	26	IENG458	D
72	2013-14	1	26	IENG323	D+
73	2013-14	1	26	IENG441	D+
74	2013-14	1	26	IENG490	C
75	2013-14	1	26	IENG461	D-
82	2013-14	1	26	IENG385	B+
88	2013-14	1	26	IENG212	D
92	2013-14	1	26	IENG323	C
96	2013-14	1	26	IENG461	C-
98	2013-14	1	26	IENG484	F
99	2013-14	1	26	IENG492	B-
105	2013-14	1	26	IENG212	F
110	2013-14	1	26	IENG441	B
111	2013-14	1	26	IENG461	C+
112	2013-14	1	26	IENG458	D+
113	2013-14	1	26	IENG484	C-
114	2013-14	1	26	IENG492	C+
115	2013-14	1	26	IENG419	B-
116	2013-14	1	26	IENG431	D+
117	2013-14	1	26	IENG461	C
118	2013-14	1	26	IENG484	D+
119	2013-14	1	26	IENG492	C
121	2013-14	1	26	IENG332	D
122	2013-14	1	26	IENG314	C+
123	2013-14	1	26	IENG372	B
128	2013-14	1	26	IENG372	B+
129	2013-14	1	26	IENG441	B-
130	2013-14	1	26	IENG490	B
131	2013-14	1	26	IENG484	B-
132	2013-14	1	26	IENG409	B
133	2013-14	1	26	IENG301	B-
134	2013-14	1	26	IENG332	B-
135	2013-14	1	26	IENG372	B+
136	2013-14	1	26	IENG441	B-
139	2013-14	1	26	IENG323	D
141	2013-14	1	26	IENG314	A-
142	2013-14	1	26	IENG372	A-
143	2013-14	1	26	IENG410	S
144	2013-14	1	26	IENG210	S
146	2013-14	1	26	IENG323	D+
147	2013-14	1	26	IENG332	D
148	2013-14	1	26	IENG314	B-
149	2013-14	1	26	IENG490	C+
151	2013-14	1	26	IENG310	S
152	2013-14	1	26	IENG461	B-
154	2013-14	1	26	IENG410	S
155	2013-14	1	26	IENG492	C

Appendix a continuous					
156	2013-14	1	26	IENG419	C+
159	2013-14	1	26	IENG212	D-
160	2013-14	1	26	IENG301	C
161	2013-14	1	26	IENG313	C
162	2013-14	1	26	IENG431	D-
163	2013-14	1	26	IENG441	D+
164	2013-14	1	26	IENG490	B-
165	2013-14	1	26	IENG461	D-
167	2013-14	1	26	IENG419	D+
169	2013-14	1	26	IENG310	S
170	2013-14	1	26	IENG431	D+
171	2013-14	1	26	IENG441	D+
174	2013-14	1	26	IENG492	B
175	2013-14	1	26	IENG409	C
177	2013-14	1	26	IENG461	B
186	2013-14	1	26	HIST280	B
190	2013-14	1	26	IENG212	D+
192	2013-14	1	26	IENG385	D-
193	2013-14	1	26	IENG332	C+
194	2013-14	1	26	IENG314	C-
195	2013-14	1	26	IENG372	B-
196	2013-14	1	26	IENG458	B
197	2013-14	1	26	IENG313	C
198	2013-14	1	26	IENG323	D
199	2013-14	1	26	IENG385	D-
200	2013-14	1	26	IENG332	D-
201	2013-14	1	26	IENG314	B
203	2013-14	1	26	IENG301	D+
204	2013-14	1	26	IENG323	D-
205	2013-14	1	26	IENG314	C+
209	2013-14	1	26	IENG441	D+
210	2013-14	1	26	IENG490	B
211	2013-14	1	26	IENG484	C-
212	2013-14	1	26	IENG458	B-
213	2013-14	1	26	IENG461	B-
216	2013-14	1	26	IENG492	C
217	2013-14	1	26	IENG458	B
218	2013-14	1	26	IENG409	C
222	2013-14	1	26	IENG492	B+
223	2013-14	1	26	IENG409	C
224	2013-14	1	26	IENG458	C+
227	2013-14	1	26	IENG431	D+
228	2013-14	1	26	IENG461	B
230	2013-14	1	26	IENG484	B-
231	2013-14	1	26	IENG492	A-
232	2013-14	1	26	IENG409	C
233	2013-14	1	26	IENG419	A-

235	2013-14	1	26	IENG355	D
236	2013-14	1	26	IENG431	F
237	2013-14	1	26	IENG441	D
238	2013-14	1	26	IENG490	B-
239	2013-14	1	26	IENG458	B-
240	2013-14	1	26	IENG313	C
241	2013-14	1	26	IENG332	D
242	2013-14	1	26	IENG314	C-
243	2013-14	1	26	IENG372	B
280	2013-14	1	26	IENG301	B-
283	2013-14	1	26	IENG431	B
284	2013-14	1	26	IENG461	A-
286	2013-14	1	26	IENG484	A-
287	2013-14	1	26	IENG492	B+
291	2013-14	1	26	IENG441	C+
293	2013-14	1	26	IENG484	D+
294	2013-14	1	26	IENG492	B-
299	2013-14	1	26	IENG314	A-
300	2013-14	1	26	IENG372	A
301	2013-14	1	26	IENG441	B
302	2013-14	1	26	IENG490	A
303	2013-14	1	26	IENG409	B
304	2013-14	1	26	IENG458	B
306	2013-14	1	26	IENG431	D
307	2013-14	1	26	IENG441	B
308	2013-14	1	26	IENG490	C+
317	2013-14	1	26	IENG385	F
319	2013-14	1	26	IENG212	D+
424	2013-14	1	26	IENG372	B
425	2013-14	1	26	IENG458	B-
443	2013-14	1	26	IENG372	A-
444	2013-14	1	26	IENG355	B
455	2013-14	1	26	IENG385	A
457	2013-14	1	26	IENG355	B+
459	2013-14	1	26	IENG323	B-
461	2013-14	1	26	IENG332	A
462	2013-14	1	26	IENG314	A
463	2013-14	1	26	IENG355	B+
464	2013-14	1	26	IENG490	A-
465	2013-14	1	26	IENG458	A
466	2013-14	1	26	IENG313	F
467	2013-14	1	26	IENG323	A-
468	2013-14	1	26	IENG385	B+
469	2013-14	1	26	IENG332	A-
470	2013-14	1	26	IENG314	B+
476	2013-14	1	26	IENG301	C
477	2013-14	1	26	IENG355	B+
481	2013-14	1	26	IENG323	B

Appendix A continuous…					
482	2013-14	1	26	IENG385	B
484	2013-14	1	26	IENG372	A
487	2013-14	1	26	IENG301	B+
488	2013-14	1	26	IENG313	A-
489	2013-14	1	26	IENG323	A-
520	2013-14	1	26	IENG263	D+
543	2013-14	1	26	IENG263	B
546	2013-14	1	26	IENG212	D
619	2013-14	1	26	IENG385	A
620	2013-14	1	26	IENG355	B
671	2013-14	1	26	IENG313	B+
672	2013-14	1	26	IENG323	A
673	2013-14	1	26	IENG385	C+
674	2013-14	1	26	IENG332	D+
675	2013-14	1	26	IENG314	B
676	2013-14	1	26	IENG263	A
689	2013-14	1	26	IENG263	C+
692	2013-14	1	26	IENG212	D-
706	2013-14	1	26	IENG212	D-
724	2013-14	1	26	IENG212	B+
892	2013-14	1	26	IENG431	C
893	2013-14	1	26	IENG461	B-
897	2013-14	1	26	IENG210	U
902	2013-14	1	2C	IENG355	B+
903	2013-14	1	2C	IENG409	B-

Appendix B: CGPA of Students for the Academic Year 2013-14 (Fall)

	Sem.	Per.	Dept.	GPA	CGPA
1	2013-14	1	26	3.05	2.37
2	2013-14	1	26	2.64	2.30
5	2013-14	1	26	2.99	1.96
6	2013-14	1	26	2.42	2.10
7	2013-14	1	26	2.97	2.36
8	2013-14	1	26	1.07	1.43
9	2013-14	1	26	1.64	2.02
10	2013-14	1	26	2.89	2.29
11	2013-14	1	26	2.53	2.22
12	2013-14	1	26	2.19	2.03
14	2013-14	1	26	1.38	2.12
15	2013-14	1	26	0.95	1.84
16	2013-14	1	26	1.00	1.97
17	2013-14	1	26	0.94	1.95
18	2013-14	1	26	1.61	2.04
19	2013-14	1	26	1.36	1.92
21	2013-14	1	26	0.51	1.85
22	2013-14	1	26	0.00	1.27

23	2013-14	1	26	2.23	2.06
24	2013-14	1	26	1.63	2.04
25	2013-14	1	26	2.26	2.09
26	2013-14	1	26	2.93	2.46
27	2013-14	1	26	2.87	2.11
28	2013-14	1	26	2.83	2.14
29	2013-14	1	26	1.64	2.02
30	2013-14	1	26	2.40	2.08
31	2013-14	1	26	1.39	1.86
32	2013-14	1	26	1.12	2.02
33	2013-14	1	26	1.92	2.07
34	2013-14	1	26	2.76	2.44
35	2013-14	1	26	1.08	1.75
36	2013-14	1	26	1.46	1.62
37	2013-14	1	26	2.11	2.08
38	2013-14	1	26	1.52	1.96
39	2013-14	1	26	1.55	1.91
40	2013-14	1	26	2.20	2.12
41	2013-14	1	26	2.04	2.21
42	2013-14	1	26	1.98	2.11
43	2013-14	1	26	0.35	1.63
44	2013-14	1	26	2.68	2.23
45	2013-14	1	26	1.11	1.87
46	2013-14	1	26	2.09	2.02
47	2013-14	1	26	0.24	1.50
48	2013-14	1	26	1.33	1.69
49	2013-14	1	26	2.35	2.36
50	2013-14	1	26	2.13	1.98
51	2013-14	1	26	0.00	1.34
52	2013-14	1	26	2.13	1.96
53	2013-14	1	26	3.40	2.65
54	2013-14	1	26	2.02	2.07
55	2013-14	1	26	3.41	2.24
56	2013-14	1	26	2.12	2.13
58	2013-14	1	26	1.50	2.13
59	2013-14	1	26	0.81	1.92
60	2013-14	1	26	0.00	3.32
61	2013-14	1	26	1.96	1.95
62	2013-14	1	26	2.21	2.14
63	2013-14	1	26	2.31	2.20
64	2013-14	1	26	3.04	2.63
65	2013-14	1	26	0.00	4.00
66	2013-14	1	26	0.00	4.00
67	2013-14	1	26	2.00	1.74
68	2013-14	1	26	0.74	1.75
69	2013-14	1	26	3.16	2.84
70	2013-14	1	26	2.05	2.26
71	2013-14	1	26	1.16	2.04

Appendix B continuous …					
72	2013-14	1	26	1.48	1.82
73	2013-14	1	26	3.10	3.43
74	2013-14	1	26	0.35	0.54
75	2013-14	1	26	1.62	1.75
76	2013-14	1	26	0.00	0.35
77	2013-14	1	26	1.69	1.71
78	2013-14	1	26	0.71	1.28
79	2013-14	1	26	2.36	2.17
80	2013-14	1	26	0.00	3.86
81	2013-14	1	26	0.00	3.77
82	2013-14	1	26	0.00	4.00
83	2013-14	1	26	1.08	1.87
84	2013-14	1	26	3.24	3.20
85	2013-14	1	26	1.06	1.57
86	2013-14	1	26	3.46	3.05
87	2013-14	1	26	3.61	3.45
88	2013-14	1	26	2.93	3.11
89	2013-14	1	26	2.32	2.55
90	2013-14	1	26	2.65	3.15
91	2013-14	1	26	2.74	3.31
92	2013-14	1	26	0.96	2.41
93	2013-14	1	26	1.60	1.87
94	2013-14	1	26	3.68	3.89
95	2013-14	1	26	2.33	2.33
96	2013-14	1	26	1.13	1.13
98	2013-14	1	26	1.90	1.90
99	2013-14	1	26	3.84	3.84
101	2013-14	1	26	0.94	0.94
102	2013-14	1	26	0.55	0.81
103	2013-14	1	26	1.91	2.47
104	2013-14	1	26	3.70	3.79
106	2013-14	1	26	4.00	4.00
107	2013-14	1	26	2.35	2.18
108	2013-14	1	26	1.70	3.30
109	2013-14	1	26	3.57	3.40
110	2013-14	1	26	3.57	3.54
111	2013-14	1	26	3.80	3.60
112	2013-14	1	26	2.77	2.75
113	2013-14	1	26	3.67	3.60
114	2013-14	1	26	3.00	3.00
115	2013-14	1	26	4.00	4.00
116	2013-14	1	26	3.85	3.93
117	2013-14	1	26	4.00	4.00
118	2013-14	1	26	3.50	3.68
119	2013-14	1	26	4.00	3.93
120	2013-14	1	26	3.90	3.94
121	2013-14	1	26	4.00	4.00

Appendix B continuous …					
122	2013-14	1	26	0.00	0.41
123	2013-14	1	26	3.67	3.69
124	2013-14	1	26	3.47	2.91
125	2013-14	1	26	3.71	3.71
126	2013-14	1	26	4.00	4.00
127	2013-14	1	26	3.85	3.50
128	2013-14	1	26	3.64	3.49
129	2013-14	1	26	0.33	1.44
130	2013-14	1	26	1.24	1.88
131	2013-14	1	26	2.93	2.96
132	2013-14	1	26	1.46	1.88
133	2013-14	1	26	2.84	3.03
134	2013-14	1	26	3.84	3.71
135	2013-14	1	26	1.01	1.95
136	2013-14	1	26	2.20	2.44
144	2013-14	1	26	1.26	2.13
145	2013-14	1	26	1.09	1.38
146	2013-14	1	26	1.85	2.33
147	2013-14	1	26	2.38	1.97
148	2013-14	1	26	0.13	1.08
149	2013-14	1	26	0.13	0.18
154	2013-14	1	26	4.00	4.00
155	2013-14	1	26	1.00	1.00
156	2013-14	1	26	3.15	3.15
157	2013-14	1	26	3.30	3.30
158	2013-14	1	26	0.00	0.00
159	2013-14	1	26	3.50	3.50
160	2013-14	1	26	1.68	1.68
161	2013-14	1	26	3.58	3.58
174	2013-14	1	26	3.57	3.57
175	2013-14	1	26	4.00	4.00
176	2013-14	1	26	1.85	1.85
177	2013-14	1	26	4.00	4.00
178	2013-14	1	26	0.00	0.00
179	2013-14	1	26	1.47	1.47
180	2013-14	1	26	0.00	0.00
181	2013-14	1	26	2.24	2.08
182	2013-14	1	26	0.00	2.10
183	2013-14	1	26	3.10	2.85
184	2013-14	1	26	1.46	1.94
185	2013-14	1	26	2.10	2.52
186	2013-14	1	26	0.63	0.86
187	2013-14	1	26	0.76	1.30
188	2013-14	1	26	2.86	3.05
189	2013-14	1	26	2.69	2.39
190	2013-14	1	26	0.98	1.54
191	2013-14	1	26	2.25	2.95

Appendix C: 2012-2013 fall CGPA

081724	3.27	2.55
081726	2.18	1.87
081727	1.69	1.98
081728	1.52	1.79
081729	2.60	2.44
081730	1.56	1.81
081731	0.89	1.69
081734	1.22	1.93
081735	2.57	1.91
081736	2.67	2.52
081737	1.00	1.62
081738	1.00	1.50
081745	1.95	1.95
081747	3.03	3.13
081748	2.85	3.25
081750	2.87	2.32
081751	0.40	1.42
081752	1.00	1.49
081757	0.77	1.68
081782	2.15	2.23
081783	2.78	2.31
081788	2.21	1.95
081792	1.35	1.83
081793	2.65	2.26
081794	2.33	1.82
081795	1.99	1.92
081796	2.92	2.22
081797	0.29	1.51
081799	2.94	3.01
081803	1.14	1.59
081804	1.63	1.64
086024	0.00	4.00
087252	0.79	1.47
087254	3.16	2.23
087255	1.82	2.03
089603	2.90	2.61
090705	0.70	1.87
090706	2.46	2.05
090707	1.97	1.96
090709	1.22	1.74
096001	0.00	3.32
096006	0.00	3.73
097093	3.06	2.92
098619	2.31	2.21
099114	3.59	3.10
100105	3.63	2.93

100107	2.06	2.12
100108	1.59	1.81
100111	2.21	2.35
100112	2.29	2.18
103027	2.13	2.25
105008	3.00	3.63
105103	0.00	3.67
105368	3.70	3.77
105442	0.00	3.14
105445	0.00	4.00
110821	2.90	2.90
110822	1.00	1.00
110823	3.83	3.83
110824	0.26	0.26
110826	1.75	1.75
110827	1.82	1.82
110829	1.00	1.00
110830	2.12	2.12
110831	0.48	0.48
111512	1.73	1.85
115081	3.90	3.83
115169	3.83	3.78
115609	3.65	3.65
116117	3.85	3.83

Appendix D: Table showing IENG314 assessment information for fall 2013-2024

H= homework, Q=question, Lab=laboratory exams, Atten=attendance, G= grade, #= number , of students enrolled

#	H1	Q1	Q2	Mid-term	26% Mid term	Q3	Q4	H2	Lab	Lab 16%	Atten	4% Atten	Final	36% Final	Total	G
1	0	2	3	64	16.64	0	2.7	2	76	12.16	81.43	3.2572	60	21.6	63.5572	C+
2	2	2	4	78	20.28	4.6	3.1	2	71	11.36	82.86	3.3144	83	29.88	80.0344	A-
3	0	1	2	81	21.06	2	1.5	2	81.75	13.08	77.14	3.0856	62	22.32	68.8456	B-
4	2	2	0	50	13	2.4	2	2	67.75	10.84	70	2.8	68	24.48	61.12	C
5	2	2	4	73	18.98	1.4	3	2	61	9.76	80	3.2	67	24.12	67.96	B-
6	2	1	1	57	14.82	2.7	1.6	2	88.25	14.12	55.11	2.2044	69	24.84	64.9844	C+
7	2	1	3	65	16.9	2.2	3	2	41	6.56	81.43	3.2572	59	21.24	60.1572	C
8	1	2	4	72	18.72	4	2.9	2	100	16	90	3.6	86	30.96	82.98	A-
9	2	2	3	83	21.58	3.7	3.1	2	82	13.12	97.14	3.8856	80	28.8	81.7856	A-
10	0	0	1	32	8.32	2.4	1	2	28.85	4.616	67.14	2.6856	48	17.28	39.3016	D-
11	1	2	4	74	19.24	2.4	1.5	2	76.75	12.28	91.43	3.6572	73	26.28	72.9572	B
12	1	3	4	87	22.62	3.4	4.4	2	72.25	11.56	94.29	3.7716	93	33.48	86.2316	A
13	1	2	3	73	18.98	2.3	2.9	2	76.75	12.28	80	3.2	82	29.52	74.88	B+
14	0	2	4	63	16.38	2.2	3.7	2	90	14.4	74.29	2.9716	77	27.72	73.1716	B

Appendix E: A sample Lingo LP models and results for a DMU (student)

```
Max = 0.82*u1 + 2.64*u2;
1.79*v1 + 3.85*v2 = 1;
0.82*u1 + 2.64*u2-1.79*v1 - 3.85*v2<=0;
1.32*u1 + 3.40*u2-1.69*v1 - 3.85*v2<=0;
1.07*u1 + 2.60*u2-1.93*v1 - 3.85*v2<=0;
0.61*u1 + 2.53*u2-1.68*v1 - 3.85*v2<=0;
0.82*u1 + 2.88*u2-1.64*v1 - 3.85*v2<=0;
0.71*u1 + 2.80*u2-1.78*v1 - 3.85*v2<=0;
0.71*u1 + 2.42*u2-1.82*v1 - 3.85*v2<=0;
1.18*u1 + 3.74*u2-2.35*v1 - 3.85*v2<=0;
1.32*u1 + 3.45*u2-2.35*v1 - 3.85*v2<=0;
0.36*u1 + 1.45*u2-2.08*v1 - 3.85*v2<=0;
1.07*u1 + 2.93*u2-3.26*v1 - 3.85*v2<=0;
1.43*u1 + 3.49*u2-3.42*v1 - 3.85*v2<=0;
```

```
1.17*u1 + 3.01*u2-3.00*v1 - 3.85*v2<=0;
1.07*u1 + 3.29*u2-3.28*v1 - 3.85*v2<=0;
v1>0;
v2>0;
u1>0;
u2>0;
END
```

```
Global optimal solution found.
  Objective value:                              0.7648815
  Infeasibilities:                               0.000000
  Total solver iterations:                              4

  Model Class:                                         LP

  Total variables:                      4
  Nonlinear variables:                  0
  Integer variables:                    0

  Total constraints:                   20
  Nonlinear constraints:                0

  Total nonzeros:                      64
  Nonlinear nonzeros:                   0
```

Appendix E continues

```
                                Variable           Value
Reduced Cost
                                      U1        0.000000
0.1734188
                                      U2       0.2897278
0.000000
                                      V1       0.1492537
0.000000
                                      V2       0.1903470
0.000000

                                     Row     Slack or
Surplus      Dual Price
                                       1       0.7648815
1.000000
                                       2        0.000000
0.7648815
                                       3       0.2351185
0.000000
                                       4        0.000000
0.6489903
```

```
                                              5         0.2676032
0.000000
                                              6         0.2505707
0.000000
                                              7         0.1431958
0.000000
                                              8         0.1872695
0.000000
                                              9         0.3033363
0.000000
                                             10          0.000000
0.1158911
                                             11
0.8402107E-01        0.000000
                                             12         0.6231782
0.000000
                                             13         0.3705004
0.000000
                                             14         0.2321335
0.000000
                                             15         0.3085162
0.000000
                                             16         0.2691835
0.000000
                                             17         0.1492537
0.000000
                                             18         0.1903470
0.000000
                                             19          0.000000
0.000000
                                             20         0.2897278
0.000000
```

Appendix F: Table shows 2013-2014spring and 2013-1014 fall student-course instructor survey

		2013-2014 Spring		*2013-2014 Fall*	
#	**Course Code**	*Course ave*	*Instructor*	*Course ave*	*Instructor*
1.	IENG112	3.28	3.29	-	-
2.	**IENG210 (S or U)**	3.36	3.45	3.74	3.74
3.	IENG212	3.69	3.75	2.48	2.47
4.	IENG263	3.00	3.10	-	-
5.	IENG301	-	-	3.16	3.18
6.	**IENG310 (S or U)**	3.75	3.68	3.53	3.52

7.	IENG313	3.57	3.73	3.13	3.29
8.	IENG314	3.66	3.82	3.47	3.54
9.	IENG323	3.36	3.58	3.57	3.59
10.	IENG332	3.71	3.78	3.45	3.48
11.	IENG355	3.50	3.49	3.57	3.60
Appendix F continues					
12.	IENG356	3.93	3.95	-	-
13.	IENG372	3.54	3.74	3.42	3.56
14.	IENG385	3.20	3.17	3.31	3.48
15.	IENG409	3.25	3.25	3.41	3.40
16.	**IENG410 (S or U)**	3.47	3.50	3.58	3.58
17.	IENG419	-	-	3.67	3.68
18.	**IENG420**	3.29	3.39	2.84	3.10
19.	IENG431	3.60	3.64	2.59	2.79
20.	IENG441	3.53	3.67	3.48	3.64
21.	**IENG444 (S or U)**	3.90	3.89	-	-
22.	**IENG450**	3.86	3.88	3.69	3.75
23.	**IENG451**	3.75	3.73	-	-
24.	IENG458				
25.	IENG461	3.83	3.86	2.96	3.03
26.	IENG484	3.82	3.78	3.72	3.79
27.	IENG490	4.00	4.00	3.66	3.76
28.	IENG492	2.83	3.00	3.17	3.17

Appendix G: Figure shows Letter Grades Description

Letter Grade	Grade Point Equivalent	Description
A	4.00	High honor
A-	3.70	High honor
B+	3.30	Honor
B	3.00	Honor
B-	2.70	Satisfactory
C+	2.30	Satisfactory
C	2.00	Satisfactory
C-	1.70	Conditional Pass
D+	1.30	Conditional Pass
D	1.00	Conditional Pass
D-	0.70	Unsatisfactory
F	0.00	Unsatisfactory
NG	0.00	Nil Grade due to poor attendance
S	---	Satisfactory (pass)
U	---	Unsatisfactory (fail)
I	---	Incomplete
W	---	Withdrawal
E	---	Exempted
TP		Satisfactory - End of Term Thesis Project
TU		Unsatisfactory - End of Term Thesis Project
TS		Thesis Defense Approved
TI		Thesis Defense Approved with Modifications
TR		Repetition of Thesis Defense
TJ		Thesis Defense Rejected
QS		Satisfactory – Ph. D. Qualifying Exam
QU		Unsatisfactory - Ph. D. Qualifying Exam